Renewable Energy Consumption and Economic Growth Nexus in South Asia Countries: Revealing True Picture

Khan, I[1*], Ahmed, M.[1]
[1]Department of Management Sciences, COMSATS University, Islamabad, Pakistan.
[*]Corresponding Author
Email: eishtiaqkhan@yahoo.com

Abstract

The present study re-examines the causal nexus between renewable energy consumption (REC) and economic growth (Y) for four selected South Asian economies (Bangladesh, India, Pakistan and Sri-Lanka) by making use of latest available data from 1990 to 2011. Earlier studies on this subject make use of first generation panel tests (unit root as well as for cointegration) with built-in assumption of cross-sectional units' independence, which is obviously a very restrictive assumption and generally does not hold especially in the case of chosen countries due to geographical as well as other socio-economic linkages between them. Thus, it is wise to re-analyze this issue using second generation panel unit root and cointegration tests which is what has been done in the present study. The empirical findings, based on multivariate set up that includes capital and labor force as two additional variables, confirm the existence of long run relationship between the selected variables. In addition, an evidence of unidirectional causality is found that runs from Y to REC in long run only. These findings provide some useful policy insights.

Key Words: Second Generation Tests; Panel Data; Causality

1. Introduction

Energy is the main pillar of an economy as it supports and secures a country economically as well as socially (Ghosh [1]). Indeed, when a country develops and grows up, its energy demand in all sectors (industrial, transport, residential and commercial among others) increases (Sadorsky [2]. The causal link between energy consumption and economic growth remains a popular topic of academic debates for several years and the results have important policy implications (see Ahmed et al. [3]; Payne [4]; Ozturk [5] among others). Furthermore, consumption of carbon based fuels results environmental degradation in the form of global warming and CO_2 emission etc. (Sadorsky [2])**.** In 1997, International agreement (Kyoto Protocol) has been signed by both developing and developed worlds for greenhouse gas (GHG) emission reduction with the purpose of restraining GHG emissions for advanced economies (Chang et al. [6]. The substitution of conventional energy with non-conventional (renewable energy which includes solar, wind, geothermal, biomass including organic solid waste and hydro energy) is an alternative source of energy for GHG emission reduction, sustainable development as well as energy security. In addition, fluctuation of fuel prices, dependency on energy exporting economies, environmental degradation etc., attracted energy consumers' attention towards clean and problem free energy resources.

Much work has been done on renewable energy issues. However, in recent past, the focus of most of the studies is shifted to explore relationship between energy (renewable) consumption and economic growth, mainly focusing on the issue of 'whether economic growth increases through improvements in energy (renewables) consumption or vice versa. In particular, a strong correlation exists between energy usage and economic output (PES [7]). The causal link between energy consumption (EC) and economic growth (Y) can be subcategorized into four different hypotheses: a) *growth hypothesis*—a unidirectional causality exists and runs from EC to Y, b) *conservation hypothesis*—a unidirectional causality running from Y to EC, c) *feedback hypothesis*—bidirectional causality between EC and Y and d) *Neutrality hypothesis*—no causal relationship between the EC and Y.

The literature on the relationship between EC and Y starts with Kraft and Kraft [8] where the causal nexus between the focal variables is explored for the United States for annual time series data (1947 to 1974) lending support to conservation hypothesis. Since Kraft and Kraft [8], several studies have been done to predict the causal link for different countries (see for example, (Narayan and Doytch [9]; Koçak and Şarkgüneşi [10]; Dogan [11]; Bhattacharya et al. [12]; Inglesi-Lotz [13] for some recent studies). However, the major concern for the policy makers is that the conclusions regarding the direction of causal relationship for most of the studies are mixed. More specifically, some studies claim that the causality exists with a direction from renewable energy consumption (REC) towards economic growth (Y) (see for example, Koçak and Şarkgüneşi [10]; Bhattacharya et al. [12]; Inglesi-Lotz [13]; Wesseh Jr and Lin [14]; Kahia et al. [15]; Hamit-Haggar [16]; Saidi and Mbarek [17]; Naseri et al. [18]; Jebli and Youssef [19]; Ohler and Fetters [20]; Zeb et al. [21]; Long et al. [22]; Maji [23]; Inglesi-Lotz, [24]; Tiwari, [25], [26]; Yildirim et al. [27] and Payne [4] among recent studies), while results of some studies suggest a unidirectional causality that runs from Y to REC (see for example, Dogan [11]; Cho et al. [28]; Zeb et al. [21]; Sadorsky [2], [29] among many others). Some studies advocate the existence of bidirectional relationship between Y and REC (see for example, Kahia et al. [15]; Shahbaz et al. [30]; Saidi and Mbarek [17]; Chang et al. [31]; Ibrahiem [32]; Cho et al. [28]; Shahbaz et al. [33]; Bloch et al. [34]; Al-mulali et al. [35]; Apergis and Danuletiu [36]; Sebri and Ben-Salha [37]; Pao et al. [38]; Jebli et al. [39]; Bildirici and Ozaksoy [40]; Al-mulali et al. [41]; Bildirici [42]; Apergis and Payne [43]; Apergis and Payne [44], [45], while some others including Narayan and Doytch [9]; Dogan [46]; Ben Aïssa et al. [47]; Lin and Moubarak [48]; Menegaki, [49]; Abanda et al. [50]; Bowden and Payne [51] and Payne [52] suggest no causal link between REC and Y.

The summary of studies conducted for single as well as multiple countries is provided in Table 2 (single country) and Table 3 (multiple countries) respectively in Appendix. It can be noted that results regarding the causal link between the focal variables are mixed. Since the findings of most of the studies are mixed so it is challenging for policy makers to devise a sound policy for any country. There may be several reasons behind these mixed and conflicting outcomes in the existing literature such as individual country's characteristics, use of different data sets and variables as well as distinct econometric methodologies employed (Ahmed et al. [3]). To tackle these issues, some studies rely on time series approaches, like unit root and cointegration tests, however, such tests have low power while treating small samples which is mostly likely the case in majority of the studies based on single country (Ahmed et al. [3]). To improve upon this, some use panel data methods (panel unit root and panel cointegration tests) and analyze several countries together. Using panel data methods to increase the power of time series unit root and cointegration tests seems a plausible route. However, most of the existing studies makes use of only first-generation panel unit root and panel cointegration tests. A well noted problem with these tests is reliance on the assumption of cross-sectional independence. It is emphasized that, this is a very restrictive assumption which gets violated in most cases especially when countries are in some sense related either geographically and/or via socio-economic characteristics. This problem can be overcome with the use of generation of panel unit root and panel cointegration tests which can incorporate the issue of cross-sectional dependence with their testing mechanism and thus do not suffer from the problem usually faced by earlier studies analyzing the causal nexus between REC and Y.

The present study re-examines the causal nexus between REC and Y for selected South Asian countries—Bangladesh, India, Sri Lanka and Pakistan. The empirical analysis makes use of latest available data and employs second generation panel unit root and panel cointegration tests which is still missing from the existing literature on this subject for the chosen countries. The empirical analysis makes use of multivariate set up by including total capital stock and total labor force as two additional variables along with REC and Y, following Ahmed et al. [3], Apergis and Payne [44], Bowden and Payne [51] and Payne [52]. The multivariate framework is adopted to avoid omitted variable bias which may arise if one uses only the two key variables (REC and Y). The empirical analysis based on time series annual data from 1990 to 2011 suggests the existence of a unidirectional causality running from Y to REC (long run only)—thus lending support to conservation hypothesis suggesting that energy conservation policies are suitable for this group of countries as reduction in energy consumption and wastages doesn’t have adverse impact on economic growth.

Rest of the paper is organized as:

Section 2 sheds light on current energy scenario of the four chosen countries. Section 3 briefly discusses the relevant literature on the subject while section 4 provides details on relevant data used and econometric methodology along with empirical findings. Finally, the last section concludes the study with some policy recommendations.

2. Energy Scenario of Selected South Asian Countries

The South Asian region has higher developing rate as well as higher energy consumption ratio as compared to other regions. The primary energy mix and the development pattern varies across countries (ESSA [53]). There are eight economies in South Asian region including: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. This region

contains developing economies with higher population density and lower income level as compared to other regions. According to regional energy security report for south Asia, these countries are highly dependent on foreign fuel which is likely to increase in next two decades. Some of the countries having higher GDP rate are striving to develop their energy sectors to accelerate their economic growth. As stated earlier, due to unavailability of relevant data, only four out of eight countries are selected (Bangladesh, India, Sri Lanka and Pakistan) for analysis.
A brief overview of each selected country starting with Pakistan and followed by India, Sri Lanka and Bangladesh, is provided below.

Pakistan is an energy deficit country and is heavily dependent on foreign energy resources. This energy shortage has impeded the economic growth especially in the industrial sector which is considered as main driver of economy (PEYB [54]). The energy shortage leads to a load-shedding varying between 10 to 20 hours daily. The government spends around 14 billion US dollars every year, which is equivalent to over 60% of the country's export earnings, on energy imports and to overcome energy deficit which puts extra burden on the economy. Furthermore, with fast growing population and due to exploitation of indigenous energy resources, the government is failed to utilize the available resources properly (Doggar [55]). Thus, the energy demand is growing each year and energy demand and supply gap—the energy shortfall, is increasing accordingly (see Table 1). Primary energy supply mix of Pakistan consists of more than 80% of fossil fuels. The overall worth of primary energy supply is 66.8 million TOEs with a compound growth rate of about 3.6% since 1991 (PES [7]). The present energy supply mix consists of different energy resources with oil and gas as core constituents. Contribution of energy resources such as natural gas, oil, hydro-power, coal, nuclear along with imported fuel are 46.7%, 35.0%, 11.4%, 5.4% and 2% respectively (see Figure 1).

India has higher GDP growth rate (about 7 percent in 2008) in comparison with other three selected South Asian countries (ESSA [53]). In fact, it is fourth largest consumer of energy after China, United States and Russia. India is unique being having a separate ministry of renewable energy in contrast with other South Asian countries. India has higher proven coal reserves as well as rich in renewable resources, however, more than 35% of its energy needs are fulfilled via foreign imports. Therefore, India needs to exploit its available energy resources to meet its escalating energy demands (Meisen [56]). According to regional energy security report for south Asia (ESSA [53], India ranks below Pakistan on the basis of per capita energy consumption and is one third that of China. In the last decade, India reduces energy consumption to GDP ratio by 18%, while China lowers the same by over 45%. Nevertheless, escalating energy demand and uncertain foreign energy resources are the main challenges for the Indian government (Meisen [56]).

According to Sri Lankan energy balance report (SLSEA [57]), the dominant sources of energy in the energy supply mix of Sri Lanka are from renewable as well as non-renewable energy resources. The contribution of energy supply mix (primary) in 2004, obtained from crude oil and petroleum products is 44.2% while it was 48.2% from biomass and just 7.6% from hydro power and other renewable sources. Thus, the overall contribution of non-renewable energy resources in the energy supply mix in Sri Lanka is comparatively at a lower scale. Sri Lanka has scarce reserves of biomass and hydro-based energy resources which is among the major challenges for the Sri Lankan government to get relief from the foreign energy resources as more than 30% of export earnings and 6% of GDP are used to import energy. With the increasing demand for energy, the projection for the energy demand till 2010 was 15mTOE with an annual growth rate of 3% (ESSA [53]). The main resources for energy supplies in Sri Lanka are hydro and biomass. Government is continuously striving to harness these resources to meet their escalating energy demand. Like other South Asian countries, Sri Lanka imports foreign energy sources to meet its growing short-term energy demand, however, renewable as well as non-renewable energy resources need to be developed to meet long term energy demand.

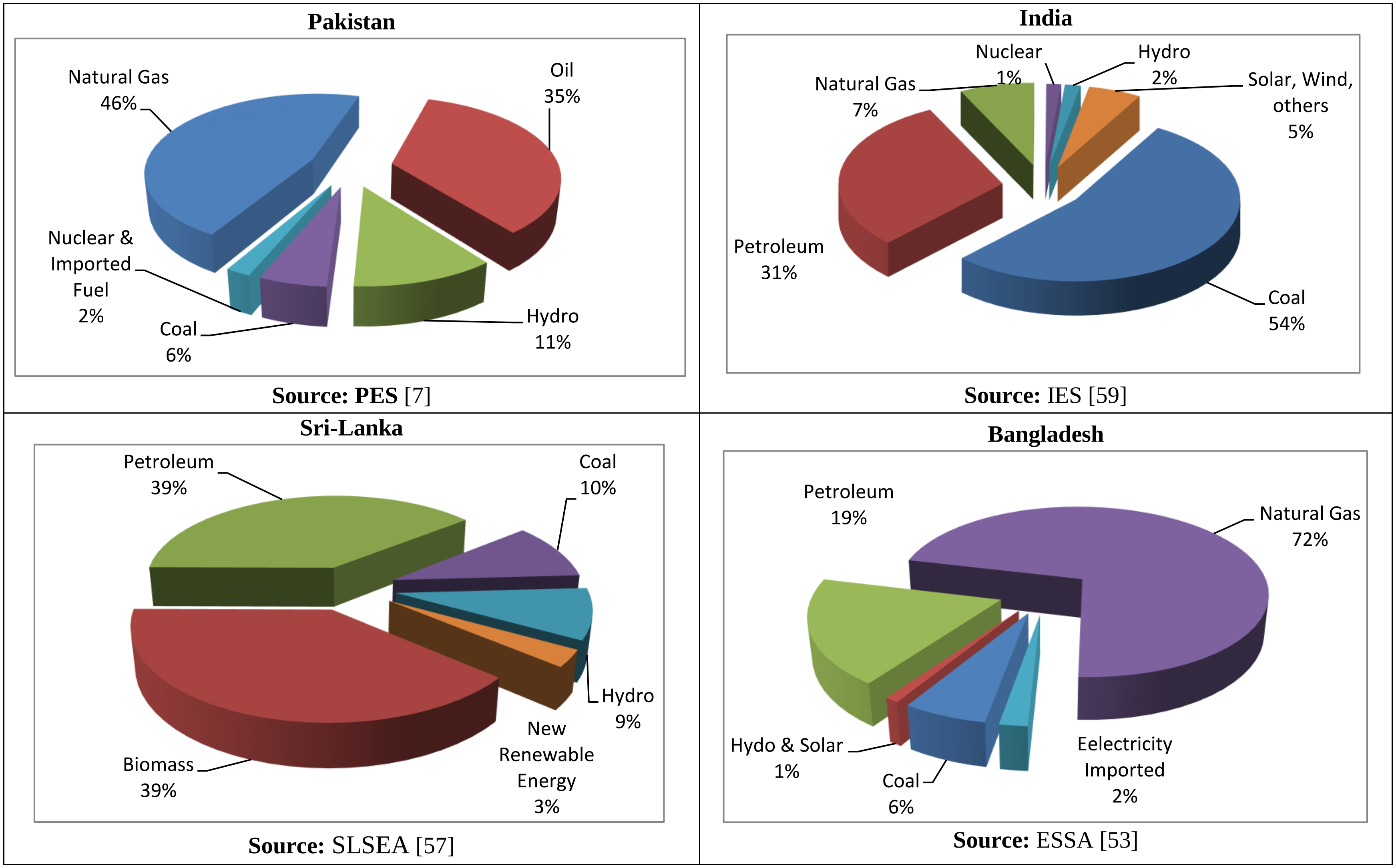
Bangladesh comes at 7th place among Asian countries in natural gas production in 2012. The annual increase in the natural gas production is 7% since last decade. Acute shortfall in the electricity supply results due to limited supply of natural gas to energy sector for electricity generation. Bangladesh government strives hard to increase natural gas production by importing it from foreign countries in the form of LNG (Liquefied Natural Gas) to limit and reduce energy blackouts [58]. Bangladesh generates 55% of the total energy from biomass is while 24% from natural gas and 2% from hydro (ESSA [53]. For Bangladesh, main source of energy for commercial sector is natural gas with an overall share of 70% followed by petroleum (19%) while the remainder is from hydropower and coal (see Figure 1). Moreover, the country has about 217 kgoe is the per capita annual commercial energy consumption. The government body is planning to increase its per capita annual commercial energy consumption from 217 kgoe to 1000 kgoe approaching the world average of 1500 kgoe. Foreign energy import mostly comes from Bhutan and Nepal, especially in the rainy months when these countries have a large surplus of energy (ESSA [53]).

For better understanding, the energy shortfalls for the four selected countries is provided in Table 1 while the primary energy supply mix for the same countries is illustrated in Figure 1.

Table 1: Energy shortfall for selected four countries

Years	India	Pakistan	Bangladesh	Sri Lanka
1990	24.927652	8.679647	1.978077	1.324998
1991	27.920456	7.818171	1.708285	1.4001
1992	36.425347	9.115595	1.887177	1.418185
1993	40.606342	10.277169	2.033488	1.798125
1994	42.983252	11.737666	2.157559	1.82008
1995	48.511732	12.493239	3.120203	1.927444
1996	54.4202	14.361397	3.031601	2.516509
1997	59.139903	15.630829	3.608141	2.61815
1998	70.314543	15.765527	3.706338	2.761168
1999	88.898789	17.28049	3.209614	3.012877
2000	90.80874	17.172008	3.447072	3.578841
2001	89.993885	16.221447	4.024889	3.486387
2002	93.872949	15.95074	4.020929	3.65451
2003	93.134739	13.810524	4.172891	4.026786
2004	109.224247	15.324641	4.158838	4.03285
2005	115.531134	15.507961	4.59815	4.080585
2006	127.166531	18.307551	4.231859	3.928569
2007	143.819835	20.30858	4.655184	4.184938
2008	155.161713	19.878716	4.647587	3.870022
2009	184.090139	19.55169	4.627269	3.974399
2010	192.439358	20.00805	4.995893	4.300517
2011	208.508088	19.777988	5.204372	5.091217

Figure 1 Energy Supply Mix of Selected South Asian Economies



From the brief review of the current energy scenarios of four selected economies, it is noted that India is at leading position in energy production (as well as electricity generation) from its all indigenous resources. Due to environmental concern, all the countries are switching their energy resources towards non-conventional energy resources—renewables as it is clearly a better alternative to overcome the GHG and to boost economic growth in the long run. It is also emphasized that the energy obtained from renewable sources is affordable, secured and environmentally sustainable and therefore it is now mandatory for these developing economies to exploit their indigenous resources for their energy mix.

3. Data, Methodology and Empirical Results

3.1. Data and its Sources

Empirical investigation is carried out by using annual time series data (1990-2011) for four selected South Asian countries—Bangladesh, India, Pakistan and Sri Lanka. The choice of countries and the sample period is solely based on the availability of data on relevant variables. Following Ahmed et al. [3], Payne [52], Bowden and Payne [51] and Apergis and Payne [44], multivariate framework is used by including capital stock (K) and total labor force (L) as two additional variables. The rationale of choosing multivariate set up is to avoid any specification bias due to omitted variables if one uses bivariate set up by considering only subject variables (renewable energy consumption—REC and economic growth—Y). The variable REC is measured in million tons of oil equivalent (mTOE), and the variable Y is proxied by real GDP measured in US dollars at 2005 prices, while capital stock (K) is proxied by gross fixed capital formation, measured in US dollars at 2005 prices and total labor force (L) is taken in millions. All the data is taken from World Development Indicators (WDI), the World Bank database. Table 4 in Appendix provides the basic summary statistics of all the variables included in the analysis.

3.2. Econometric Methodology and Empirical Findings

Following linear specification is used for the long run relationship between REC, Y, K and L.

$$Y_{it} = \alpha_{1i} + \alpha_{2i} REC_{it} + \alpha_{3i} K_{it} + \alpha_{4i} L_{it} + \varepsilon_{it} \qquad [1]$$

Where, $i = 1,2, \dots, N$ refers to each cross-sectional unit and t$= 1,2, \dots, T$ indicates time period, $\alpha_i' s$ ($i = 1,2,3,4$) are regression coefficients and ε is a white noise error term.

The empirical analysis is based on following steps:

Step 1: Testing for Cross-Sectional dependence

First step in the empirical analysis is to test if all cross-sectional units are independent. It is important to emphasize that this assumption is seldom tested by most of the existing studies and hence their findings may be questionable. Cross-sectional dependence (CD) test proposed by Pesaran [60] is used in this study. The p-value of CD test is found to be very small (zero to three decimal places) rejecting the null of cross sectional independence and suggesting that the chosen four countries are correlated with each other. There may be several reasons for this correlation, for example, due to same geographical region, economy, trading behavior and/or other socio-economic factors.

Step 2: Testing for the Order of Integration

To test for the order of integration, cross-sectionally augmented IPS (CIPS) second generation panel unit root test proposed by Pesaran [61] is applied. Here again, it is important to note that CIPS test is specifically designed to take into account the cross-sectional dependence information and thus provides better inferences regarding the stationarity of the data series under examination as opposed to first generation panel unit root tests used by the existing studies on this subject. Table 5 presents the results of CIPS test conducted at levels as well as at first difference of the selected variables, for the two specifications—constant and constant with trend.

Table 5: Pesaran [61] **Panel Unit Root Test (CIPS)**

Variable	**Level**		**First Difference**	
	Constant	**Constant and trend**	**Constant**	**Constant and trend**
Y	4.274 (1.000)	1.048 (0.853)	-7.131*** (0.000)	-6.664*** (0.000)
REC	0.455 (0.675)	-0.346 (0.365)	-6.936*** (0.000)	-6.340*** (0.000)
K	4.260 (1.000)	1.668 (0.952)	-6.988*** (0.000)	-6.716*** (0.000)
L	0.391 (0.652)	2.090 (0.982)	-2.642*** (0.004)	-1.405* (0.080)

Notes:
1) H_0: Series is non-stationary.
2) Schwarz Information criterion is used for optimal lag length calculation.
3) Parentheses include p-values.
4) *, **, *** denote significance at 10%, 5% and 1% significance level respectively.

Table 5 reports that all series under consideration are non-stationary at level and become stationary at their first difference under both specifications (constant as well as constant with trend). Thus the order of integration of each series is unity—I (1).

Step 3: Testing for (possible) Cointegration

After testing the variables for their order of integration, the next step is to test for the presence of (possible) long-run relationship among them. For this purpose, four second generation panel cointegration tests proposed by Westerlund [62] are used that account for cross-sectional dependence between all cross-sectional units. The results are summarized in Table 6.

Table 6: Westerlund [62] **Panel Cointegration Tests**

Test Statistic	Calculated Statistic	p-value	Robust p-value
G_t	-1.572	0.843	0.000
G_a	-1.843	0.990	0.000
P_t	-2.902	0.694	0.000
P_a	-0.877	0.963	0.000

Notes:
1) H_0: There is no cointegration
2) Akaike Information Criterion is used for optimal lag/lead length selection.
3) Bartlett-kernel window's width is set at 2.
4) Robust p-values are calculated by performing 400 bootstrap replications.

From Table 6, it is noted that when conventional p-value is used, the null of no cointegration is not rejected at all three conventional significance levels (1%, 5% and 10%). However, when robust p-values calculated via bootstrapping are used which considers cross-sectional dependence into account, the null hypothesis is rejected at 1% significance level (in all cases). These findings suggest the existence of long run relationship among the chosen variables.

Step 4: Estimating Long-Run Parameters

Once long run relationship is established, the parameters (long run) are estimated via dynamic ordinary least squares (DOLS). In particular, two equations are estimated. One taking natural logarithm of economic growth (LY) as dependent variable while the second is estimated taking natural logarithm of REC (LREC) as dependent variable and in both of the equations, the rest of the variables are taken as independent variables. The rationale of using DOLS to estimate long-run parameters is that it gives robust results even in small samples as compared to its rival, fully modified OLS (FMOLS). The results of DOLS estimates are tabulated in Table 7.

Table 7: DOLS Long-Run Estimates

Independent variable	LY as dependent variable		LREC as dependent variable	
	Coefficient	**p-values**	**Coefficient**	**p-values**
LREC	0.557658	0.897	-	-
LY	-	-	0.1992835	0.000
LL	0.3780628	0.386	0.23042352	0.042
LK	0.5223262	0.000	0.5341013	0.000
Obs.	88		88	
R-square	0.8645		0.39022	
Wald Statistics (p-value)	245.97 (0.000)		2984.48 (0.000)	

Note: Variables presented in the tables are in natural logarithms

From Table 7, when economic growth (LY) is dependent variable, only natural logarithm of capital (LK) is found to be significant at 1% significance level with a positive coefficient whereas natural logarithm of renewable energy consumption (LREC) and natural logarithm of labor (LL) are found to be insignificant. At the same significant level, the joint significance of the entire variables is determined from Wald statistic's p value. In contrast, when LREC is taken as dependent variable, then all variables LY, LL and LK are found to be individually as well as jointly significant. Since variables are used in their natural logarithms, so the coefficients are interpreted as elasticity. In the equation, where, LY is dependent variable, a 1% increase in capital stock leads to 52.23% increase in economic growth holding the effect of all other variables fixed, while in the equation where LREC is dependent variable, a 1% increase in K, total L and Y leads to 53.4%, 23.4% and 20% increase in REC respectively (keeping other variables fixed).

Step 5: Testing for Causality

The last step is to perform the causality test to investigate the natural of causal relationship between REC and Y. For this purpose, panel vector error correction model (VECM) is used. To make it clear, first the long run equation in [1] is estimated using OLS and residual are obtained. Then taking lagged residuals as error correction term, a panel VECM is provided in [2a]—[2d] is estimated.

$$\Delta Y_{it} = v_{1j} + \sum_{k=1}^{q} \psi_{11ik}\, \Delta Y_{it-k} + \sum_{k=1}^{q} \psi_{12ik}\, \Delta REC_{it-k} + \sum_{k=1}^{q} \psi_{13ik}\, \Delta K_{it-k} + \sum_{k=1}^{q} \psi_{14ik}\, \Delta L_{it-k} + \lambda_{1i}\varepsilon_{it-1} + u_{1it} \qquad [2a]$$

$$\Delta REC_{it} = v_{2j} + \sum_{k=1}^{q} \psi_{21ik}\, \Delta Y_{it-k} + \sum_{k=1}^{q} \psi_{22ik}\, \Delta REC_{it-k} + \sum_{k=1}^{q} \psi_{23ik}\, \Delta K_{it-k} + \sum_{k=1}^{q} \psi_{24ik}\, \Delta L_{it-k} + \lambda_{2i}\varepsilon_{it-1} + u_{2it} \qquad [2b]$$

$$\Delta K_{it} = v_{3j} + \sum_{k=1}^{q} \psi_{31ik}\, \Delta Y_{it-k} + \sum_{k=1}^{q} \psi_{32ik}\, \Delta REC_{it-k} + \sum_{k=1}^{q} \psi_{33ik}\, \Delta K_{it-k} + \sum_{k=1}^{q} \psi_{34ik}\, \Delta L_{it-k} + \lambda_{3i}\varepsilon_{it-1} + u_{3it} \qquad [2c]$$

$$\Delta L_{it} = v_{4j} + \sum_{k=1}^{q} \psi_{41ik}\, \Delta Y_{it-k} + \sum_{k=1}^{q} \psi_{42ik}\, \Delta REC_{it-k} + \sum_{k=1}^{q} \psi_{43ik}\, \Delta K_{it-k} + \sum_{k=1}^{q} \psi_{44ik}\, \Delta L_{it-k} + \lambda_{4i}\varepsilon_{it-1} + u_{4it} \qquad [2d]$$

Where, Δ is the first-difference operator; the optimal lag length (q) is chosen via Schwartz Bayesian Information Criterion (SBIC); $u_j's$ $(j = 1,2,3,4)$ is a white noise error term with no contemporaneous correlation. The short run causality is assessed by the significance of the differenced variables on the right-hand side of [2a]—[2d] via partial F-statistic while long run causality is confirmed if the respective error correction term's coefficients in each equation [2a]—[2d] is found to be significant. The empirical findings of panel VECM are provided in Table 8.

Table 8: Panel causality tests

Dependent variables	Causality Sources				
	Short-run				Long-run
	DLY	DLREC	DLL	DLK	ECT
LY	-	-0.172 (0.517)	-5.597 (0.42)	0.058* (0.062)	-0.176 (0.176)
LREC	.033263 (0.630)	-	2.111193 (0.347)	-0.028** (0.011)	-0.344** (0.028)
LL	0.746*** (0.004)	0.099 (0.194)	-	-0.004 (0.419)	0.024** (0.022)
LK	1.554 (0.321)	0.752 (0.312)	2.961 (0.495)	-	-0.470*** (0.003)

Notes:
1) The ECT represents error correction term's coefficient.
2) P values are placed in parenthesis.
3) *, **, *** indicate 10%, 5% and 1% significance level respectively.

The first row of Table 7 provides estimation results of [2a], it can be noted that in the short run, only capital stock affects economic growth significantly with a positively sign while rest of the variables LREC and LL are found to be insignificant in the short run. This implies that capital formation is the single variable that can boost the economic growth. The results of [2b], suggest that LK affects LREC in the short run like LY. The coefficient of error correction term in [2b] is found to be significant while it is found to be insignificant in [2a]. So the findings suggest that no causal relationship exists between renewable energy consumption and economic growth in the short run, however, in the long run, a unidirectional causality exists that runs from economic growth to renewable energy consumption and not in opposite direction. Thus, the empirical findings support the conservation hypothesis suggesting that energy conservation policies are suitable for selected four South Asian countries. These findings are in line with Dogan [11]; Ocal and Aslan [63] for Turkey, Cho et al. [28] for developed economies of OECD & Non-OECD group, Sadorsky [2], [29] for G-7 and 18 emerging economies, Sari et al. [64] for United States and in contrast with Koçak and Şarkgüneşi [10], for 9 Black Sea and Balkan countries, Shahbaz et al. [30]; Sebri and Ben-Salha [37] for BRICS economies, Kahia et al. [15] for MENA economies, Chang et al. [31]; Tugcu et al. [65] for G7 countries, Ibrahiem [32] for Egypt, Dogan [46]; Sari and Soytas [66] for Turkey, Long et al. [22] for China, Shahbaz et al. [33]; Zeeshan et al. [67]; Muhammad et al. [68] for Pakistan, Inglesi-Lotz [13], [24]; Naseri et al. [18]; Ohler and Fetters [20]; Apergis and Payne [44] for OECD economies, Zeb et al. [21] for SAARC group of countries and Tiwari, [25] for India.

4. Conclusion and Policy Implications

The issue of examining the nature of causal relationship between energy consumption and economic growth is critical and has been in debate since past three decades. Most of the existing studies on this subject relies only on the first-generation panel unit root and panel cointegration tests that assume that all cross sectional units being examined are independent. However, this assumption is seldom met when dealing with real data, hence the findings of most of the existing studies based on these testing schemes may mislead. This study takes a lead and re-examines this issue for four selected South Asian countries—Bangladesh, India, Pakistan and Sri Lanka using latest available annual time series data. The empirical analysis is done via second generation of panel unit root and panel cointegration tests which have the ability of providing robust results even under cross-sectional dependence which is likely the case for the chosen countries due to geographical as well as other socio-economic linkages between them. Multivariate set up is used by including two additional variables (labor force and capital stock) in addition to two core variables (REC and Y) and analysis has been performed over annual data (1990 to 2011). The empirical findings confirm the existence of long run relationship between the selected variables and provide evidence of unidirectional causality that runs from Y to REC in the long-run with no short-run causality. These results support *conservation hypothesis*; granting the opportunity to conserve energy resources, harvested through expensive conversion technologies. Therefore, a sound economy is pivotal to breed the renewable energy resources. These findings also have some important policy implications; suggesting that enactment of energy conservation policies in the stated economies can rein the energy consumption as well as the wastage without suffocating economic growth. For this reasons, strict reforms in the existent energy legislation and management system are instantly required to plug the loopholes and beef up the whole system.

References

[1] S. Ghosh, "Electricity consumption and economic growth in India," *Energy Policy*, vol. 30, no. 2, pp. 125–129, 2002.

[2] P. Sadorsky, "Renewable energy consumption, CO2 emissions and oil prices in the G7 countries," *Energy Econ.*, 2009.

[3] M. Ahmed, K. Riaz, A. Maqbool Khan, and S. Bibi, "Energy consumption-economic growth nexus for Pakistan: Taming the untamed," *Renew. Sustain. Energy Rev.*, vol. 52, pp. 890–896, 2015.

[4] J. E. Payne, "On biomass energy consumption and real output in the US," *Energy Sources, Part B Econ. Plan. Policy*, vol. 6, no. 1, pp. 47–52, 2011.

[5] I. Ozturk, "A literature survey on energy-growth nexus," *Energy Policy*, vol. 38, no. 1, pp. 340–349, 2010.

[6] T. H. Chang, C. M. Huang, and M. C. Lee, "Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from OECD countries," *Energy Policy*, 2009.

[7] PES, "Energy, Chapter 14 › Pakistan Economic Survey 2014," 2014.

[8] J. Kraft and A. Kraft, "On the relationship between energy and GNP," *J. Energy Dev.*, 1978.

[9] S. Narayan and N. Doytch, "An investigation of renewable and non-renewable energy consumption and economic growth nexus using industrial and residential energy consumption," *Energy Econ.*, 2017.

[10] E. Koçak and A. Şarkgüneşi, “The renewable energy and economic growth nexus in black sea and Balkan Countries,” *Energy Policy*, 2017.

[11] E. Dogan, “Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data,” *Renew. Energy*, vol. 99, pp. 1126–1136, 2016.

[12] M. Bhattacharya, S. R. Paramati, I. Ozturk, and S. Bhattacharya, “The effect of renewable energy consumption on economic growth: Evidence from top 38 countries,” *Appl. Energy*, vol. 162, pp. 733–741, 2016.

[13] R. Inglesi-Lotz, “The impact of renewable energy consumption to economic growth: A panel data application,” *Energy Econ.*, 2016.

[14] P. K. Wesseh and B. Lin, “Can African countries efficiently build their economies on renewable energy?,” *Renew. Sustain. Energy Rev.*, vol. 54, pp. 161–173, Feb. 2016.

[15] M. Kahia, M. S. Ben Aïssa, and L. Charfeddine, “Impact of renewable and non-renewable energy consumption on economic growth: New evidence from the MENA Net Oil Exporting Countries (NOECs),” *Energy*, vol. 116, pp. 102–115, Dec. 2016.

[16] M. Hamit-Haggar, “Clean energy-growth nexus in sub-Saharan Africa: Evidence from cross-sectionally dependent heterogeneous panel with structural breaks,” *Renew. Sustain. Energy Rev.*, vol. 57, pp. 1237–1244, May 2016.

[17] K. Saidi and M. Ben Mbarek, “Nuclear energy, renewable energy, CO2 emissions, and economic growth for nine developed countries: Evidence from panel Granger causality tests,” *Prog. Nucl. Energy*, vol. 88, pp. 364–374, 2016.

[18] S. F. Naseri, S. Motamedi, and M. Ahmadian, “Study of Mediated Consumption Effect of Renewable Energy on Economic Growth of OECD Countries,” *Procedia Econ. Financ.*, vol. 36, no. 16, pp. 502–509, 2016.

[19] M. Ben Jebli and S. Ben Youssef, “Output, renewable and non-renewable energy consumption and international trade: Evidence from a panel of 69 countries,” *Renew. Energy*, vol. 83, pp. 799–808, Nov. 2015.

[20] A. Ohler and I. Fetters, “The causal relationship between renewable electricity generation and GDP growth: A study of energy sources,” *Energy Econ.*, vol. 43, pp. 125–139, May 2014.

[21] R. Zeb, L. Salar, U. Awan, K. Zaman, and M. Shahbaz, “Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: Progress towards green economy,” *Renew. Energy*, vol. 71, pp. 123–132, Nov. 2014.

[22] X. Long, E. Y. Naminse, J. Du, and J. Zhuang, “Nonrenewable energy, renewable energy, carbon dioxide emissions and economic growth in China from 1952 to 2012,” *Renew. Sustain. Energy Rev.*, vol. 52, pp. 680–688, Dec. 2015.

[23] I. K. Maji, “Does clean energy contributes to economic growth? Evidence from Nigeria,” *Energy Reports*, vol. 1, pp. 145–150, 2015.

[24] R. Inglesi-Lotz, “The Impact of Renewable Energy Consumption to Economic Welfare: A Panel Data Application,” 2013.

[25] A. K. Tiwari, “Volume 31 , Issue 2 A structural VAR analysis of renewable energy consumption , real GDP and,” *Econ. Bull.*, vol. 31, no. 2, pp. 1793–1806, 2011.

[26] A. K. Tiwari, “Comparative performance of renewable and nonrenewable energy source on economic growth and CO2 emissions of europe and eurasian countries: A PVAR approach,” *Econ. Bull.*, 2011.

[27] E. Yildirim, Ş. Saraç, and A. Aslan, “Energy consumption and economic growth in the USA: Evidence from renewable energy,” *Renew. Sustain. Energy Rev.*, vol. 16, no. 9, pp. 6770–6774, 2012.

[28] S. Cho, E. Heo, and J. Kim, “Causal relationship between renewable energy consumption and economic growth: comparison between developed and less-developed countries,” *Geosystem Eng.*, vol. 18, no. 6, pp. 284–291, Nov. 2015.

[29] P. Sadorsky, “Renewable energy consumption and income in emerging economies,” *Energy Policy*, 2009.

[30] M. Shahbaz, G. Rasool, K. Ahmed, and M. K. Mahalik, “Considering the effect of biomass energy consumption on economic growth: Fresh evidence from BRICS region,” *Renew. Sustain. Energy Rev.*, vol. 60, pp. 1442–1450, 2016.

[31] T. Chang, R. Gupta, R. Inglesi-Lotz, B. Simo-Kengne, D. Smithers, and A. Trembling, “Renewable energy and growth: Evidence from heterogeneous panel of G7 countries using Granger causality,” *Renew. Sustain. Energy Rev.*, vol. 52, pp. 1405–1412, Dec. 2015.

[32] D. M. Ibrahiem, “Renewable Electricity Consumption, Foreign Direct Investment and Economic Growth in Egypt: An ARDL Approach,” *Procedia Econ. Financ.*, vol. 30, pp. 313–323, Jan. 2015.

[33] M. Shahbaz, N. Loganathan, M. Zeshan, and K. Zaman, “Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan,” *Renew. Sustain. Energy Rev.*, vol. 44, pp. 576–585, 2015.

[34] H. Bloch, S. Rafiq, and R. Salim, "Economic growth with coal, oil and renewable energy consumption in China: Prospects for fuel substitution," *Econ. Model.*, vol. 44, pp. 104–115, 2015.

[35] U. Al-Mulali, H. G. Fereidouni, and J. Y. M. Lee, "Electricity consumption from renewable and non-renewable sources and economic growth: Evidence from Latin American countries," *Renew. Sustain. Energy Rev.*, vol. 30, pp. 290–298, 2014.

[36] N. Apergis and D. C. Danuletiu, "Renewable Energy and Economic Growth : Evidence from the Sign of Panel Long-Run Causality," *Int. J. Energy Econ. Policy*, vol. 4, no. 4, pp. 578–587, 2014.

[37] M. Sebri and O. Ben-Salha, "On the causal dynamics between economic growth, renewable energy consumption, CO2 emissions and trade openness: Fresh evidence from BRICS countries," *Renew. Sustain. Energy Rev.*, vol. 39, pp. 14–23, 2014.

[38] H. T. Pao, Y. Y. Li, and Hsin-Chia Fu, "Clean energy, non-clean energy, and economic growth in the MIST countries," *Energy Policy*, vol. 67, pp. 932–942, 2014.

[39] M. Ben Jebli, S. Ben Youssef, and I. Ozturk, "The Role of Renewable Energy Consumption and Trade: Environmental Kuznets Curve Analysis for Sub-Saharan Africa Countries," *African Dev. Rev.*, vol. 27, no. 3, pp. 288–300, Sep. 2015.

[40] M. E. Bildirici and F. Özaksoy, "The relationship between economic growth and biomass energy consumption in some European countries," in *Journal of Renewable and Sustainable Energy*, 2013, vol. 5, no. 2.

[41] U. Al-Mulali, H. G. Fereidouni, J. Y. Lee, and C. N. B. C. Sab, "Examining the bi-directional long run relationship between renewable energy consumption and GDP growth," *Renew. Sustain. Energy Rev.*, vol. 22, pp. 209–222, 2013.

[42] M. E. Bildirici, "The relationship between economic growth and biomass energy consumption," *J. Renew. Sustain. Energy*, vol. 4, no. 2, p. 023113, Mar. 2012.

[43] N. Apergis and J. E. Payne, "On the causal dynamics between renewable and non-renewable energy consumption and economic growth in developed and developing countries," *Energy Syst.*, 2011.

[44] N. Apergis and J. E. Payne, "Renewable energy consumption and economic growth: Evidence from a panel of OECD countries," *Energy Policy*, vol. 38, no. 1, pp. 656–660, 2010.

[45] N. Apergis and J. E. Payne, "Renewable energy consumption and growth in Eurasia," *Energy Econ.*, 2010.

[46] E. Dogan, "The relationship between economic growth and electricity consumption from renewable and non-renewable sources: A study of Turkey," *Renew. Sustain. Energy Rev.*, vol. 52, pp. 534–546, 2015.

[47] M. S. Ben Aïssa, M. Ben Jebli, and S. Ben Youssef, "Output, renewable energy consumption and trade in Africa," *Energy Policy*, vol. 66, pp. 11–18, Mar. 2014.

[48] B. Lin and M. Moubarak, "Renewable energy consumption – Economic growth nexus for China," *Renew. Sustain. Energy Rev.*, vol. 40, pp. 111–117, Dec. 2014.

[49] A. N. Menegaki, "Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis," *Energy Econ.*, 2011.

[50] F. H. Abanda, A. Ng'ombe, R. Keivani, and J. H. M. Tah, "The link between renewable energy production and gross domestic product in Africa: A comparative study between 1980 and 2008," *Renew. Sustain. Energy Rev.*, vol. 16, no. 4, pp. 2147–2153, 2012.

[51] N. Bowden and J. E. Payne, "Sectoral analysis of the causal relationship between renewable and non-renewable energy consumption and real output in the US," *Energy Sources, Part B Econ. Plan. Policy*, vol. 5, no. 4, pp. 400–408, 2010.

[52] J. E. Payne, "On the dynamics of energy consumption and output in the US," *Appl. Energy*, vol. 86, no. 4, pp. 575–577, 2009.

[53] ESSA, "Regional energy security for South Asia," 2010.

[54] PEYB, "Pakistan Energy Yearbook 2014," no. December. pp. 85–93, 2014.

[55] M. G. Doggar, "Prospects and potential of renewable energy resources," 2011, vol. 0342281665.

[56] P. Meisen, "Overview of Sustainable Renewable Energy Potential of India," 2010.

[57] SLSEA, "Sri Lanka Energy Balance," *sri Lanka Sustain. Energy Auth.*, 2015.

[58] S. Islam and M. Z. R. Khan, "A Review of Energy Sector of Bangladesh," *Energy Procedia*, vol. 110, pp. 611–618, Mar. 2017.

[59] IES, "Central statistics office national statistical organization ministry of statistics and program implementation government of India," no. 20th, 2017.

[60] M. Hashem Pesaran, "General Diagnostic Tests for Cross Section Dependence in Panels," 2004.

[61] M. H. Pesaran, "A simple panel unit root test in the presence of cross-section dependence," *J. Appl. Econom.*, vol. 22, no. 2, pp. 265–312, Mar. 2007.

[62] J. Westerlund, “Testing for Error Correction in Panel Data,” *Oxf. Bull. Econ. Stat.*, vol. 69, no. 6, pp. 709–748, Dec. 2007.

[63] O. Ocal and A. Aslan, “Renewable energy consumption – economic growth nexus in Turkey,” *Renew. Sustain. Energy Rev.*, vol. 28, pp. 494–499, 2013.

[64] R. Sari, B. T. Ewing, and U. Soytas, “The relationship between disaggregate energy consumption and industrial production in the United States: An ARDL approach,” *Energy Econ.*, vol. 30, no. 5, pp. 2302–2313, Sep. 2008.

[65] C. T. Tugcu, I. Ozturk, and A. Aslan, “Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries,” *Energy Econ.*, 2012.

[66] R. Sari and U. Soytas, “Disaggregate energy consumption, employment and income in Turkey,” *Energy Econ.*, vol. 26, no. 3, pp. 335–344, 2004.

[67] M. Zeshan, M. Shahbaz, and T. Afza, *Renewable Energy Consumption and Economic Growth in Pakistan Sustainable Development Policy Institute (SDPI), Islamabad, Pakistan*. LAP LAMBERT Academic Publishing, 2012.

[68] S. S. Muhammad, Z. Muhammad, and S. Muhammad, “Renewable and nonrenewable energy consumption, real GDP and CO2 emissions nexus: a structural VAR approach in Pakistan,” *Bull. Energy Econ.*, vol. 2, no. 3, pp. 91–105, 2014.

[69] H. T. Pao and H. C. Fu, “Renewable energy, non-renewable energy and economic growth in Brazil,” *Renew. Sustain. Energy Rev.*, vol. 25, pp. 381–392, 2013.

[70] V. Kulionis, “consumption , CO 2 emissions and economic growth,” *Lund Univ.*, no. June 2013, p. 69, 2013.

[71] N. Magnani and A. Vaona, “Regional spillover effects of renewable energy generation in Italy,” *Energy Policy*, vol. 56, pp. 663–671, 2013.

[72] J. E. Payne, “The causal dynamics between US renewable energy consumption, output, emissions, and oil prices,” *Energy Sources, Part B Econ. Plan. Policy*, vol. 7, no. 4, pp. 323–330, 2012.

[73] V. Bobinaite, A. Juozapaviciene, and I. Konstantinaviciute, “Assessment of Causality Relationship between Renewable Energy Consumption and Economic Growth in Lithuania,” *Inz. Ekon. Econ.*, vol. 22, no. 5, pp. 510–518, 2011.

[74] B. T. Ewing, R. Sari, and U. Soytas, “Disaggregate energy consumption and industrial output in the United States,” *Energy Policy*, vol. 35, no. 2, pp. 1274–1281, 2007.

[75] A. Alper and O. Oguz, "The role of renewable energy consumption in economic growth: Evidence from asymmetric causality," *Renew. Sustain. Energy Rev.*, 2016.

[76] M. A. Destek, "Renewable energy consumption and economic growth in newly industrialized countries: Evidence from asymmetric causality test," *Renew. Energy*, vol. 95, pp. 478–484, 2016.

[77] A. Omri, N. Ben Mabrouk, and A. Sassi-Tmar, "Modeling the causal linkages between nuclear energy, renewable energy and economic growth in developed and developing countries," *Renew. Sustain. Energy Rev.*, 2015.

[78] N. Apergis and J. E. Payne, "The electricity consumption-growth nexus: Renewable versus non-renewable electricity in central America," *Energy Sources, Part B Econ. Plan. Policy*, 2012.

[79] R. A. Salim and S. Rafiq, "Why do some emerging economies proactively accelerate the adoption of renewable energy?," *Energy Econ.*, 2012.

[80] N. Apergis and J. E. Payne, "A global perspective on the renewable energy consumption-growth nexus," *Energy Sources, Part B: Economics, Planning and Policy*. 2012.

[81] N. Apergis and J. E. Payne, "The renewable energy consumption-growth nexus in Central America," *Appl. Energy*, 2011.

[82] N. Apergis and J. E. Payne, "Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model," *Energy Econ.*, 2012.

[83] N. Apergis and J. E. Payne, "Renewable and non-renewable electricity consumption-growth nexus: Evidence from emerging market economies," 2011.

Appendix

Table 2: Studies Based on Single Countries

S. No.	Authors	Countries (Period)	Variables	Causality Test	Supported Hypothesis
1	Dogan [11]	Turkey (1988-2012)	Y, REC, NREC, K , L	VECM GC	C (short run), F (long run)
2	Dogan [46]	Turkey (1990-2012)	RELC, Y, NREC, L,K	VECM GC	N
3	Long et al. [22]	China (1952–2012)	Y, COALC,OILC, CO2, GASC, ELEC, HYDC, NUC	GC	G
4	Ibrahiem [32]	Egypt (1980-2011)	Y, RELC, FDI,	GC	F
5	Shahbaz et al. [33]	Pakistan (1972–2011)	Y, REC, K, L	GC	F
6	Bloch et al. [34]	China (1965–2013)	CO, OC, REC, CO2, OP, CP, L, K	GC	F
7	Maji [23]	Nigeria (1971-2011)	Y, REC	ARDL	G
8	Lin and Moubarak [48]	China (1977–2011)	Y, REC,CO2, L	GC	N (Y& REC) Short Run F (Y& REC) Long Run
9	Pao and Fu [69]	Brazil (1980-2010)	Y, L, K, REC, N-REC	GC	Mixed Results F (EG and REC) G (NHREC & EG)
10	Ocal and Aslan [63]	Turkey (1990-2010)	REC, Y, K, L	TY	C
11	Viktoras Kulionis [70]	Denmark (1972-2012)	REC, Y, CO_2	GC	N
12	Magnani and Vaona [71]	Italy (1997–2007)	REC, Y	GC	G
13	Yildirim et al. [27]	US (1949-2010)	Y, E, investment, REC	TY	G (biomass-waste-derived) N (For all other RE)

14	Zeeshan et al. [67]	Pakistan (1972-2011)	Y, REC, N-REC, K, L	VECM GC	F
15	Payne [72]	US (1949-2009)	REC, Y, real OP, CO2	TY	N
16	Muhammad et al. [68]	Pakistan (1972-2010)	Y, REC, N-REC, CO_2	VD	G
17	Tiwari [25]	India (1960-2009)	REC, Y, CO_2	SVAR	G
18	Payne [4]	US (1949-2007)	Biomass EC, Y	TY	G
19	Bobinaite et al. [73]	Lithuania (1990-2009)	REC, Y	GC	G
20	Bowden and Payne [51]	US (1949-2006)	Y, REC / N-REC, K, E	TY	N
21	Payne [52]	US (1949-2006)	REC, N-REC, Y	TY	N
22	Sari et al. [64]	US (2001-2005)	REC, industrial output, E	ARDL	C
23	Ewing et al. [74]	US (2001-2005)	REC, real output	VD	G
24	Sari and Soytas [66]	Turkey (1969-1999)	EC, Y, E	VD	G

Notes: Y is the gross domestic product, EC is energy consumption, REC is the renewable energy consumption, N-REC is the non-renewable energy consumption, RELC is the renewable electricity consumption, N-RELC is the non-renewable electricity consumption, L is labor force, K is capital, CO2 is carbon emission, E is employment, CPI consumer price index, OP is oil prices, F is Feedback Hypothesis, G is Growth Hypothesis, C is Conservation Hypothesis, N is Neutrality Hypothesis, TY is the Toda-Yamamoto causality, ARDL is Auto Regressive Distributed Lag approach, GC is Granger causality test, SVAR is structural VAR and VD is variance decomposition approach.

Table 3: Studies Based on Multiple Countries

S. No.	Authors	Name / No of Countries (Period)	Variables	Causality Test	Supported Hypothesis
1	Koçak and Şarkgüneşi [10]	9 Black Sea and Balkan (1990–2012)	Y,REC, K,L,	Dumitrescu and Hurlin (2012) Panel Causality	G
2	Narayan and Doytch [9]	89 (1971-2011)	REC,NREC,Y	GC	N
3	Bhattacharya et al. [12]	38 (1991- 2012)	REC, Y	Dumitrescu-Hurlin causality	G
4	Inglesi-Lotz [13]	34 OECD (1990-2010)	REC, Y	GC	G
5	Kahia et al. [15]	MENA (1980-2012)	Y, REC, NREC, K, L	GC	G (short run), F (long run)
6	Hamit-Haggar [16]	11 Sub-Saharan African (1971–2007)	REC,Y	GC	G
7	Shahbaz et al. [30]	BRICS (1991–2015)	REC,Y	PVECM	F
8	Aslan and Ocal [75]	7 (1990–2009)	Y, REC, K, L	Hatemi-J causality	Mix results
9	Wesseh Jr and Lin [14]	34 African (1980-2011)	REC, NREC, L, K, Y	GC	G
10	Saidi and Mbarek [17]	9 developed (1990-2013)	NEC, CO2, REC, Y,K ,L	GC	G (short run), F (long run)
11	Naseri et al. [18]	OECD (1990-2012)	REC, Y	ARDL	G
12	Destek [76]	7 (1971-2011)	REC,Y, K, L	Asymmetric causality approach by Hatemi-J	Mixed Results
13	Omri et al. [77]	17 developed & developing (1990–2011)	REC, Y, NEC,	DSEM Approach	Mixed Results
14	Chang et al. [31]	G7 (1990–2011)	REC Y	PVECM	F
15	Cho et al. [28]	31 OECD & 49 Non-OECD (1990-2010)	REC, Y	PVECM	C (for developed) &

					F (for less-developed)
16	Jebli and Youssef [19]	69 (1980–2010)	REC, NREC, K, L, Import, Export, Y	Engle and Granger Approach	G
17	Al-mulali et al. [35]	18 Latin American (1980-2010)	Y, REC, NREC,K, L, total trade	PVECM	F
18	Ohler and Fetters [20]	20 OECD (1990- 2008)	REC, K, L, Y	PVECM	G
19	Apergis and Danuletiu [36]	80 (1990-2012)	REC, K, L,Y	Canning and Pedroni (2008) causality test	F
20	Zeb et al. [21]	SAARC (1975-2010)	Env. Degradation, Poverty, CO2,Y,REC	PVECM	G (India); N (for other countries)
21	Ben Aïssa et al. [47]	11 African (1980-2008)	Export, Import Y, L, K,REC	PVECM	N
22	Sebri and Ben-Salha [37]	BRICS (1971-2010)	REC, CO2,Trade Openness, Y	PVECM	F
23	Pao et al. [38]	MIST (Mexico, Indonesia, South Korea, and Turkey) (1990-2010)	Y, K, L, REC, FF	VECM	F
24	Aïssa et al. [47]	24 sub-Saharan African (1980-2010)	Y, CO2, REC	Engle and Granger (1987)	F
25	Al-mulali et al. [41]	80 (1980-2009)	REC, EG	FMOLS established by Phillips and Hansen 1990	Mixed Results F (79% countries) N (19% countries) G and C (2% countries)

26	Bildirici and Ozaksoy [40]	10 (1960-2010)	REC, Y	GC	F
27	Bildirici [42]	Developing and emerging (1980-2009)	REC, Y	GC	F
28	Apergis and Payne [78]	Six American (1990-2007)	Y, RElC, N-RElC, K, L	GC	Mixed Results G (in short-run) F (in long-run)
29	Tugcu et al. [65]	G7 (1980-2009)	REC, Y	Causality test by Hatemi-J (2012)	Mixed Results N for France, Italy, Canada, U.S. F for U.K and Japan. C for Germany.
30	Salim and Rafiq [79]	6 (1980-2006)	REC, Y	GC	Mixed Results C (in long-run) F (in short-run)
31	Apergis and Payne [80]	80 (1990-2007)	EG, REC, L, K	Multivariate Panel Error Correction Model	F
32	Apergis and Payne [81]	6 Central American (1980-2006)	REC, Y	PVECM	F
33	Apergis and Payne [82]	80 (1990-2007)	Y, RELC, N-RElC, K, L	PVECM	F
34	Apergis and Payne [83]	16 (1990-2007)	Y, RElC, N-RElC, K, L	PVECM	Mixed Results
35	Apergis and Payne [43]	Developed (25), Developing (55) (1990-2007)	EG, REC, N-REC, K, L	PVECM	F (each country panel)

36	Menegaki [49]	27 European (1997-2007)	Y, gross inland EC, final EC, CO2, E	PVECM	N
37	Tiwari [26]	16 European and Eurasian (1965-2009)	REC, N-REC, CO2, Y	GC	G
38	Apergis and Payne [45]	13 Eurasian (1992-2007)	REC, Y, K, L	PVECM	F
39	Apergis and Payne [44]	20 OECD (1985-2005)	REC, Y	PVECM	F
40	Sadorsky [29]	18 (1994-2003)	REC, Y, K, L	PVECM	C

Notes: EC is energy consumption, REC is the renewable energy consumption, N-REC is the non-renewable energy consumption, RELC is the renewable electricity consumption, N-RELC is the non-renewable electricity consumption, Y is the gross domestic product, L is labor force, K is capital, C02 is carbon emission, E is employment, CPI consumer price index, OP is oil prices, F is Feedback Hypothesis, G is Growth Hypothesis, C is Conservation Hypothesis, N is Neutrality Hypothesis, PVECM is panel vector error correction model, GC is Granger causality, ARDL is Auto Regressive Distributed Lag approach, DSEM is dynamic simultaneous-equation modeling approach, FMOLS is fully modified least square approach.

.

Table 4: Basic Summary Statistics

Country	Variable	Mean	SD	Median	IQR	Min	Max	obs
Bangladesh	Y	3.70e+10	2.02e+10	2.99e+10	2.79e+10	1.51e+10	8.69e+10	41
	REC	6736.712	1269.726	6874.789	2031.042	4455.196	8835.719	41
	K	7.00e+09	6.18e+09	4.48e+09	8.08e+09	2.32e+08	2.22e+10	41
	L	1.10e+08	2.78e+07	1.10e+08	5.00e+07	6.76e+07	1.53e+08	41
India	Y	4.74e+11	3.25e+11	3.54e+11	4.16e+11	1.53e+11	1.33e+12	41
	REC	135336.1	23388.12	135289.3	32805	95779.53	184800.6	41
	K	1.38e+11	1.34e+11	8.20e+10	1.14e+11	2.99e+10	5.05e+11	41
	L	8.88e+08	2.01e+08	8.86e+08	3.44e+08	5.68e+08	1.22e+09	41
Pakistan	Y	6.53e+10	3.52e+10	6.13e+10	5.33e+10	2.02e+10	1.33e+11	41
	REC	19514.95	5776.767	19306.43	10084.09	10628.92	29355.3	41
	K	1.46e+10	6.42e+09	1.49e+10	9.98e+09	5.36e+09	2.66e+10	41
	L	1.15e+08	3.62e+07	1.14e+08	6.41e+07	6.08e+07	1.76e+08	41
Sri Lanka	Y	1.52e+10	8.43e+09	1.26e+10	1.16e+10	5.26e+09	3.60e+10	41
	REC	3805.309	672.9064	3915.564	1144.936	2738.272	5053.438	41
	K	3.76e+09	2.46e+09	2.93e+09	2.23e+09	6.00e+08	1.02e+10	41
	L	1.70e+07	2464520	1.73e+07	4209000	1.27e+07	2.09e+07	41
Total	Y	1.48e+11	2.50e+11	4.13e+10	1.23e+11	5.26e+09	1.33e+12	164
	REC	41348.28	56041.69	9732.317	57789.14	2738.272	184800.6	164
	K	4.09e+10	8.73e+10	1.02e+10	2.47e+10	2.32e+08	5.05e+11	164
	L	2.83e+08	3.68e+08	1.12e+08	3.31e+08	1.27e+07	1.22e+09	164