Renewable and Non-renewable Energy, Economic Growth and Natural Resources Impact on Environmental Quality: Empirical Evidence from South and Southeast Asian Countries with CS-ARDL Modeling

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ABSTRACT

This study aims to estimate the effects of economic growth, renewable and non-renewable energy consumption (EC) and natural resources on carbon emissions for the period of 1990-2014, in 11 countries, using 3 panels: (i) Full countries panel, (ii) South Asian countries and (iii) Southeast Asian countries. For all panels, the long-run elasticities were estimated. The results suggest that non-renewable and renewable EC increase economic development in the three panels. Besides, natural resources impede the economic growth in South Asian and full countries panels while natural resources increase the economic activities in Southeast Asian countries. Non-renewable and economic growth increase CO_2 emissions, whereas, renewable EC lessens the carbon emissions. Natural resources also contributed to CO_2 emissions in the case of South Asian and full countries panels while improved the environmental quality in the Southeast Asian region. It was also observed that there is cointegration among the variables in all three panels. Policy recommendations can be made, in the sense that renewable energy sources should be preferred to decrease CO_2 emissions, and education and corruption should be improved to estimulate the economic growth in the studied areas.

Keywords: Renewable Energy, Non-renewable Energy, CO_2 Emissions, Natural resources, CS-ARDL
JEL Classifications: Q43, Q44, Q56

1. INTRODUCTION

From the last few decades climate change has been a very wide spoken phenomenon and exhalation of carbon dioxide (CO_2 emissions) is considered its chief source. The intensity of the CO_2 emissions has been risen by 45% from the last 130 years which is constantly deteriorated the environmental quality (Carbon Footprint, 2018).

According to the existing literature, several drivers of CO_2 emissions (CO_2) have been discussed such as economic growth (GDP), industrialization, urbanization (URB), deforestation, waste management, air pollution, renewable energy (RE) sources, non-renewable energy (NRE) sources (Arshad et al.,

2020) and natural resources (NR) etc. To meet the demand for the ever increasing population of this planet, labor, capital and other inputs of production (especially energy sources), uplift of human efforts are considered liable for the world's astonishing economic progress (Owusu and Asumadu-Sarkodie, 2016), which ultimately raised the level of carbon emissions. Briefly speaking the release of carbon dioxide has proved itself for the threat to environment system and human development (Bekun et al., 2019). The gaseous emission alarming increased from the figure of 9434.4 million tons in 1961 to a gigantic figure of 34649.4 million tons in year 2011 (IPCC, 2014). British Petroleum agency (2018) report reveals that a uplift of carbon dioxide from 29714.2 million tons in 2009-33444 million tons in 2017 was observed on the globe.

The dynamic that has affected the energy-related carbon emissions have been widely discussed in the existing literature: Farhani and Shahbaz (2014) for Middle East and North African (MENA) countries, Shafiei and Salim (2014) for OECD countries, Ben Jebli and Ben Youssef (2015) for Tunisia, Bhattacharya et al. (2017) for 85 developed and developing economies, Bento and Moutinho (2016) for the Italian case, Rasoulinezhad and Saboori (2018) for the commonwealth of independent states (CIS), Dong et al. (2019) for 128 countries and Adam and Nsiah (2019) for 28 Sub-Saharan African economies, are some examples.

Besides, the economic growth and NR nexus is also discussed in the existing literature, that provides the mixed (positive and negative) substantiation of a NR on economic growth (Satti et al., 2014). The economies with abundant NR perform lesser than the NR-scarce nations (Sachs and Warner, 1995). For instance, Korea, Singapore, Japan, Hong Kong and Switzerland, performed very well and made enormous progress with no or very limited access to natural resources (Krueger, 1998) and contrary to NR abundant countries made 3 times more progress (Auty, 2001; Sachs and Warner, 1995). Shaw (2013) also proved that NR abundance is the only reason for low economic growth in Azerbaijan.

Conversely, some South American countries took advantage of the NR boom to enhance their economic growth. Notably, Ecuador increased its GDP per capita during the boom period of NR (Sachs and Warner, 1999). Besides, the resources of ore and coal in England and Germany were the significant ingredients behind the industrial revolution in Europe (Sachs and Warner, 1995). The exploitation of NR abundance was also behind the success story of Norway to achieve a high level of income prosperity with proper economic planning (Gylfason, 2001).

Furthermore, natural resources (NR) are also included in different studies to investigate the impact on environmental quality. Recently, Bekun et al. (2019) analyzed the causal interaction between economic growth, NR rent, RE and NRE consumption in CO_2 emissions for EU 16 countries covering the period of 1996-2014 by pooled mean group (PMG)-ARDL models. The Kao cointegration techniques confirmed the long-run relationship between the variables, and the study suggested that NR rent have a significant positive impact on CO_2 emissions. It indicates that overdependence on the NR rent has effects on environmental sustainability if a proper management is ignored. The study also noted that NRE and economic growth increase, whereas RE consumption decrease the CO_2 emissions. The causality results display a feedback result effect amidst NRE, RE and economic development. Further, the study also found feedback causality between NR rent and economic growth.

The above discussion about energy (RE and NRE) consumption-CO_2 emissions nexus disclosed mixed results for different countries and economies with different time spam. Moreover, NR abundance or scarce role in the economic growth has been a challenge in developing and developed countries, and their impact on CO_2 emissions requires more research, as existing results are not consensual. For this purpose, the current study investigates the linkages between economic growth, NR rent, CO_2 emissions, RE

and NRE consumption over the period of 1990-2014 for the South and Southeast Asian countries (SSEA). We developed two models to full fill the aim of the study: Model 1, to access the impact of RE, NRE and NR effects on economic growth, Model 2, to access the impact of all the discussed variables on CO_2 emissions.

Although several studies have considered the factors influencing CO_2 emissions at single-country, regional and global perspective, there is a limited number of studies examining the impacts of economic growth, NR rent, RE and NRE consumption on carbon emissions within the same framework for SSEA countries.

Further, this piece of writing dissent from the current composition in several modes. Firstly, it is a humble effort to meet the literature gap, by studying SSEA economies, using the referred variables, as the estimations were made for 3 panels: (i) Full countries panel, (ii) South Asian countries and (iii) Southeast Asian countries. Secondly, this article considers advance panel data techniques that allow the heterogeneous unobserved parameters and cross-sectional dependence (CD) of the sample countries. Thirdly, the study uses the advance PMG technique to estimate the short and long-run dynamics. Fourthly, to robust the PMG estimation we have applied a new technique named as dynamic common correlated effects (DCCE) CS-ARDL introduced by Chudik et al. (2016). Finally, this paper controls for the result of diagnostic and specification tests, which have been rarely considered in prior studies.

Different cointegration techniques such as Pedroni, Kao, Fisher and Westerlund allowed us to conclude a long-run relationship exist among the considered variables. Findings from the PMG and DCCE CS-ARDL estimations reveal that RE and NRE rise the economic development in the selected three panels. Besides, natural resources impede the economic growth in South Asian and full countries panels while increase the economic activities in Southeast Asian countries. In the case of Model 2, results demonstrated that NRE and economic growth increased the CO_2 emissions, whereas, RE consumption lessens the carbon emissions in all three selected panels. However, natural resources also contributed to raise CO_2 emissionsin the case of South Asian and full countries panels while improved the environmental quality in the Southeast Asian region.

The policy implication in this regard, is that RE sources should be preferred to decrease CO_2 emissions in the SSEA countries. Moreover, for the better use of natural resources, the government should concentrate on education and corruption to improve the economic growth in the selected studied areas.

The remaining portion of paper has arranged in following way: The literature review chapter, the models construction, data overview and methodology chapter, the result and discussion chapter and in the end, the conclusions, policy implications, limitations and future recommendation chapter.

2. LITERATURE REVIEW

The anterior literature has discussed the linkages among energy consumption (EC), renewable energy (RE), non-renewable

energy (NRE), energy prices, industrialization, economic growth and other macro-economic variables such as foreign investment (FDI), financial development (FD), trade openness (TRD), and natural resource (NR) abundance, with CO_2 emissions as a proxy of greenhouse gases (GHGs).

We divided our literature into two strands: (i) The effect of (RE), (NRE), economic development and other macro-economic variables with environmental degradation in the form of carbon emissions and (ii) the influence of NR on economic growth and on CO_2 emissions (CO_2).

2.1. Economic Growth (GDP), CO_2 Emissions (CO_2), Renewable (RE) and Non-renewable Energy (NRE)

Numerous studies that investigated the environmental pollution-macroeconomic variables nexus are quite insignificant to justify such extensive phenomenon at single-country level, territorial scale and worldwide. For instance, in the case of the MENA countries, Farhani and Shahbaz (2014) examined the relationship among RE, NRE, GDP and CO_2 emissions for 1980-2009. The study used the fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) method to investigate the long-run elasticities. The results show that RE and NRE consumption increase carbon emissions. The study also found an inverted U-shaped environment Kuznets curve (EKC) with economic growth and CO_2 emissions. Unidirectional causality running from RE, NRE and output to CO_2 emissions were found in the short run, while in the long run, bidirectional causality running from RE and NRE to CO_2 emissions was observed.

In addition to the concern mentioned above, Shafiei and Salim (2014) focused on the OECD countries during 1980-2011 and investigated with STIRPAT model the relationship between urbanization, CO_2 emissions, RE and NRE consumption. The results show that NRE has a direct impact on CO_2 emissions, while RE decreases carbon emissions. The study also confirmed the EKC hypothesis with urbanization and CO_2 emissions. Besides, in Tunisia, Ben Jebli and Ben Youssef (2015) derived similar results with data covering years 1980-2009. Further, Bhattacharya et al.(2017) demonstrated the role of RE consumption and institutions on economic growth and in combating CO_2 emissions for 85 developing and developed economies of different income groups around the globe. The results from the generalized moment method (GMM) and FMOLS show that RE has a significant favorable impact on economic growth and improved environmental quality. The production of RE is the key to mitigating carbon emissions in Italy, as concluded by Bento and Moutinho (Bento and Moutinho, 2016).

For the case of Turkey, Pata (2018) analyzed the short and long-run dynamic relationship between GDP per capita, CO_2 emissions, urbanization, RE consumption, FD, hydropower EC and alternative EC, during 1974-2014 with ARDL bound testing and FMOLS method. The work reveals the ultimate relationships among mutable with Gregory-Hansen and Hatemi-J cointegration approaches. In addition, the study noted that economic growth, urbanization and FD increase CO_2 emissions, whereas RE consumption, hydropower consumption and alternative EC sources had insignificant effects on environmental quality.

Inglesi-Lotz and Dogan (2018) confirmed the long-run relationships between income, TRD, NRE, RE consumption and CO_2 emissions for the ten biggest electricity generators in Sub-Saharan Africa over the period of 1980 to 2011. Moreover, the authors concluded that the use of RE improved while NRE worsened the environment quality, and that there is unidirectional causality running from income, CO_2 emissions, TRD and NRE towards RE. Top RE users countries need to increase RE production, FD and TRD to lessen the carbon emissions (Dogan and Seker, 2016). Conversely, Rasoulinezhad and Saboori (2018) noted the long-run connections between RE, NRE, TRD, GDP, financial openness and carbon emissions for the commonwealth of independent states (CIS) for 1992-2015. The results from panel cointegration methods such as FMOLS and DOLS declared that RE has no impact on CO_2 emissions and that fossil fuel proxy of NRE consumption declined whereas financial openness improved the environmental quality in the long run.

In more recent studies, authors illustrated different linkages between variables. For instance, Sharif et al. (2019) concentrated on the ultimate liaison connecting NRE, RE consumption and carbon emissions. The long-run elasticities show an inverse impact of RE and direct effects of NRE consumption on the environment for the panel of 74 nations during 1990-2015. Also, Belaïd and Zrelli (2019) and Chen et al. (2019) explored similar findings for 9 Mediterranean countries and regional study in China, respectively.

However, Adam and Nsiah (2019) noticed that both RE and NRE consumption increased the CO_2 emissions in 28 economies of Sub Saharan Africa. In another scenario, Dong et al. (2019) estimated the linkages between RE intensity, NRE and economic growth with STIRPAT modeling the global and regional context of an unbalanced panel dataset of 128 countries covering 1990-2014. The results indicated that at a global level, RE intensity, NRE, economic growth and population deteriorated the environment. Nonetheless, the regional perspective findings suggested that RE declined the CO_2 emissions in the two regions such as South and Central America and Europe and Eurasia.

2.2. Natural Resources (NR)-Economic Growth (GDP)-Environmental Pollution Nexus

The natural resources (NR)-economic growth (GDP) nexus has been discussed into two scenarios: resource abundance and resource dependence in the prior literature. Resource abundance can be explained by "annual per capita rent of resource production"(Apergis and Payne, 2014; Brunnschweiler, 2008) whereas resource dependence can be measured by "rents from NR over GDP" (Auty, 2007; Bhattacharyya and Hodler, 2014),"the share of total natural resource in total export" (Dietz et al., 2007), or "the share of total natural resource export in GDP" (Boschini et al., 2013; Sachs and Warner, 1995).

Several studies have been discussed the linkages between NR abundance and economic indicators around the globe. For instance, Sarmidi et al. (2014) proved that NR abundance affects growth positively after the threshold level of institutional quality. After 2003, the oil abundance affects positively economic growth in MENA countries (Apergis and Payne, 2014). Conversely, Satti

et al. (2014) inspected the connection among NR abundance, economic growth, FD, capital and trade by ARDL bounds testing approach and VECM for 1971-2011. The findings confirmed the existence of long-run relationship between the considered variables and suggested that NR abundance impedes the economic growth whereas FD, trade openness and capital stock improve the economic development in Venezuela. Ahmed et al. (2016) also proved the association between NR, economic growth, capital, labour and exports by Cobb-Douglas production function. The results show that a 1% increase in NR results in 0.47% decline in GDP in the long-run. It means that NR abundance slowed the economic development in Iran during 1965-2011. The causality results proved the feedback effect between economic growth and NR abundance. Besides, Kim and Lin (2017) noticed similar linkages between NR abundance and economic growth by heterogeneous panel cointegration technique for 40 developing countries covering the period from 1990 to 2012. Ben-Salha et al. (2018) determined the causal connections between NR rent and economic growth by PMG estimator to identify the short and long-run dynamics for top NR abundance economies covering the period of 1970-2013. The result shows that NR rent increased the economic development (FD) in the long run. Further, the result of the causality analysis shows that bidirectional relationship exists between the selected variables. Shahbaz et al. (2018) also investigated the stimulating role of NR abundance in financial development for the USA for 1960-2016. The study also included additional variables such as education, economic growth and capitalization as FD in the financial demand function. The existence of cointegration confirmed between FD and its determinants. The empirical results also show that NR abundance, economic growth and education have a positive impact on FD while capitalization is inversely linked with FD.

Furthermore, in the meta-analysis of last two decades studies about natural resources and economic growth, Havranek et al. (2016) observed that 40% of studies reported insignificant result, 40% studies supports the natural resource curse whereas the last 20% studies find blessing of natural resources. The authors noticed that institutional quality, investment activities, different nature of natural resources and natural resources scarce or abundance could be possible in explaining the differences across the studies.

However, in recent years some studies found that NR-abundant countries have positive and rapid economic growth, especially with cross-sectional data. Researchers believe that to have a clear picture of the connection between economic growth and NR needs to be studied more in time series and panels frameworks (Badeeb et al., 2017).

Moreover, the role of NR is also included in different studies to investigate the impact on environmental quality. Among of them, Balsalobre-Lorente et al. (2018) employed the carbon function to investigate the EKC hypothesis for European countries such as Germany, Spain, England, France and Italy for the 1985-2016 period. The study also included other additional variables such as TRD, NR abundance, RE consumption and energy innovation to augment the carbon emission function. Results confirmed the existence of the N-shaped EKC phenomenon. Findings also suggested that NR, RE consumption and energy innovation mitigate CO_2 emissions whereas, TRD and the interaction between economic growth and RE consumption deteriorated the environmental quality.

In this regard, the review of limited literature represents quite distinct results, that has influenced in extending the vagueness regarding the specific association between the variables, thus requiring new investigation to clarify and validate the inconclusive findings of existing studies (Balcilar et al., 2018).

3. MODELS, DATA AND METHODOLOGY

This section consists of three parts: (i) We will develop the empirical models, (ii) we will discuss the definition of the variables with data sources, and also demonstrate the individual country variables role over the year and descriptive statistics and (iii) we will discuss the different econometrics techniques which are going to be the part of the analysis.

3.1. Models Construction
The focus of the study is to determine the linkages between economic growth, renewable energy (RE), non-renewable energy (NRE), natural resources (NR) rent and carbon emissions. For this purpose, we use two models.

Model 1: We observe the impact of RE, NRE, NR rent on economic development. One of the aims is to examine the relationship between GDP, RE, NRE consumption and NR rent in SSEA region. The general form of the economic growth function model is designed as follows:

$$GDP = f(RE, NRE, RENT) \qquad (1)$$

Where *RE*, *NRE*, *RENT* and *GDP* represent renewable EC, non-renewable EC, natural resources rent and economic growth, respectively. A large number of studies have jointly examined the nexus between natural resources and economic growth along with other macro-economic indicators (Sarmidi et al., 2014; Satti et al., 2014; Ahmed et al., 2016; Kim and Lin, 2017; Shahbaz et al., 2018; Ben-Salha et al., 2018 etc). Based on the prior relevant studies, our empirical model is as follows:

$$LGDP_{2it} = \alpha_{1it} + \alpha_{rit} LRE_{it} + \alpha_{nrit} LNRE_{it} + \alpha_{renit} RENT_{it} + \epsilon_{it} \quad (2)$$

Model 2: The role of economic growth, RE, NRE and NR rent in CO_2 emissions is accessed. Further to probe the connection among dependent variable CO_2 emissions and independent variables such as RE consumption, NRE consumption, economic growth and NR rent, the basic framework of carbon emission is established based on the model of Balsalobre-Lorente et al. (2018) and Bekun et al.(2019):

$$CO_2 = f(RE, NRE, RENT, GDP) \qquad (3)$$

Where CO_2 symbolizes CO_2 emissions per capita and the rest of the variables we have already discussed in equation 1. The estimated equation for this model was:

$$LCO_{2it}=\beta_{1it}+\beta_{yit}\,LGDP_{it}+\beta_{rit}\,LRE_{it}+\beta_{nrit}\,LNRE_{it}+\beta_{renit}\,LRENT_{it}+\mu_{it}\quad(4)$$

For equation (2) and (3) L stands for log-linear specification; ϵ_{it} and μ_{it} are the idiosyncratic error terms, independent and identically distributed, that represents the standard normal distribution with unit variance and zero mean; i represent the country ($i = 1, 2,\ldots\ldots14$); t stands for a time period ($t = 1, 2, 3,\ldots\ldots25$); α_{1it} is intercept; α_{rit}, α_{nrit}, α_{renit} are the long-run elasticity's estimates of economic growth ($LGDP$) with respect to the explanatory variables such as renewable energy consumption (LRE), non -renewable energy ($LNRE$) and rent ($LRENT$) in Model 1.

Furthermore, equation 4 implies that β_{1it} is the intercept whereas β_{yit}, β_{rit}, β_{nrit} and β_{renit} are the long-run elasticity's estimates of CO_2 emissions per capita (LCO_2) concerning the independent variables such as real GDP per capita ($LGDP$), renewable energy consumption (LRE), non-renewable energy consumption ($LNRE$) and natural resources rent ($LRENT$) respectively.

3.2. Data
Our empirical analysis is established on the yearly time series data covering the time span from 1990 to 2014 for 5 South[1] and 6 Southeast [2] Asian countries. The data was retrieved both for the period and selected countries from World Development Indicator (2019). CO_2 emissions are measured in (metric tons per capita); renewable EC consists in EC from of hydro, solar, wind, biogas and biofuels, in percentage of total final EC; non-renewable energy (NRE) consumption refers to "use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport, measured in kg of oil equivalent per capita" (World Bank, 2019); real GDP was stated in per capita constant 2010 U.S. dollar and the total natural resources are "the sum of oil, natural gas, coal, minerals and forest rents in percentage of GDP" (World Bank, 2019). In Table 1 we present variables definition as well as supporting references for each one.

Evolution of the selected variables with respect to countries is presented in Figure 1. Figure shows that Singapore has the highest income, while the lowest GDP per capita is verified in Nepal. Construct to these graphs, the highest CO_2 emissions per capita was in Singapore although with a negative trend whereas the lowest level was in Nepal. In the case of RE and NRE consumption picture clearly shows that sample countries relay more on NRE rather than in RE sources. Besides, total natural resources have a decreasing rate over the years in all the sample countries.

Furthermore, Table 2 reflects the statistics summary of selected variables for the three panels, between 1990 and 2014. The

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1   Pakistan, India, Bangladesh, Sri Lanka and Nepal
2   Indonesia, Philippines, Malaysia, Vietnam, Singapore and Thailand

Table 1: Description and sources of the variables

Variables	Definition	Supporting reference	Source
CO$_2$	CO$_2$ emissions (metric tons per capita)	(Adams and Nsiah, 2019; Amri, 2019; Belaïd and Zrelli, 2019)	WDI
RE	Renewable energy consumption (% of total final energy consumption)	(Ben Jebli and Ben Youssef, 2015; Dogan and Seker, 2016; Sharif et al., 2019)	WDI
NRE	Non-renewable energy consumption (kg of oil equivalent per capita)	(Dogan, 2016; Shafiei and Salim, 2014; Sharif et al., 2019)	WDI
RENT	Total natural resources rent (% of GDP)	(Balsalobre-Lorente et al., 2018; Bekun et al., 2019; Shahbaz et al., 2018)	WDI
GDP	GDP per capita constant (2010 US$)	(Belaïd and Zrelli, 2019; Dong et al., 2019; Mert et al., 2019)	WDI

WDI: World development indicator

Table 2: Descriptive statistics and correlation matrix

Economies	Variables	Min	Max	Mean	SD	CO$_2$	GDP	NRE	RE	RENT
South Asian	CO$_2$	0.03	1.73	0.56	0.39	1	0.38	0.75	−0.75	0.66
	GDP	357.20	3506.73	997.31	671.29		1	0.54	−0.25	−0.19
	NRE	118.89	636.57	366.57	122.44			1	−0.25	0.41
	RE	36.65	95.11	61.72	16.68				1	−0.40
	RENT	0.10	7.35	1.45	1.21					1
Southeast Asian	CO$_2$	0.30	18.04	3.94	3.99	1	0.77	0.90	−0.80	−0.22
	GDP	431.8	52244.4	8805.10	13006.8		1	0.92	−0.67	−0.40
	NRE	260.79	7370.65	1719.68	1698.1			1	−0.79	−0.31
	RE	0.19	76.08	27.37	20.53				1	0.15
	RENT	0.00	25.80	5.40	5.04					1
Overall	CO$_2$	0.03	18.04	2.40	3.40	1	0.804	0.92	−0.77	0.06
	GDP	357.20	52244.4	5256.1	10362.0		1	0.92	−0.62	−0.15
	NRE	118.65	7370.65	1104.63	1424.98			1	−0.74	−0.01
	RE	0.19	95.11	42.99	25.47				1	−0.26
	RENT	0.00	25.80	3.60	4.28					1

Authors own calculation based on the data over the period 1990-2014. Mean: Simple average, Max: Maximum; Min: Minimum; SD: Standard deviation and right columns presented pair-wise correlations and results reported till second decimal

Figure 1: CO_2 emissions per capita, renewable energy consumption, non-renewable energy consumption, total natural resources rent by country from 1990 to 2014
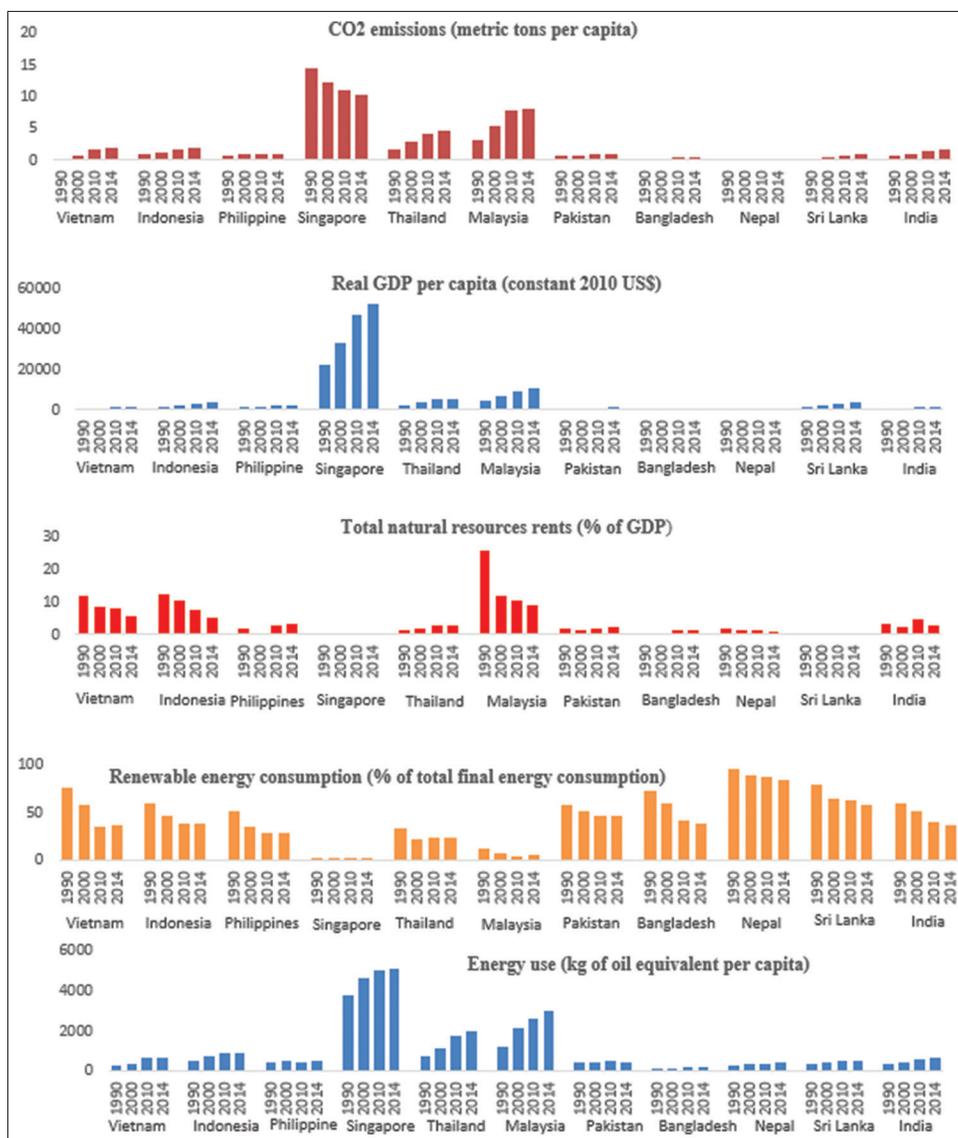
Southeast Asian countries have the highest mean value of CO_2 emissions per capita (3.99) compared to South Asian (0.56) whereas on the overall panel, countries are facing carbon emissions of 2.40. Besides, Southeast Asian countries have high volatility than South Asian countries.

When analyzing the GDP per capita, we observe that Southeast Asian are richer than South Asian economies. Concerning renewable energy, the highest consumption is registered by South Asian countries (61.72) compared to the Southeast Asian (27.37).

However, in the case of non-renewable energy Southeast Asian countries consumed more than South Asian economies. In terms of volatility, South Asian economies are more consistent users of RE and NRE sources as they have the lowest standard deviation. Furthermore, the average natural resources rent in South Asian countries is 5.40 while in South Asia is 1.40. Concerning the volatility of natural resources rent, Southeast Asian countries are more volatile than South Asian economies.

3.3. Methodology

3.3.1. Cross-sectional dependence (CD) and panel heterogeneity

we used balanced panel data of 11 SSEA countries in the current study. One of the assumptions of panel data is that there may occur a cross-sectional dependence (CD) among the variables, which may produce unreliable and biased results (Pesaran, 2007). From the existing literature, it is concluded, that panel data models are expected to exhibit significant cross-sectional dependence in the errors (De Hoyos and Sarafidis, 2006). The reason for the cross-correlation of errors might be due to omitted common effects, unobserved components and spatial effects or the presence of common shocks (Pesaran, 2004). From Figure 1 it can be noted that the countries investigated in the present study illustrate a different pattern in their economic growth performance, RE, NRE, RENT and, therefore, provides an indication of inherent heterogeneity of individual cross-sectional units. Moreover, the CD across the Asian economies will be an essential issue to account because of the substantial economic and financial integration of the economies (Bhat, 2018). This indicates that there is

a strong interdependence between cross-sectional units (Belaïd and Zrelli, 2019). Moreover, these steps also allow us to choose suitable unit root tests for further analysis. Several tests has been performed to check the CD among the countries, as Friedman (1937), Breusch and Pagan LM (1980), Frees (1995) and Pesaran (2004) CD tests. However, for further empirical analysis we used well-known Breusch-Pagan LM (1980) test, since it works better in the case of panels featured with N < T, where N stand for cross-sectional dimensions while, T represents the time dimensions of the panel. It means that no desirable statically properties are required (Pesaran, 2004). Besides, it is applicable in balance or unbalance panel data. For the robustness of the LM results Pesaran (2004) CD test is also applied.

3.3.2. Stationarity
The second step is to confirm the stationarity after investigated the CD in the panel data modelling. After the confirmation of cross-sectional dependence, the next step consists in examining the stationary problem in the panel of variables, in determining the presence of stochastic trends, which is broadly designed to elaborate on the postulation of cross-sectional dependence (Arshad et al., 2020). Numerous tests of the unit root have been discussed in the prior literature for instance, (Breitung, 2001; Choi, 2001; Hadri, 2000; Harris and Tzavalis, 1999; Im et al., 2003; Levin et al., 2002; Maddala and Wu, 1999; Pesaran, 2007; Quah, 1994). The researchers divided them into two groups such as first-generation (Breitung, Hadri and Levin Lin Chu tests) who deals with cross-sectional independence and second-generation (ADF-Fisher, PP-Fisher, CIPS, CADF and IPS [IM Pesaran shin]) that considered cross-sectional dependence. However, it is evident that the cross-sectional dependence exists, so we used two second-generation test names as Augmented Dickey-Fuller (CADF) and cross-sectional IPS (CIPS) who deals with heterogeneous panels and CD, as proposed by (Pesaran, 2007).

3.3.3. Cointegration
The next step is the cointegration process after the confirmation of the stationarity of the variables at the same level. This process helps us to identify whether long-run relationships exist between considered variables, that means that the variables moves together in the long-run. This panel cointegration method can also be used to study the long-run equilibrium process. Therefore, we applied four cointegration methods. Three belongs to the first generation method such as Pedroni (2004), Kao (1999) and Fisher proposed by (Maddala and Wu, 1999) to identify the long-run relationships between variables. Besides, to robust the first generation cointegration tests, we applied Westerlund (2007) cointegration technique which is known as a second-generation method. and not only deals with the cross-sectional dependence but it also not relays on integrated order of the variables, what makes this method applicable in very general conditions.

3.3.4. PMG regression
The PMG regression suggested by Pesaran (1997) and Pesaran et al. (1999) is applied, which permits convergence speed and short-run adjustment to estimate the heterogeneity of each country. The PMG estimation is the revised version of mean group regression (MG) (Pesaran and Smith, 1995). According to the Pesaran et al. (1999), MG is a kind of pooled estimation because this model use average values of the coefficients of each group and assume that the slope coefficients and error variance are

indistinguishable. However, PMG model takes the cointegration form of the simple ARDL model and adapts it to a panel set by allowing the intercepts, short-run coefficients and cointegrating terms to differ across cross-sections. It further executes the restrictions of the cross-country homogeneity on the long-run coefficients (Pesaran et al., 1999). To achieve the Pesaran et al. (1999) PMG estimation, the ARDL (p, q) models are as follows:

$$\Delta\left(üüüü_{\ i}\right)_t = \sum_{j=1}^{p-1}\rho_j^i\Delta\left(\quad_i\right)_{t-j} + \sum_{j=0}^{q-1}\delta_j^i\Delta\left(\quad_i\right)_{t-j}$$
$$+\theta^i\left[\left(GDP_i\right)_{t-1} - \alpha_1^i\left(Y_i\right)_{t-j}\right] + e_{it} \tag{5}$$

$$\Delta\left(CO_{2i}\right)_t = \sum_{j=1}^{p-1}\rho_j^i\Delta\left(CO_{2i}\right)_{t-j} + \sum_{j=0}^{q-1}\delta_j^i\Delta\left(y_i\right)_{t-j}$$
$$+\theta^i\left[\left(CO_{2i}\right)_{t-1} - \alpha_1^i\left(Y_i\right)_{t-j}\right] + e_{it} \tag{6}$$

Where and refer to short and long-run coefficients, respectively; and represents short and long-run patterns with reference to CO_2 emissions respectively; and are the short-run coefficients; θ^i is the error correction term; $(y_i)_{t-j}$ and $(y_j)_{t-j}$ are the values of short-run and long-run variables; are the long-run coefficients; $e_{it} = \mu_i + v_{it}$; μ_i and v_{it} represents country-specific fixed and time-variant effects in both equations respectively.

3.3.5. DCCE CS-ARDL
Chudik and Pesaran (2015) introduced a new panel technique named as "dynamic common correlated effects" (DCCE) which is helpful to handle the problem of cross-sectional dependence. Besides, this approach is the extension of common correlated effect (CCE) by Pesaran (2006). DCCE approach considers CD by assuming that the variables can be represented by common factor. DCCE technique is developed on the principle of mean group (MG), PMG and CCE estimations presented by Pesaran and Smith (1995), Pesaran (1997) and Pesaran (2006) respectively. According to the approach of DCCE we can make the estimator more consistent by including more lags of CD in regression. Moreover, DCCE have four advantages over the existing techniques in the relevant literature (Chudik and Pesaran, 2015) (1) deals the problem of CD by taking logs and average values of all the cross-sectional units. (2) It computes the DCCE by considering heterogeneous slopes and assuming the variables represented by common factor. (3) It can handle the small sample size. (4) This technique can also apply in the presence of structural breaks and un-balance panel data (Ditzen, 2016). Besides, for the long-run estimation of coefficients two methods can be applied, first, cross-sectional augmented distributed lag (CS-DL) which directly estimates the long-run coefficients (Chudik et al., 2016). Second, cross-sectional augmented ARDL (CS-ARDL) method (Chudik et al., 2016). However, we have employed DCCE CS-ARDL method to estimate the long-run coefficients.

3.3.6. Dumitrescu-hurlin causality (DH) test
The last step of the empirical analysis is the causality test to identify the direction causality of the variables. The direction could be the unidirectional bidirectional or no causality. For this purpose, we used Dumitrescu and Hurlin (DH) (2012) causality test as it is an befitting approach for the directional causality and presents more advantages compared to the traditional Granger

(1969) causality test and presents the two critical spheres of heterogeneity, known as the heterogeneity of the regression model and the heterogeneity of the causal relationship.

4. RESULTS AND DISCUSSION

4.1. Cross-sectional Dependence

South and Southeast Asian economies such as Pakistan, India, Bangladesh, Thailand, Malaysia, Indonesia are being affected from cross-sectiond ependence (CD), transborder pollutants' effect and cross-country heterogeneity (Behera and Dash, 2017). Due to different characteristics of the countries, and to robust the LM test results Breusch-Pagan LM (1980) CD and Pesaran (2004) CD tests were performed.

Table 3 which describes the results of both tests denies the null hypothesis of no CD at 1% level of significance. There is significant evidence of the presence of CD among the variables considered, such as CO_2 emissions, GDP, RE, NRE and NR rent in all cases.

4.2. Unit Root Tests

Countries have different characteristics and the panels may contain the presence of CD which may lead to unreliable and biased results (Park et al., 2018). Pesaran (2007) presented two unit root tests named IPS cross-sectional (CIPS) and augmented Dickey-Fuller (CADF) that are used to handle the ambiguity of CD. The results of the CADF and CIPS panel unit root tests have been described in Table 4.

Table 3: Cross sectional dependence

Tests	Variables	LCO$_2$	LGDP	LNRE	LRE	LRENT
Pesaran CD	South Asia	14.05[a] (0.00)	15.60[a] (0.00)	13.66[a] (0.00)	13.29[a] (0.00)	3.947[a] (0.00)
	Southeast Asia	6.86[a] (0.00)	18.68[a] (0.00)	6.13[a] (0.00)	7.90[a] (0.00)	3.84[a] (0.00)
	Overall	22.10[a](0.00)	36.06[a] (0.00)	20.15[a] (0.00)	22.33[a] (0.00)	7.26[a] (0.00)
Breusch-Pagan LM	South Asia	198.50[a] (0.00)	243.41[a] (0.00)	189.07[a] (0.00)	178.03[a] (0.00)	107.19[a] (0.00)
	Southeast Asia	214.91[a] (0.00)	349.11[a] (0.00)	163.51[a] (0.00)	200.48[a] (0.00)	70.98[a] (0.00)
	Overall	936.30[a] (0.00)	1300.87[a] (0.00)	804.30[a] (0.00)	841.82[a] (0.00)	414.22[a] (0.00)

[a]Represents the significance level 1% and P-values reported in the parenthesis

Table 4: Second generation unit root analysis

Tests									
		CIPS		CADF					
				Without trend			With trend		
Economies	Variables	Without trend	With trend	T-bar	Z-t-tilde-bar	P-value	T-bar	Z-t-tilde-bar	P-value
Overall	LCO$_2$	−1.25	−1.88	−1.47	0.99	0.84	−1.93	1.39	0.91
	Δ LCO$_2$	−6.04[a]	−6.15[a]	−3.81[a]	−6.98[a]	0.00	−3.49[a]	−5.81[a]	0.00
	LGDP	−0.49	−2.32	−1.84	−0.25	0.40	−1.96	1.26	0.89
	Δ LGDP	−5.71[a]	−5.90[a]	−2.93[a]	−3.98[a]	0.00	−3.37[a]	−3.77[a]	0.00
	LNRE	−1.04	−2.25	−1.70	0.22	0.59	−2.06	0.92	0.82
	Δ NRE	−5.88[a]	6.09[a]	−4.02[a]	−8.33[a]	0.00	−4.27[a]	−6.96[a]	0.00
	LRE	−1.08	−2.04	−1.67	0.32	0.62	−1.85	1.64	0.95
	Δ RE	−5.62[a]	−5.99[a]	−3.80[a]	−6.65[a]	0.00	−3.95[a]	−5.81[a]	0.00
	LRENT	−0.51	−2.97	−1.50	0.92	0.82	−2.93	−2.19	0.01
	Δ LRENT	−6.02[a]	−6.22[a]	−4.51[a]	−9.37[a]	0.00	−4.63[a]	−8.24[a]	0.00
South Asia	LCO$_2$	−0.39	−1.81	−0.91	1.95	0.97	−1.26	2.52	0.99
	Δ LCO$_2$	−6.08[a]	−6.40[a]	2.96[a]	−2.76[a]	0.00	−3.14[b]	−2.01[b]	0.02
	LGDP	−0.037	−3.24	−2.50	−1.72	0.04	−2.36	−0.12	0.45
	Δ LGDP	−6.11[a]	−6.27[a]	−3.73[a]	−4.54[a]	0.00	−4.05[a]	−4.20[a]	0.00
	LNRE	−0.16	−1.04	−1.03	1.67	0.95	−0.81	3.59	1.00
	Δ NRE	−5.50[a]	−5.96[a]	−2.74[a]	−2.26[a]	0.01	−3.07[b]	−1.84[b]	0.03
	LRE	0.10	−1.80	−1.35	0.93	0.82	−1.68	1.51	0.93
	Δ RE	−5.14[a]	−5.37[a]	−2.63[b]	1.99[b]	0.02	−2.82[c]	−1.24[c]	0.10
	LRENT	−0.30	−3.13	−0.97	1.81	0.96	−2.79	−1.71	0.12
	Δ LRENT	−5.83[a]	−6.03[a]	−4.39[a]	−6.07[a]	0.00	−4.39[a]	−5.01[a]	0.00
Southeast Asia	LCO$_2$	−1.36	−1.84	−1.96	−0.50	0.30	−2.27	0.09	0.53
	Δ LCO$_2$	−5.82[a]	6.04[a]	−3.79[a]	−5.12[a]	0.00	−3.81[a]	−3.97[a]	0.00
	LGDP	−1.92	−1.91	−1.82	−0.17	0.43	−1.45	2.24	0.98
	Δ LGDP	−6.12[a]	−6.42[a]	−2.67[a]	−2.30[a]	0.01	−3.03[b]	−2.03[b]	0.02
	LNRE	−1.63	−2.55	−2.31	−1.39	0.08	−2.47	−0.44	0.32
	Δ NRE	−5.83[a]	−6.30[a]	−3.97[a]	−5.58[a]	0.00	−3.91[a]	−4.22[a]	0.00
	LRE	−0.77	−2.34	−1.88	−0.30	0.38	−2.20	0.26	0.60
	Δ RE	−6.12[a]	−6.42[a]	−3.75[a]	−5.02[a]	0.00	−3.91[a]	−4.22[a]	0.00
	LRENT	−0.58	−2.31	−1.52	0.60	0.72	−2.50	−0.50	0.30
	Δ LRENT	−6.11[a]	−6.36[a]	−3.90[a]	−5.41[a]	0.00	−4.06[a]	−4.61[a]	0.00

[a,b,c]Represents the significance level 1%, 5% and 10% respectively. we also reported (T-bar) and Z (t-tilde-bar) statistics in the table

In all the three panels, almost all the variables represent non-stationary results at the level. Nevertheless, the null hypothesis is rejected at 5% as variables represent the stationary results at first difference. Thus, we can declare the similar findings both for CADF and CIPS.

4.3. Cointegration

Following the first order integration of variables, further was to examine the cointegration process among variables. To do so, three traditional test, namely Pedroni (2004), Kao (1999), Fisher proposed by (Maddala and Wu, 1999), were used. Moreover, to handle the cross-sectional dependence and robust the traditional cointegration tests, Westerlund (2007) was applied. The results of Pedroni, Kao and Fisher panel cointegration tests are presented in Table 5. In the case of South Asian, Southeast Asian and of the full panel of the 11 countries, the results illustrated that a set of four out of seven (statistics) reject the null hypothesis of no cointegration. Furthermore, Kao results ensured the existing of cointegration among the variables and Fisher results also support this conclusion. To robust the traditional cointegration test results, the Westerlund cointegration test was also used, which even overcomes the issue of cross-sectional dependence. From, Table 6 it is disclosed that the alternative hypothesis of cointegration is accepted which means that considered variables move together in the long-run. The above mentioned four cointegration methods have the same results. This merely illustrates that the long-run relationship occurs between

CO_2 emissions, GDP, RE consumption, NRE consumption and NR rent in SSAE region over the period considered. The results of cointegration among the variables confirm the ones of Bekun et al., (2019) and Shahbaz et al. (2018).

4.4. PMG Regression versus Mean Group Regression (MG)

The current study aim is to examine the effect of considerable explanatory variables on economic growth and CO_2 emissions. First, we determined the impact of RE consumption, NRE consumption and NR rent on economic growth which is known as Model 1.

In the second model, we investigated the impact of RE consumption, NRE consumption, NR rent and economic growth on CO_2 emissions.

To achieve the statements mentioned above for two proposed models, we applied PMG estimator to investigate the short and long-run dynamics in the South and Southeast Asian regions as PMG estimator constrains long-run coefficients to be equal across all group. In the case of the homogenous model, PMG estimator will be consistent whereas mean group (MG) estimator will be inconsistent. However, MG estimators and PMG estimators will be consistent and inconsistent respectively in case of heterogeneous model (Mert and Bölük, 2016). To do so first, we applied mean

Table 5: Pedroni, Kao and Fisher cointegration analysis

Pedroni test		Null hypothesis: No cointegration		Newey-west automatic bandwidth selection and Bartlett kernel			
Economies		South Asia		Southeast Asia		Overall	
		Statistic	Weighted stat	Statistic	Weighted stat	Statistic	Weighted stat
Within – dimension	Panel v	0.7515 (0.22)	−0.3322 (0.63)	0.1929 (0.42)	0.2472 (0.40)	0.4586 (0.32)	−0.0797 (0.53)
	Panel rho	−0.5826 (0.28)	−0.1686 (0.43)	1.028 (0.84)	0.7933 (0.78)	0.8706 (0.80)	0.4107 (0.65)
	Panel PP	−4.2189[a] (0.00)	−4.2234[a] (0.00)	−4.0364[a] (0.01)	−1.548[c] (0.06)	−1.4410[c] (0.07)	−4.1479[a] (0.00)
	Panel ADF	−2.2965[a] (0.01)	−3.7051[a] (0.00)	−0.5058[a] (0.00)	−1.1653[c] (0.09)	−1.7504[b] (0.05)	−3.0163[a] (0.00)
Between– dimension	Group rho	0.2820 (0.61)		1.6985 (0.95)		1.4446 (0.92)	
	Group PP	−4.8840[a] (0.00)		−5.083[a] (0.00)		−7.0474[a] (0.00)	
	Group ADF	−3.1626[a] (0.01)		−2.7371[a] (0.00)		−2.8798[a] (0.00)	
Kao residual cointegration test							
ADF		T-Stat	Prob	T-Stat	Prob	T-Stat	Prob
		−3.1591[a]	0.0008	−2.9940[a]	0.0014	−4.2508[a]	0.0000
Automatic lag length selection based on SIC				**Newey-west automatic bandwidth selection and Bartlett kernel**			
Johansen Fisher panel cointegration test							
No of cointegration		Trace	Max eigen test	Trace	Max eigen test	Trace	Max eigen test
None		94.47[a] (0.00)	56.95[a] (0.00)	280.1[a] (0.00)	232.1[a] (0.00)	490.2[a] (0.00)	374.8[a] (0.00)
At most 1		46.53[a] (0.00)	27.68[a] (0.00)	188.8[a] (0.00)	140.4[a] (0.00)	286.6[a] (0.00)	189.9[a] (0.00)
At most 2		26.61[a] (0.00)	11.82 (0.29)	86.57[a] (0.00)	69.13[a] (0.00)	144.8[a] (0.00)	110.9[a] (0.00)[a]
At most 3		24.16[a] (0.00)	19.29[b] (0.03)	33.29[a] (0.00)	27.27[a] (0.00)	60.75[a] (0.00)	45.82[a] (0.00)
At most 4		20.42[b] (0.02)	20.42[b] (0.02)	24.98[a] (0.01)	24.98[a] (0.01)	53.65[a] (0.00)	53.65[a] (0.00)

[a,b,c]Represents the significance level 1%, 5% and 10% respectively. The P-values for Pedroni and Fisher tests reported in parenthesis

Table 6: Westerlund cointegration

Statistics	South Asia			Southeast Asia			Full countries		
	Value	Z-value	P-value	Value	Z-value	P-value	Value	Z-value	P-value
Gt	−6.058	**−7.873**	0.00[a]	−3.226	−2.002	0.02[b]	−2.879	−1.505	0.06[c]
Ga	−3.552	3.573	1.00	−8.035	1.573	0.94	−8.497	1.930	0.97
Pt	−9.489	−3.617	0.00[a]	−6.360	−1.213	0.10[c]	−5.889	−1.705	0.04[b]
Pa	−5.679	2.132	0.98	−4.954	1.406	0.92	−4.487	2.108	0.98

[a,b,c]Represents the significance level 1%, 5% and 10% respectively

group regression along with PMG estimator. Hereafter we used a Hausman test to confirm the long-run homogeneity (Blackburne and Frank, 2007). The findings of the Hausman test indicated the rejection of the null hypothesis in both models for all the cases such as South Asian, Southeast Asian and full countries panels. Hence, the findings of the Hausman test confirmed the homogeneity of the models. It implies that the PMG estimator is more appropriate than MG estimator for different panels and models of SSEA region (Table 7).

4.4.1. PMG regression
4.4.1.1. Long-run elasticity's (Model-1)
The PMG results reported in Table 8 to explain the short and long-run dynamics in the two proposed models. According to the PMG long-run results of model 1, the results show that NRE and RE are a significant positive contribution to economic development in all three considered panels. It is also observed that NRE has a stronger impact on economic growth than RE. Our results for RE and NRE impact on economic growth are in line with (Paramati et al., 2018).

Concerning, NR nexus economic growth results show that NR impedes the economic development for the cases of South Asia and full country for 1990-2014. It means that NR slows down the economic activities in the case of South Asian and

overall countries. There are four main channel of transmissions to NR to slow down economic growth such as Dutch disease, overconfidence, neglect of education and rent-seeking (Gylfason, 2001). However, we found the inverse role of NR in economic development in the Southeast Asian panel. Our results are consistent with (Ahmed et al., 2016; Ben-Salha et al., 2018; Sarmidi et al., 2014; Satti et al., 2014).

Moreover, the significant negative error terms –0.47, –0.26 and –0.23 in Southeast Asia, South Asia and full countries panels respectively confirm the long-run relationships between variables. The error correction terms show that the speed of adjustment back towards the equilibrium is corrected by 47%, 26% and 23% in Southeast, South and overall country's panels respectively in each year.

4.4.1.2. Short-run analysis (Model-1)
For the short-run analysis, we found that only NRE has a significant and positive impact on economic growth, in the case of South Asia and full countries panels. However, we did not find any significant results in the case of the Southeast Asian region.

4.4.1.3. Long-run elasticity's (Model-2)
Table 8 also reported the Model 2 estimation, where PMG long-run results revealed that economic growth increased the CO_2 emissions

Table 7: Hausman results

Model 1 dependent variable: Economic growth					
Economies	**Variables**	**Coefficients**			
		(b) MG	**(B) PMG**	**(b-B) Difference**	**Sqrt (diag (V_b-V_B)) S. E**
Overall	LNRE	0.16	1.16	–1	1.26
	LRE	–0.62	0.02	–0.64	0.70
	LRENT	–0.09	–0.11	0.02	0.06
$Chi^2 (3)=(b-B)'[(V\_b-V\_B)^{-1}] (b-B)=1.79, Prob>Chi^2=0.61$					
South Asia	LNRE	0.27	0.99	–0.72	0.80
	LRE	–1.06	0.13	–0.93	0.96
	LRENT	–0.08	–0.25	0.17	0.26
$Chi^2 (3)=(b-B)'[(V\_b-V\_B)^{-1}] (b-B)=1.89, Prob>Chi^2=0.82$					
Southeast Asia	LNRE	0.07	0.47	–0.40	0.70
	LRE	–0.25	0.21	–0.46	0.89
	LRENT	–0.09	0.07	–0.16	0.20
$Chi^2 (3)=(b-B)'[(V\_b-V\_B)^{-1}] (b-B)=1.96, Prob>Chi^2=0.58$					
Model 2 dependent variable: CO_2 emissions					
Economies	**Variables**	**Coefficients**			
		(b) MG	**(B) PMG**	**(b-B) Difference**	**Sqrt (diag (V_b-V_B)) S. E**
Overall	LNRE	–0.39	1.27	–1.66	2.04
	LGDP	0.76	0.35	–0.41	0.70
	LRE	–3.94	–0.25	–3.69	5.49
	LRENT	–0.12	0.02	–0.14	0.23
$Chi^2 (4)=(b-B)'[(V\_b-V\_B)^{-1}] (b-B)=5.01, Prob>Chi^2=0.28$					
South Asia	LNRE	–2.48	1.34	–2.88	4.48
	LGDP	1.06	0.40	0.66	0.99
	LRE	–9.29	–0.04	–9.25	12.11
	LRENT	–0.33	0.04	–0.37	0.45
$Chi^2 (4) = (b-B)'[(V\_b-V\_B)^{-1}] (b-B)=4.32, Prob>Chi^2=0.36$					
Southeast Asia	LNRE	1.34	0.70	0.64	0.94
	LGDP	0.50	0.26	0.24	0.31
	LRE	0.51	–0.42	0.93	1.03
	LRENT	–0.04	–0.01	–0.03	0.10
$Chi^2 (4)=(b-B)'[(V\_b-V\_B)^{-1}] (b-B)=2.89, Prob>Chi^2=0.57$					

b: Consistent under Ho and Ha; obtained from xtpmg, B: İnconsistent under Ha, efficient under Ho; obtained from xtpmg and Ho: difference in coefficients not systematic

Table 8: Pooled mean group regression

Model 1 dependent variable: GDP						
Variables	**South Asia**		**Southeast Asia**		**Overall**	
Long-run coefficients	**Coefficients**	**Prob**	**Coefficients**	**Prob**	**Coefficients**	**Prob**
LNRE	0.9919[a]	0.0000	0.4765[a]	0.0002	1.1696[a]	0.0000
LRE	0.1393[c]	0.0769	0.2127[a]	0.0022	0.0252[b]	0.0428
LRENT	−0.2597[a]	0.0000	0.0713[a]	0.0000	−0.1077[a]	0.0000
Error correction coefficients	−0.2676[a]	0.0019	−0.4741[a]	0.0006	−0.2346[a]	0.0001
Short-run coefficients						
D (LNRE)	0.5880[b]	0.0126	0.0327	0.7881	0.4302[a]	0.0009
D (LRE)	0.1173	0.6216	−0.2790	0.1816	−0.0608	0.4894
D (LRENT)	−0.0016	0.7873	−0.0492	0.1680	0.0043	0.7197
Constant	1.6127[a]	0.0078	2.0124[a]	0.0005	1.4519[a]	0.0002
Model 2 Dependent Variable: CO_2 Emissions						
Long-run coefficients	**Coefficients**	**Prob**	**Coefficients**	**Prob**	**Coefficients**	**Prob**
LGDP	0.4070[a]	0.0000	0.2627[a]	0.0000	0.3537[a]	0.0000
LNRE	1.3489[a]	0.0000	0.7064[a]	0.0000	1.2721[a]	0.0000
LRE	−0.0453	0.8582	−0.4294[a]	0.0000	−0.2522[a]	0.0005
LRENT	0.0430[b]	0.0403	−0.0184[c]	0.0910	0.0266[a]	0.0286
Error correction coefficients	−0.4067[a]	0.0064	−0.4894[b]	0.0144	−0.3566[a]	0.0002
Short-run coefficients						
D (GDP)	−0.8004[a]	0.0052	0.1562	0.8393	−0.0130	0.8856
D (LNRE)	0.8997[c]	0.0926	0.1679	0.5448	−0.3970	0.3377
D (LRE)	−1.8111	0.2470	0.0239	0.9312	0.4186	0.1902
D (LRENT)	−0.0142	0.5751	−0.0812	0.1605	−1.0956	0.1307
Constants	−4.5572[a]	0.0056	−2.4130[a]	0.0093	−0.0511	0.1729

[a,b,c]Represents the significance level 1%, 5% and 10% respectively

in all the selected panels. It means that the economic activities deteriorated the environmental quality in SSEA region. According to our first model, results suggested that NRE increases economic growth. Notably, NRE is mostly produced by fossil fuels to fulfill the requirement of different economic activities which ultimately increases the CO_2 emissions. Our results are consistent with Al-Mulali et al. (2015) in the case of 77 developed and developing countries.

Long-run elasticities of CO_2 emissions concerning NRE consumption are 1.34%, 0.70% and 1.27% in the South, Southeast and full countries panels, respectively. It means that NRE deteriorated the environmental quality in the SSEA region, with a higher impact on South countries. The rapid wave of urbanization is one of the causes of energy demand, which ultimately raises CO_2 emissions in the SSEA regions. Besides, the rapid changes in population in the South and Southeast Asian region, especially in Pakistan, India, and Bangladesh, lead the companies to accelerate their shifting towards this region because of cheap labor and intense market. Moreover, upcoming projects increase the energy demand, the significant portion of non-renewable electricity is derived by fossil fuels which ultimately increases the CO_2 emissions.

Moreover, the impact of RE on CO_2 emissions in long run implies that 1% increase in the RE consumption improved the environmental quality 0.04%, 0.42% and 0.25% in the South, Southeast Asian and 11 countries panels, respectively. It means that the use of RE sources mitigates the carbon emissions in the selected countries, with a remarked impact on the Southeast countries. Our results about NRE and RE impacts on CO_2 emissions are in line with (Belaïd and Zrelli, 2019; Ben Jebli et al.,

2016; Bölük and Mert, 2015; Inglesi-Lotz and Dogan, 2018; Sharif et al., 2019).

Finally, results suggest that natural resources have significant positive impact on CO_2 emissions in the South Asian and full countries panel. Our results are consistent with Bekun et al. (2019). However, in the case of Southeast Asian countries natural resources decrease the CO2 emissions in the long-run. Our findings are in line with Balsalobre-Lorente et al. (2018). Moreover, the significant negative error terms also confirm the long-run relationships between variables in all three selected panels.

4.4.1.4. Short-run analysis (Model-2)
Moreover, in the short run analysis we did not find any significant effect of RE, NRE, NR rent and GDP on CO_2 emission for all three selected panels.

4.4.1.5. Coefficient diagnostics
Furthermore, coefficient diagnostics test has been performed, the red mark in the center confirms that the estimation of the proposed models presents a significant confidence level (Figure 1 in appendix).

4.5. DCCE CS-ARDL
The traditional methods such as MG, PMG, FMOLS, DOLS and AMG may be provided weak outcomes due to CD (Chudik and Pesaran, 2015; Dogan et al., 2017). Therefore, we also applied the DCCE CS-ARDL technique to calculate the coefficients of the considered variables and to robust the PMG estimation. However, we find similar signs of the coefficients, although coefficients of the variables are different than PMG estimation (Tables 8 and 9 for comparision).

Figure 2: Causality directions
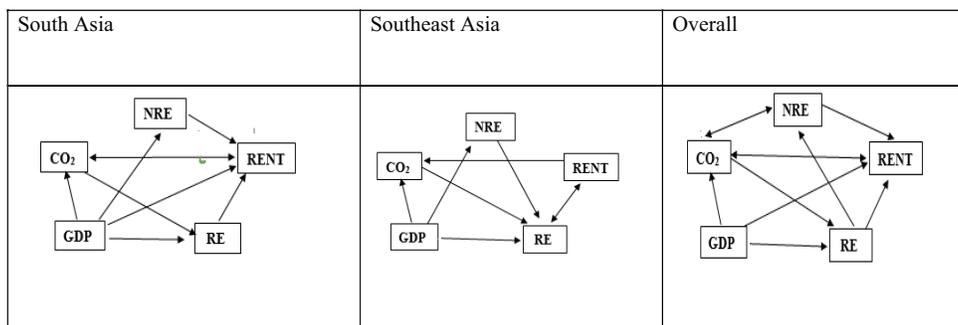
Source: ↔, → shows bidirectional, unidirectional causality between variables

Table 9: Dynamic common correlated effects

	Model 1 dependent variable: GDP					
Variables	South Asia		Southeast Asia		Overall	
Long-run coefficients	Coefficients	Prob	Coefficients	Prob	Coefficients	Prob
LNRE	0.7762[a]	0.000	0.8682[b]	0.000	0.7780[a]	0.000
LRE	0.4292[a]	0.003	0.1902[b]	0.003	3.6441[b]	0.042
LRENT	−0.0003[a]	0.000	0.0236[a]	0.000	−0.1477[b]	0.050
Short–run coefficients						
D (LNRE)	0.2237[a]	0.006	0.1317[b]	0.072	0.2219[a]	0.011
D (LRE)	0.2063	0.322	−0.1253	0.524	0.0764	0.585
D (LRENT)	0.0030	0.868	0.0213	0.544	−0.0162	0.322
	Model 2 dependent variable: CO_2 emissions					
Long-run coefficients	Coefficients	Prob	Coefficients	Prob	Coefficients	Prob
LGDP	0.4236[a]	0.041	8.1753[b]	0.051	2.9541[a]	0.014
LNRE	1.3701[b]	0.071	0.6797[b]	0.087	0.0552	0.919
LRE	−0.3190[b]	0.086	−1.7937	0.298	−0.6606[b]	0.058
LRENT	−0.0024[c]	0.091	−0.3761[c]	0.101	0.2493[c]	0.084
Short-run coefficients						
D (GDP)	−1.1889	0.579	−1.7695	0.418	−1.2825	0.233
D (LNRE)	2.3701	0.041	0.3202	0.420	0.9447	0.082
D (LRE)	0.4002	0.862	−0.5632	0.263	−0.1040	0.842
D (LRENT)	−0.0460	0.649	−0.1729	0.332	−0.1543	0.247

[a,b,c]Represents the significance level 1%, 5% and 10% respectively

Table 10: Pairwise dumitrescu hurlin panel causality test

Economies	Overall			South Asia			Southeast Asia		
Null hypothesis	W-Stat.	Z bar-Stat.	Prob.	W-Stat.	Z bar-Stat.	Prob.	W-Stat.	Z bar-Stat.	Prob.
LGDP ----- LCO_2	3.29	4.28	0.00[a]	6.10	3.38	0.00[a]	3.96	1.64	0.09[c]
LCO_2 ----- LGDP	0.40	−1.37	0.16	1.17	−0.93	0.34	2.22	−0.02	0.98
LNRE ----- LCO_2	1.91	1.58	0.10[c]	3.79	1.35	0.17	2.47	0.21	0.83
LCO_2 ------ LNRE	2.35	2.43	0.01[b]	3.12	0.76	0.44	2.21	−0.03	0.97
LRE ------ LCO_2	1.33	0.45	0.65	2.18	−0.05	0.95	1.98	−0.25	0.79
LCO_2 ------ LRE	2.25	2.24	0.02[b]	4.37	1.85	0.06[c]	4.32	2.07	0.06[c]
LRENT ------ LCO_2	1.94	1.63	0.10[c]	4.04	1.57	0.10[c]	3.54	1.68	0.09[c]
LCO_2 ------ LRENT	3.75	5.18	0.00[a]	5.30	2.67	0.00[a]	2.41	0.15	0.87
LNRE ------ LGDP	0.53	−1.11	0.26	1.98	−0.22	0.81	2.84	0.57	0.56
LGDP ------ LNRE	3.93	5.53	0.00[a]	6.69	3.89	0.00[a]	3.73	1.66	0.09[a]
LRE ------ LGDP	0.78	−0.63	0.52	2.43	0.16	0.86	1.23	−0.97	0.33
LGDP ------ LRE	1.92	1.61	0.09[c]	4.34	1.83	0.06[b]	2.22	1.62	0.09[c]
LRENT ------ LGDP	1.32	0.42	0.66	2.60	0.30	0.75	2.37	0.12	0.90
LGDP ------ LRENT	2.38	2.50	0.01[a]	7.34	4.46	0.00[a]	1.87	−0.35	0.72
LRE ------ LNRE	2.60	2.93	0.00[a]	2.88	0.55	0.57	2.43	0.18	0.85
LNRE ------ LRE	1.20	0.19	0.84	2.79	0.47	0.63	3.10	1.64	0.08[c]
LRENT ------ LNRE	0.89	−0.41	0.67	3.24	0.87	0.38	0.93	−1.26	0.20
LNRE ------ LRENT	4.04	5.74	0.00[a]	6.22	3.48	0.00[a]	3.12	0.84	0.39
LRENT ------ LRE	1.77	1.30	0.19	2.70	0.39	0.69	4.53	2.19	0.02[b]
LRE ------- LRENT	4.49	6.62	0.00[a]	7.02	4.18	0.00[a]	4.10	1.78	0.07[c]

[a,b,c]Represents the significance level 1%, 5% and 10% respectively and ----- stands as does not homogeneously cause

4.6. Pairwise Dumitrescu Hurlin (DH) Panel Causality

Table 10 report the causality results and Figure 2 illustrate the causality direction of the selected variables in the South, Southeast Asian and full countries panels. For the case of South Asian economies causality, results show that six significant unidirectional causalities are running from GDP to CO_2 emissions, GDP to RE, GDP to NRE, GDP to rent, NRE to rent and RE to rent. Furthermore, we found a bidirectional causality running from CO_2 emissions to rent.

Concerning the Southeast Asian region, results show that significant unidirectional causality running from GDP to CO_2, GDP to NRE, GDP to rent, CO2 to RE, NRE to RE and rent to CO_2 while bidirectional causality found between RE and rent.

Lastly, full countries panel results illustrate unidirectional causality running from GDP to RE, GDP to rent, GDP to CO_2, CO_2 to RE, RE to rent, RE to NRE and NRE to rent, while CO_2 and NRE, CO2 and rent represent bidirectional causality.

5. CONCLUSION AND POLICY IMPLICATIONS

The current study tried to develop the linkages between renewable (RE) and non-renewable energy (NRE) consumption, economic growth (GDP), natural resources (NR) and CO_2 emissions in the South and Southeast Asian (SSEA) countries for the period of 1990-2014. Our empirical findings confirmed the long-run relationship by using Pedroni, Kao, Fisher and Westerlund cointegration tests in the selected panels. Moreover, we examined the long-run elasticities with two proposed models by using PMG method. Firstly, we explored the long-run elasticities of RE consumption, (NRE) consumption, and NR concerning economic growth. Our results suggested that RE consumption and NRE consumption increased the economic growth in all panels. Furthermore, in South Asian and full countries panels, NR decreased the economic development in the long run. However, we found a significant and positive impact of NR on economic growth in the Southeast Asian region.

Secondly, we identified the long-run impact of RE consumption, NRE consumption, economic growth, and NR on CO_2 emissions. The findings demonstrated that NRE and economic growth worsened the environment quality in all three selected panels. Conversely, in the case of RE consumption, results suggested that RE consumption mitigates the carbon emission for all three panels.

However, NR also contributed to CO_2 emissionsin the case of South Asian and full countries panels while NR improved the environmental quality in the Southeast Asian region. The DH causality test was applied to examining the causal relationship. The causality results illustrated that unidirectional causality running from GDP to CO_2 emissions, GDP to RE and GDP to NRE consumption in South, Southeast and overall countries panels. However, we found bidirectional causality exists between CO_2 emissions and natural resources.

The current results lead to some policy implications. For instance, the countries should be concentrating on RE sources such as wind, solar, geothermal and biomass etc. rather than NRE sources to improve the environmental quality. Besides, policymakers need to encourage environment-friendly projects to sustain economic growth.

On the other hand, policymakers should be aware of the natural resource's management. The best way to improve the contribution of NR in economic growth could be by decreasing corruption and improving education level. Particularly, in South Asian countries, natural resources can be a curse on the economic growth, while in Southeast Asian region, NR can be managed as an important source of economic development. As stated by Sovacool (2010) ASEAN region promoted entrepreneurial activities and private actors in the resource production process. They encourage industrialization, and each country has co-operated as an active partner to the exploration, production, and distribution process, especially with international oil and gas firms.

Finally, we have a few limitations for this research which will give us direction for future research. For instance, we have ignored some GHG emissions such as sulfur dioxide (SO_2), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and particulate matter $PM_{2.5}$, PM_{10} as an air pollutant due to unavailability of data. Moreover, we use CO_2 emissions per capita instead of ecological footprints and its sub-components such as biocapacity, cropland, fishing grounds, carbon footprint, grazing lands, and forest products. Future studies can use these proxies of environment quality to see how the results vary across these indicators. Furthermore, we have taken 11 countries out of a total of 19 SSEA by dropping 8 countries due to non-availability of data between 1990 and 2014. The future study will consider the dropping countries on the availability of the data. Besides, the future study can estimate the EKC hypothesis with the quadratic or cubic function.

6. ACKNOWLEDGMENTS

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APPENDIX

Figure 1: Coefficient diagnostics confidence interval (ellipse test)