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The Effect of Renewable Energy Consumption on Sustainable Economic Development: Evidence from Emerging and Developing Economies

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Abstract: The objective of the paper is to figure out the nexus between renewable energy consumption and sustainable economic development for emerging and developing countries. In this paper, a panel of 30 emerging and developing countries is selected using the World Development Indicators (WDI) of the World Bank, Renewable Energy Country Attractiveness Index (RECAI) by Ernst and Young, and a random selection method based on the current trend of renewable energy consumption for five different regions of the world i.e., Asia, South-Asia, Latin America, Africa and the Caribbean. To achieve the objective, robust panel econometric models such as the Pesaran cross-section dependence (CD) test, second generation panel unit root test, e.g., cross-sectional augmented IPS test (CIPS) proposed by Pesran (2007), panel co-integration test, fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) are applied to check the cross-sectional dependence, heterogeneity and long-term relationship among variables. The panel is strongly balanced and the findings suggest a significant long-run relationship between renewable energy consumption and economic growth for selected South Asian, Asian and most of the African countries (Ghana, Tunisia, South Africa, Zimbabwe and Cameroon). But for the Latin American and the Caribbean countries, economic growth depends on non-renewable energy consumption. Renewable energy consumption in the selected countries of these two regions are still at the initial stage. In case of the renewable energy consumption and CO_2 emissions nexus, for selected South Asian, Asian, Latin American and African countries both GDP and non-renewable energy consumption cause the increase of CO_2 emissions. For the Caribbean countries only non-renewable energy consumption causes the increase of CO_2 emissions. An important finding regarding renewable energy consumption-economic growth nexus indicates the existence of bi-directional causality. This supports the existence of a feedback hypothesis for the emerging and developing economies. In the case of renewable energy consumption-CO_2 emissions nexus, there exists unidirectional causality. This supports the existence of the conservation hypothesis, where CO_2 emissions necessitates the renewable energy consumptions. Based on the findings, the study proposes possible policy options. The countries, who have passed the take-off stage of renewable energy consumption, can take advanced policy initiatives e.g., feed-in tariff, renewable portfolio standard and green certificate for long-term economic development. Other countries can undertake subsidy, low interest loan and market development to facilitate the renewable energy investments.

Keywords: Renewable energy consumption; sustainable economic development; CO_2 emissions

1. Introduction

Economic development is closely associated with the use of energy. At present, most of the countries of Asia, Latin America and Africa have developed their status from low-income to middle-income countries. With this shift in development pattern, the demand for energy is rapidly increasing in these countries. Energy use pattern in developing countries is mostly fossil fuel-based and the grid remote rural areas still lack required energy support. As a result, these countries are facing a two-fold energy challenge: providing basic energy services and ensuring energy sustainability.

In recent decades, worldwide attention towards Sustainable Development Goals (SDGs) and the geopolitical debate of limiting fossil fuel use have accelerated the importance of utilizing renewable energy as a viable option for inclusive and environment friendly economic growth.

According to the Chair of Renewable Energy Policy Network for the 21st Century (REN21), Arthouros Zervos, "in 2017, the contribution of renewable energy to global power generation was about 70%, but global energy-related carbon dioxide emissions rose 1.4%" (The Renewables 2018 Global Status Report, REN21 [1]). Rapid economic growth, cheaper fossil fuels and the absence of energy efficiency policies have fostered the carbon emissions. The report also points out that, at present, there is a worldwide revolutionary shift in the power sector towards a renewable energy future, but the rate of such shift is not as per the expectations. The salient finding in the report is, the positive change in the renewable energy investment pattern in some of the developing countries like, Rwanda, the Solomon Islands, the Marshall Islands and Guinea-Bissau. These countries are having renewable energy investments like most of the developed and emerging economies (p-15, REN21, 2018 report).

The uniqueness of this paper is its contribution to the body of knowledge regarding renewable energy and sustainable economic development for a panel of 30 countries from 5 different regions (Asia, South-Asia, Latin America, Africa and the Caribbean) of the world. Previous studies in this area are mostly on developed countries and some large developing countries like India, China, South Africa and Brazil etc., not on the panel of emerging and developing countries from diversified regions of the world economy. This study is important at the present era of 'sustainable development'. After adopting the Sustainable Development Goals (SDGs), most of the emerging and developing economies are now participating in the global transition to environment friendly, low-carbon energy system. For these countries, renewable energy investment is a timely decision. The objective of this paper is to determine the impact of renewable energy consumption on economic growth and CO_2 emissions in the long run.

2. Literature Review

The existing theoretical and empirical literatures give different directions of causality (unidirectional, bi-directional and neutral) between energy consumption and economic growth. The growing concern about the negative impacts of fossil fuels on environment and the sustainability debate has necessitated carrying out present economic research on renewable energy and sustainable economic development.

There are four popular hypotheses (e.g., growth, conservation, feedback and neutrality hypothesis) in the energy consumption–economic growth nexus. According to the growth hypothesis, energy consumption is pivotal for economic growth and other inputs (e.g., technological improvement, capital and labour) cannot substitute the important role of energy in the production process. This implies that, any decrease in energy consumption may bring reduction in economic growth.

Conservation hypothesis postulates that economic growth determines the energy consumption of a country. This hypothesis completely differs from the growth hypothesis (e.g., energy consumption determines economic growth).

Feedback hypothesis asserts the existence of a bi-directional causal relationship between energy consumption and economic growth. As per this hypothesis, energy consumption and economic growth are interdependent.

Neutrality hypothesis postulates of no causality between energy consumption and economic growth. According to neoclassical economists, Stern and Cleveland (2004), energy does not influence economic growth [2]. This means that, capital and labour are the primary factors of production while energy is an intermediate input of production [3].

To summarize, growth and feedback hypotheses explain the long-term causality between energy consumption and economic growth, while conservation and neutrality hypotheses explain the short-term causality between them.

A brief presentation of previous studies and their findings on the above hypotheses is presented in Table 1.

Table 1. Previous Studies and Their Findings.

Study	Method	Period	Countries	Findings
Energy/Renewable Energy Consumption and Economic Growth Nexus				
Kraft and Kraft (1978) [4]	Granger causality test	1947–1974	USA	Gross Domestic Product (GDP) determines energy consumption; (Conservation hypo.)
Soytas et al. (2001) [5]	Co-integration methodology	1960–1995	Turkey	Energy consumption contributes to GDP growth (Growth hypo.)
Ewing et al. (2007) [6]	Autoregressive Distributed Lag (ARDL) model	2001–2005	USA	GDP determines energy consumption (Conservation hypothesis)
Akinlo A.E. (2008) [7]	Autoregressive Distributed Lag (ARDL) model, Granger causality test based on vector error correction model (VECM)	1980–2003	11 Sub Saharan African countries	For Gambia, Ghana and Senegal, there is bi-directional causality between energy consumption and economic growth.
Cheng et al. (2009) [8]	Panel co-integration test	1997–2007	30 OECD countries	GDP determines energy consumption (Conservation hypo.)
Sadorosky P. (2009) [9]	Fully Modified OLS (FMOLS) for panel	1994–2003	18 emerging countries	GDP determines renewable energy consumption; (Conservation hypo.)
Apergis and Payne (2010) [10]	Panel co-integration test	1985–2005	20 OECD countries	Bi-directional relationship between GDP and energy consumption (Feedback hypo.)
Payne (2010) [11]	Granger causality test	1949–2007	USA	Biomass energy consumption contributes to GDP growth (Growth hypo.)
Apergis and Payne (2011) [12]	Panel co-integration test	1980–2006	6 Central American countries	Energy consumption contributes to GDP growth (Growth hypo.)
Menegaki A.N. (2011) [13]	Random effect model	1997–2007	27 European countries	Energy consumption and economic growth are independent from each other (Neutrality hypothesis)
Fang Y. (2011) [14]	Ordinary least square (OLS)	1978–2008	China	Renewable energy consumption contributes to GDP growth (Growth hypo.)
Tiwari A.K. (2011) [15]	Structural vector autoregressive (VAR) analysis	1960–2009	India	Renewable energy consumption contributes to GDP growth (Growth hypo.)
Shahbaz M. et al. (2012) [16]	Unit roots, Autoregressive Distributed Lag (ARDL) model and Granger causality	1972–2011	Pakistan	In both long and short run, energy consumption and economic growth has bi-directional causality (Feedback hypothesis).
Bildirici (2014) [17]	Fully Modified OLS (FMOLS) for panel	1990–2011	Transition economies	Biomass energy consumption contributes to GDP growth (Growth hypo.)
Bildirici and Ozaksoy (2014) [18]	Granger causality test	1980–2011	European transition economies	GDP determines renewable energy consumption; (Conservation hypo.) for Slovenia and Slovakia; Renewable energy consumption contributes to GDP growth for Bulgaria and Romania (Growth hypo.)
Caraiani Chirata et al. (2015) [19]	Engle and Granger causality tests	1980–2013	5 emerging European countries	GDP determines renewable energy consumption for Hungary, Poland and Turkey (Conservation hypo.); Renewable energy consumption contributes to GDP growth for Romania (Growth hypo.)
Bildirici and Ersin (2015) [20]	Causality test	1970–2013	UK, Canada, Germany, Austria, Finland, France, Italy, Mexico, Portugal and the USA	In USA bi-directional relationship between GDP and renewable energy consumption (Feedback hypo.) and for other countries, GDP determines renewable energy consumption; (Conservation hypo.)
Bloch H. et al. (2015) [21]	Autoregressive Distributed Lag (ARDL) model and vector error correction model (VECM)	1969, 1973, 1997, 1998, 2001, 2002, 2003	China	Bi-directional causality between renewable, non-renewable energy consumption and economic growth (Feedback hypo.)
Paramati R. Sudarshan et al. (2017) [22]	Panel unit root test, panel co-integration and Fully Modified OLS (FMOLS)	1980–2012	17 countries of the G20	Both renewable and non-renewable energy consumption have significant positive impact on economic output and the impact of renewable energy consumption on economic growth is more than non-renewable energy consumption.

Table 1. *Cont.*

Study	Method	Period	Countries	Findings
GDP, Energy Consumption and CO_2 Emissions Nexus				
Kaygusuz et al. (2007) [23]	Analysis of reports of European Commission and European Energy Council	2001–2004	EU-15 Member States	Wind energy plays significant role in reducing CO_2 emissions.
Sadorosky P. (2009) [9]	Pedroni co-integration test and Granger causality test	1994–2003	18 emerging countries	In the long run there exists conservation hypothesis, while in the short run neutrality hypothesis between energy consumption and CO_2 emissions
Menyah and Wolde-Rufael (2010) [24]	Granger causality test	1960–2007	USA	Unidirectional causal flow from economic growth to carbon emissions.
Apergis (2010) [25]	Causal dynamics	1984–2007	19 developing countries	Feedback hypothesis between renewable energy consumption and CO_2 emissions.
Odhiambo (2012) [26]	Causal dynamics	1970–1997	South Africa	Unidirectional causal flow from economic growth to carbon emissions.
Farhani S. (2013) [27]	Panel co-integration test	1975–2008	12 Middle East and North African (MENA) countries	In short term, growth hypothesis and in long-term conservation hypothesis between energy consumption and CO_2 emissions.
Omri A. (2013) [28]	Ordinary least square (OLS)	1990–2011	Middle East and North African (MENA) countries	GDP has positive and significant impact, but financial development and capital have negative impact on CO_2 emissions.
Zeb R. et al (2014) [29]	Panel granger causality and Fully Modified OLS (FMOLS)	1975–2010	5 SAARC countries (Bangladesh, India, Nepal, Pakistan, and Sri Lanka)	Granger causality results suggest about neutrality hypothesis between renewable electricity production and CO_2 emissions. The evidence of growth hypothesis between them in FMOLS approach.
Payne et al. (2014) [30]	Panel co-integration and vector error correction model (VECM)	1980–2011	25 OECD countries	The evidence of feedback hypothesis between renewable energy consumption and CO_2 emissions.
Mbarek, M.B (2014) [31]	Autoregressive Distributed Lag (ARDL) bounds testing approach to co-integration and error correction model (ECM)	1980–2010	Tunisia	Unidirectional relationship between GDP and CO_2emissions in the short run.
Bouznit, M. et al. (2016) [32]	Autoregressive Distributed Lag (ARDL) model	1970–2010	Algiers	A co-integration relationship between CO_2 emissions, real GDP and energy use.
Mitic Petar et al. (2017) [33]	Dynamic Ordinary Least Squares (DOLS) and Fully Modified OLS (FMOLS)	1997–2014	17 transitional economies	Statistically significant long run co-integrating relationship between CO_2 emissions and GDP.

3. Materials and Methods

3.1. Definition of Renewable Energy and Sustainable Development

Renewable energy is defined by the U.S. Energy Information Administration (EIA) as, energy from naturally replenishing sources that are inexhaustible. The major types of renewable energy sources are biomass, solar energy, hydropower, wind energy and geothermal energy [34].

Sustainability covers an interconnected model of three pillars, e.g., economy, ecology and society. The term sustainable development is defined in the Brundtland Commission report, 'Our Common Future' in 1987, as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Ensuring sustainable energy supply is one of the most important prerequisites of sustainable development [35].

Sustainable economic development is the economic development that is concerned with the improvement of the living standards of people by providing lasting and secured livelihood, minimizing resource depletion and environmental degradation [36]. It is a holistic approach of connecting economic growth with social and environmental development.

3.2. Description of Variables and Countries in the Research

In this paper, we will examine the effects of renewable energy consumption on economic growth and carbon dioxide (CO_2) emissions across the panel of 30 countries from five regions (South Asia, Asia, Latin America, Africa and the Caribbean). The data collected from different sources e.g., World Development Indicators (WDI), 2018 of the World Bank, World Energy Statistics and Balances, 2016 of the International Energy Agency and the International Labour Organization dataset 2018, International Monetary Fund (IMF) Investment and Capital Stock dataset, 2018. The dataset covers the period of 1994–2014, spanning 20 years. The variables in this study are: GDP, renewable energy consumption consisting energy from solar, hydro, wind, biogas and biofuels, non-renewable energy consumption consisting energy produced from coal, natural gas and oil, labour force participation, fixed capital and CO_2 emissions. These variables are transformed into log-linear form, to avoid the problems associated with dynamic properties of the data series.

Countries are selected from five different regions of the world economy e.g., South Asia (India, Bangladesh, Pakistan, Sri-Lanka, Nepal, and Bhutan), Asia (China, South Korea, Malaysia, Philippines, Thailand, and Indonesia), Latin America (Colombia, Peru, Bolivia, Ecuador, and Costa Rica), Africa (Ghana, Kenya, Zimbabwe, Tunisia, Uganda, Nigeria, South Africa, Senegal, Cameroon, Chad, and Mozambique) and the Caribbean (Haiti and Jamaica). All these countries have their renewable investments in solar power, wind power, hydro power and biomass sectors.

International Renewable Energy Agency's (IRENA) report (2017) on global renewable energy capacity shows that, renewable energy capacity in whole Asia reached at 918 GW in 2017. Biggest contribution in this field came from China and India. China is one of the major contributors in the worldwide growth of renewable power generating capacity. In 2017, China's solar capacity became 36 times more than it was in five years ago. In 2016, the production of electricity from solar power was 130 GW, which was more than the government's target for 2020. In 2016, India's renewable power generating capacity was 18%. The capacity became 10% of the global growth in 2017. Since 2016, India's solar energy capacity started increasing. It was about 19 GW in 2016 [37].

According to the Renewables 2018 Global Status report, use of biogas for cooking shows a sharp increase in South-Central and South-East Asian countries. In the Latin American region, biofuel production grew 2% in 2017 from the production of 2016. In spite of having positive prospects of growth, in Africa, production and use of biofuels is still at its primary stage (P-37, Renewables 2018 Global Status report REN21).

3.3. Methodology

This paper proposes to analyse two main issues. One is the impact of renewable energy consumption on economic output and another is the impact of renewable energy consumption on CO_2 emissions for the selected countries. The study employs the Cobb-Douglas production [38] function to analyse the correlation between energy consumption and economic growth. Commonly the equation of the production function is as follows:

$$Y = C \cdot R^{\alpha 1} \cdot L^{\alpha 2} \cdot K^{\alpha 3} \cdot NR^{\alpha 4} \quad (1)$$

Here, Y denotes domestic output, R stands for renewable energy consumption, NR, L and K stand for non-renewable energy consumption, labour and capital respectively, C is a positive constant (the level of technology). $\alpha 1$, $\alpha 2$, $\alpha 3$ and $\alpha 4$ denote returns to scale associated with renewable energy consumption, labour, capital and non-renewable energy consumption respectively.

Two models are developed to analyse the relationship of renewable energy consumption with economic growth and CO_2 emissions. The model-I is to analyse the impact of energy consumption on economic growth:

$$Y_{it} = f\left(REC_{it}, NREC_{it}, L_{it}, K_{it}\right) \quad (2)$$

The subscripts i and t denote country and time period respectively. As a measure of economic output, we use GDP or Y constant 2010 US$, gross fixed capital formation (K) constant 2010 US$ and total number of labour force (L). We use both renewable and non-renewable energy consumption measured in terra joules.

Equation (2) is parameterized as follows:

$$Y_{it} = \alpha \cdot REC_{it}^{\beta 1} \cdot NREC_{it}^{\beta 2} \cdot L_{it}^{\beta 3} \cdot K_{it}^{\beta 4} \quad (3)$$

The log transformation of Equation (3) is as follows,

$$\log\ Y_{it} = \log \alpha + \beta 1 \cdot logREC_{it} + \beta 2 \cdot logNREC_{it} + \beta 3 \cdot logL_{it} + \beta 4 \cdot logK_{it} + \varepsilon_{it} + \gamma_i \quad (4)$$

Here, $\log \alpha$ is constant and $\beta 1$, $\beta 2$, $\beta 3$ and $\beta 4$ are elasticities of output with respect to renewable energy consumption, non-renewable energy consumption, labour force and gross fixed capital formation respectively. ε_{it} is an error term and γ_i shows an individual effect.

Another issue related to the study is, the relationship between renewable energy consumption and CO_2 emissions. For the empirical determination of the impact of GDP, renewable and non-renewable energy consumption on carbon dioxide (CO_2) emissions, the equation of model-II is as follows,

$$CO_{2it} = f\left(Y_{it}, REC_{it}, NREC_{it}\right) \quad (5)$$

The subscripts i and t denote country and time period respectively. As economic output, we use GDP or (Y) constant 2010 US$. REC and NREC represent renewable energy consumption and non-renewable energy consumption, respectively. Equation (5) can be parameterized as follows:

$$CO_{2it} = \alpha \cdot Y_{it}^{\beta 1} \cdot REC_{it}^{\beta 2} \cdot NREC_{it}^{\beta 3} \quad (6)$$

The log transformation of the empirical equation is developed as follows:

$$logCO_{2it} = \log \alpha + \beta 1 \cdot logY_{it} + \beta 2 \cdot logREC_{it} + \beta 3 \cdot logNREC_{it} + \varepsilon_{it} + \gamma_i \quad (7)$$

Here, $\log \alpha$ is constant and $\beta 1$, $\beta 2$, $\beta 3$ are elasticities of CO_2 emissions with respect to GDP, renewable energy consumption and non-renewable energy consumption respectively. ε_{it} is an error term and γ_i shows an individual effect.

In order to determine the long-run relationship among the variables, panel unit root test is needed to identify the status of stationarity of the variables. If proven stationary, the next step is to apply an appropriate panel co-integration technique. If, the variables are found to be co-integrated, then fully modified ordinary least square (FMOLS) and dynamic ordinary least square (DOLS) methods will be applied to check long-run elasticity. At the final stage of analysis there is a test for causality through the Dumitreschu and Hurlin pair-wise panel causality test.

4. Results and Discussion

The data set is a strongly balanced panel of 30 countries covering the period of 1994–2014 (20 years).

4.1. Panel Unit Root Test

In order to select the appropriate unit root test, it is crucial to test the cross-section dependence in the panel. The first-generation unit root tests (Levin and Lin, Im Pesran Shin, Hadri) tests are based on cross sectional independence hypothesis. However, the second-generation panel unit root tests are applicable when the panel has cross-sectional dependence. Pesaran (2004) cross-section dependence (CD) test is based on a simple average of all pair-wise correlation coefficients in the OLS residuals obtained from standard augmented Dickey–Fuller regressions for each variable in the panel [39]. Table 2 presents the result of Cross- section dependence (CD).

Table 2. Cross-section dependence (CD) test.

Y	REC	NREC	K	L	CO_2
82.75 ***	39.20 ***	59.21 ***	64.85 ***	93.33 ***	63.52 ***
(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: *** indicates the rejection of null hypothesis of no cross-sectional dependence at 1% level of significance. Here Y, REC, NREC, K, L and CO_2 stand for GDP, renewable energy consumption, non-renewable energy consumption, capital, labour and CO_2 emissions respectively.

The results provide the evidence of cross-section dependence in the panel.

So, here we have applied a second-generation panel unit root test e.g., cross-section augmented IPS (CIPS) test presented in Table 3, which considers both heterogeneity and cross-sectional dependence across the panel [40].

Table 3. Panel unit root test.

	Y	REC	NREC	K	L	CO_2
Level	0.922 (0.800)	3.127 (0.999)	3.605 (0.999)	0.980 (0.792)	1.734 (0.959)	0.758 (0.690)
First difference	−2.924 *** (0.002)	−2.904 *** (0.002)	−3.612 *** (0.000)	−1.173 ** (0.030)	−2.694 *** (0.004)	−3.125 *** (0.001)

Note: **, *** indicate rejection of null hypothesis at 5% and 1% level of significance resp. Cross-section augmented IPS (CIPS) test is applied using constant and trend with 1 lag. Here Y, REC, NREC, K, L and CO_2 stand for GDP, renewable energy consumption, non-renewable energy consumption, capital, labour and CO_2 emissions respectively.

The results show that taking first-differences turns the variables stationary from non-stationary at their levels. Stationary data suggests the possibility of the existence of long-run relationship among the variables.

4.2. Panel Co-Integration Test

In this paper, we used the Pedroni (1999 and 2004) panel co-integration test to check the existence of long-run co-integration among the dependent and independent variables. There are seven test statistics (panel v-statistic, panel ϱ-statistic, panel Phillips-Perron (PP)-statistic, panel Augmented Dicky-Fuller (ADF)-statistic, group ϱ-statistic, group PP-statistic, and group ADF-statistic) in this test. It is a comprehensive co-integration test that takes into account the heterogeneous intercepts and trend coefficients across cross-sections [41,42]. Tables 4 and 5 present the results of Pedroni panel co-integration test.

Table 4. Pedroni panel co-integration test results for model-I (dependent variable: output).

Alternative hypothesis: Common AR coefficients (Within-dimension).

	Statistics	**Probability**	**Weighted Statistics**	**Probability**
Panel v-Statistic	0.804310	0.2106	0.064938	0.4741
Panel ϱ-Statistic	4.941484	1.0000	4.115011	1.0000
Panel PP-Statistic	−1.46635 **	0.04417	−1.724000 **	0.0362
Panel ADF-Statistic	−3.713810 ***	0.0001	−1.902167 **	0.0286

Alternative hypothesis: Individual AR coefficients (Between-dimension).

	Statistics	**Probability**
Group ϱ-Statistic	6.183689	1.0000
Group PP-Statistic	−3.057068 ***	0.0011
Group ADF-Statistic	−1.314386 **	0.0244

Notes: Newey–West automatic bandwidth selection with Bartlett Kernel. ** and *** denote rejection of null hypothesis of no co-integration at 5% and 1% level significance resp.

Table 5. Pedroni panel co-integration test results for model-II (Dependent variable: CO_2 emission).

Alternative hypothesis: Common AR coefficients (Within-dimension).

	Statistics	Probability	Weighted Statistics	Probability
Panel v-Statistic	0.686047	0.2463	1.909063	0.9719
Panel ϱ-Statistic	1.947982 **	0.0257	1.066686	0.1431
Panel PP-Statistic	−7.742661 ***	0.0000	−6.996249 ***	0.0000
Panel ADF-Statistic	−4.600051 ***	0.0000	−5.659427 ***	0.0000

Alternative hypothesis: Individual AR coefficients (Between-dimension).

	Statistics	Probability
Group ϱ-Statistic	0.535848	0.7040
Group PP-Statistic	−8.371437 ***	0.0000
Group ADF-Statistic	−5.158757 ***	0.0001

Notes: Newey West automatic bandwidth selection with Bartlett Kernel. ** and *** denote rejection of null hypothesis of no co-integration at 5% and 1% level of significance respectively.

Here, four out of seven test statistics confirm the presence of co-integration among the variables for both the models (e.g., model-I and model-II), confirming the existence of long-run equilibrium relationship among the variables in both cases.

4.3. Fully Modified Ordinary Least Square (FMOLS)

The long-run elasticity for the panel in this study is estimated using Fully Modified Ordinary Least Square (FMOLS) model. Pedroni (1996) introduced fully modified OLS (FMOLS) to tackle the problems of simultaneity bias, non-exogeneity and serial correlation and obtain asymptotically efficient consistent estimates in panel series [43,44]. Table 6 presents the FMOLS long-run elasticity results for panel.

Table 6. FMOLS long-run elasticity results for panel.

Dependent Variable	Independent Variable	Co-Efficient	Probability
	Model-I		
Log Y	Log REC	0.176 ***	0.002
	Log NREC	0.253 ***	0.001
	Log L	0.702 ***	0.000
	Log K	0.368 ***	0.000
	Model-II		
Log CO_2	Log Y	0.436 ***	0.000
	Log REC	−0.107 **	0.019
	Log NREC	0.558 ***	0.000

Note: ** and *** represent 5% and 1% level of significance respectively. Here, Y, REC, NREC, K, L and CO_2 stand for GDP, renewable energy consumption, non-renewable energy consumption, capital, labour and CO_2 emissions respectively.

The fully modified ordinary least square (FMOLS) test for output (model-I) shows that, increase in renewable energy consumption by 1% will increase output by 0.18%. While a 1% increase in non-renewable energy consumption will lead to a 0.25% increase in output. The findings of long run output elasticity in FMOLS suggests that renewable and non-renewable energy consumption both cause positive and significant impact on output along with labour and capital.

The fully modified ordinary least square (FMOLS) test for CO_2 emission (model-II) shows that increase in GDP by 1% will increase CO_2 emissions by 0.44% while, increase in renewable energy consumption by 1% will decrease the emission by 0.11%. However, a 1% increase in non-renewable energy consumption causes a 0.56% increase in CO_2 emission. From the findings it is seen that, non-renewable energy consumption contributes to the increase in CO_2 emission more than the GDP growth.

4.4. Dynamic Ordinary Least Square (DOLS)

The main reasons for choosing DOLS are, first, it is robust to small samples and outperforms both Ordinary Least Square (OLS) and Fully Modified Ordinary Least Square (FMOLS) estimators in terms of unbiased estimation for finite samples, and second, the superiority of DOLS estimator to other estimators in case of controlling endogeneity bias [45]. Table 7 presents the DOLS long-run elasticity results for panel.

Table 7. Dynamic ordinary least square (DOLS) long-run elasticity results for panel.

Dependent Variable	Independent Variable	Co-Efficient	Probability
	Model-I		
Log Y	Log REC	0.201 ***	0.002
	Log NREC	0.285 ***	0.000
	Log L	0.533 ***	0.000
	Log K	0.254 ***	0.000
	Model-II		
Log CO_2	Log Y	0.378 ***	0.000
	Log REC	−0.103 **	0.047
	Log NREC	0.662 ***	0.000

Note: ** and *** represent 5% and 1% level of significance respectively. Here, Y, REC, NREC, K, L and CO_2 stand for GDP, renewable energy consumption, non-renewable energy consumption, capital, labour and CO_2 emissions respectively.

The dynamic ordinary least square (DOLS) test for output (model-I) shows that, increase in renewable energy consumption by 1% will increase output by 0.20%, while increase in non-renewable energy consumption by 1% will increase output by 0.28%.

Dynamic ordinary least square (DOLS) test for CO_2 emission (model-II) shows that a 1% increase in GDP will increase CO_2 emissions by 0.38% while a 1% increase in renewable energy consumption by will decrease emission by 0.10%. An increase in non-renewable energy consumption by 1% will lead to a 0.66% increase of CO_2 emissions. From the findings, it is seen that, non-renewable energy consumption contributes more in the increase of CO_2 emissions compared to GDP.

Based on the findings from the FMOLS and DOLS tests, it is seen that both renewable and non-renewable energy consumption play important roles in economic growth. The outcomes are positive for both types of energy consumption. Important fact is, renewable energy consumption has the future prospect in ensuring sustainable economic growth, which is not possible with non-renewable energy consumption. Additionally, renewable energy consumption is found effective in reducing CO_2 emissions. From the findings of both FMOLS and DOLS it can be said that, in the long-run, renewable energy consumption can ensure green growth in emerging and developing countries.

4.5. Country-Specific FMOLS Long-Run Elasticity Analysis

This section will test the long-run elasticity for individual countries of different regions through country specific FMOLS method, which will give more specific outcomes for the countries of different regions. Table 8 presents country-specific FMOLS long-run output elasticity results.

Table 8. Country-specific FMOLS long-run output elasticity results.

Region	Country	Log REC	Log NREC	Log L	Log K	R^2	Adj. R^2
South Asia	India	1.390 ***	0.618 ***	0.773 ***	0.044	0.999	0.999
	Bangladesh	0.542 ***	−0.031	0.799 ***	0.823 ***	0.999	0.999
	Pakistan	1.722 ***	0.210 *	0.265	0.190 ***	0.997	0.996
	Sri Lanka	−0.114	0.276 **	0.391	0.669 ***	0.987	0.983
	Nepal	0.379 **	0.031	1.259 ***	0.140 **	0.996	0.994
	Bhutan	1.900 ***	0.073 ***	0.625 ***	0.034 **	0.998	0.998
Asia	Malaysia	−0.179 ***	0.368 ***	0.889 ***	0.180 ***	0.996	0.995
	Indonesia	0.396 ***	−0.046	0.992 ***	0.476 ***	0.996	0.994
	China	0.501 **	0.127	1.106 **	0.721 ***	0.997	0.997
	Philippine	−0.040	0.318 **	1.030 ***	0.553 ***	0.997	0.966
	Thailand	0.373 ***	0.307 **	0.986 ***	0.087 ***	0.994	0.992
	Korea	−0.032	0.112 ***	4.090 ***	0.110	0.988	0.984
Latin America	Columbia	0.058	0.617 ***	0.643 ***	0.127 ***	0.995	0.994
	Ecuador	0.019	0.347 ***	0.385 ***	0.239 ***	0.990	0.988
	Peru	0.112	0.208 **	0.736 **	0.227 ***	0.995	0.994
	Costa Rica	0.105 **	−0.118	0.893 ***	0.342	0.982	0.977
	Bolivia	0.074	1.853 ***	1.179 ***	1.194 ***	0.996	0.995
Africa	Ghana	0.516 ***	0.186 **	2.780 ***	0.195 **	0.989	0.987
	Mozambique	0.026	−0.083	3.116 ***	0.040	0.992	0.990
	Senegal	−0.035	0.274 **	0.366	0.243	0.990	0.987
	Chad	−3.608 **	0.313 ***	3.101 ***	0.056	0.980	0.976
	Nigeria	0.210 **	0.478 ***	0.232	0.321 ***	0.985	0.981
	Kenya	0.002	−0.201	0.631	0.369 ***	0.990	0.988
	Zimbabwe	1.976 ***	1.036 ***	0.951	0.062 ***	0.887	0.857
	Tunisia	0.281 ***	0.281 **	1.290 ***	0.063	0.997	0.996
	South Africa	1.072 ***	0.0035	0.006	0.269 ***	0.997	0.996
	Uganda	−0.253 **	−0.082	1.586 ***	0.228 ***	0.997	0.996
	Cameroon	0.134 **	−0.054	1.408 ***	0.010	0.997	0.996
Caribbean	Haiti	0.018	−0.038	0.100	0.190 ***	0.891	0.862
	Jamaica	−0.050	0.074 ***	0.632 ***	0.188 ***	0.913	0.890

Note: *, **, *** denotes significance levels of 10%, 5% and 1% respectively. Here, REC, NREC, L and K stand for renewable energy consumption, non-renewable energy consumption, labour and capital respectively.

In the country-specific long-run output elasticity results for 30 emerging and developing countries, 18 show significant long-run relationship between renewable energy and economic output. Of these 18 countries, 15 show significant and positive relation and 3 have a significant but negative relation between renewable energy and economic output. Among these 3 countries, 2 are from the African region (Uganda, Chad) and another from the Asian region (Malaysia). The present characteristics of energy consumption of these countries show a dependence on fossil fuel energy and limited investment in renewable energy sector. This is resulting in slow deployment of renewable energy. From our results, it is seen that, the impact of renewable energy consumption on economic growth is more than non-renewable energy consumption for Asian, South-Asian and most of the African countries (Ghana, Tunisia, South Africa, Zimbabwe and Cameroon). But for the Latin American and the Caribbean countries, it can be said that economic growth depends on non-renewable energy consumption. Renewable energy consumption in the selected countries of these two regions are still at the initial stage. Table 9 presents the country-specific FMOLS long-run CO_2 elasticity results.

Table 9. Country-specific FMOLS long-run CO_2 elasticity results.

Region	Country	Log Y	Log REC	Log NREC	R^2	Adj. R^2
South Asia	India	0.394 *	−1.237	0.935 ***	0.995	0.994
	Bangladesh	0.040	−0.000	1.133 ***	0.996	0.995
	Pakistan	0.044	0.093	1.127 ***	0.993	0.991
	Sri Lanka	0.312 ***	−0.702 **	1.159 ***	0.981	0.977
	Nepal	2.172 ***	−2.752 ***	0.716 ***	0.993	0.921
	Bhutan	0.603 **	1.851 *	1.114 ***	0.976	0.970
Asia	Malaysia	1.103 ***	−1.295 ***	−0.137	0.957	0.949
	Indonesia	0.738 ***	−0.973	0.798	0.902	0.896
	China	0.041	−0.144	1.084 ***	0.997	0.996
	Philippine	0.393 ***	0.159	0.796 ***	0.926	0.912
	Thailand	0.093	−0.153 **	1.138 ***	0.995	0.994
	Korea	0.598 ***	−0.167 ***	0.865 ***	0.965	0.959
Latin America	Columbia	0.055	0.164	1.458 ***	0.917	0.902
	Ecuador	1.032 **	−0.187	0.120	0.913	0.897
	Peru	0.774 ***	0.047	0.329	0.950	0.937
	Costa Rica	0.023	0.235 ***	0.758 **	0.952	0.944
	Bolivia	0.817 ***	0.385	0.032	0.907	0.890
Africa	Ghana	0.764 **	0.202	0.118	0.906	0.889
	Mozambique	0.216	−0.529	1.730 ***	0.961	0.953
	Chad	0.393 **	1.075	0.418 ***	0.990	0.989
	Nigeria	0.881 ***	−0.661 ***	0.143	0.977	0.973
	Kenya	0.841 *	−1.790 ***	1.180 ***	0.936	0.924
	Tunisia	0.444 ***	−0.220 ***	0.620***	0.993	0.991
	South Africa	0.457	−0.896 **	0.739 ***	0.923	0.909
	Uganda	0.654 **	0.088	0.646 **	0.993	0.992
	Cameroon	0.420	0.527	1.180 ***	0.910	0.897
	Senegal	2.00 ***	0.251	0.834 ***	0.830	0.800
	Zimbabwe	0.042	−0.156	1.230 ***	0.824	0.792
Caribbean	Haiti	0.245	0.378 ***	0.761 ***	0.991	0.990
	Jamaica	2.224 ***	−0.142	0.718 ***	0.892	0.863

Note: *, ** and *** denote significance levels of 10%, 5% and 1% respectively. Here, Y, REC and NREC stand for GDP, renewable energy consumption and non-renewable energy consumption respectively.

For the country specific long-run elasticity results for CO_2 emissions, out of 30 developing countries, 12 show significant results. Of them, 9 show the empirical evidence that, renewable energy consumption will reduce CO_2 emission. But for 3 countries, the increase in renewable energy consumption leads to a slight increase in CO_2 emission, although the rate is lower than that of non-renewable energy consumption. Depending on the nature and relative importance of renewable energy sources in an economy, the results may change from country to country. These countries have a common practice of using energy mixes (both renewable energy and fossil fuel energy in parallel) like solar photovoltaic (PV) for electricity and gas stove for cooking in daily household life. Sometimes, problems arise from the variation in renewable energy technology development, lack of knowledge in operation, fault in designing or installation of plants. From the results we can also see that, in case of South Asian, Asian, Latin American and African countries, both GDP growth and non-renewable energy consumption cause the increase in CO_2 emissions. While, in case of the Caribbean countries non-renewable energy consumption plays the dominant role in increasing CO_2 emissions.

4.6. Pair-Wise Dumitreschu and Hurlin Causality Test

In order to examine the direction of short-run causality among the variables, we have used the panel causality test based on Dumitreschu and Hurlin (2012). According to Dumitreschu and Hurlin (2012), the test value converges to a normal distribution under the homogeneous non-causality hypothesis. The main advantage of this test is, it assumes all coefficients are different across the cross section [46]. Table 10 presents the pair-wise Dumitreschu and Hurlin causality test.

The data series is stationary and the Schwarz information criterion (SIC) is used to determine the appropriate lag length.

Table 10. Pair-wise Dumitreschu and Hurlin causality test.

Null Hypothesis	Zbar-Stat	Probability
Log REC does not homogeneously cause Log Y	2.257 **	0.0240
Log Y does not homogeneously cause Log REC	4.427 ***	0.0001
Log NREC does not homogeneously cause Log Y	1.996 **	0.0459
Log Y does not homogeneously cause Log NREC	6.464 ***	0.0000
Log K does not homogeneously cause Log Y	3.306 ***	0.0009
Log Y does not homogeneously cause Log K	9.349 ***	0.0000
Log L does not homogeneously cause Log Y	4.942 ***	0.0000
Log Y does not homogeneously cause Log L	7.848 ***	0.0000
Log NREC does not homogeneously cause Log REC	2.978 ***	0.0029
Log REC does not homogeneously cause Log NREC	2.830 ***	0.0047
Log K does not homogeneously cause Log REC	0.904	0.3661
Log REC does not homogeneously cause Log K	3.488 ***	0.0005
Log L does not homogeneously cause Log REC	30.49 ***	0.0000
Log REC does not homogeneously cause Log L	3.817 ***	0.0010
Log K does not homogeneously cause Log NREC	5.971 ***	0.0000
Log NREC does not homogeneously cause Log K	2.248 **	0.0246
Log L does not homogeneously cause Log NREC	7.069 ***	0.0000
Log NREC does not homogeneously cause Log L	5.446 ***	0.0000
Log L does not homogeneously cause Log K	7.993 ***	0.0000
Log K does not homogeneously cause Log L	3.717 ***	0.0002
Log Y does not homogeneously Cause Log CO_2	10.748 ***	0.0000
Log CO_2 does not homogeneously Cause Log Y	3.203 ***	0.0014
Log REC does not homogeneously Cause Log CO_2	1.396	0.1627
Log CO_2 does not homogeneously Cause Log REC	2.000 **	0.0455
Log NREC does not homogeneously Cause Log CO_2	4.822 ***	0.0000
Log CO_2 does not homogeneously Cause Log NREC	2.475 **	0.0133

Note: ** and *** denote significance level at 5% and at 1% resp. Here, Y, REC, NREC, K, L and CO_2 stand for GDP, renewable energy consumption, non-renewable energy consumption, capital, labour and CO_2 emissions respectively.

In case of pair-wise relationships above, there is bi-directional causality between GDP and all other inputs (e.g., energy consumption, labour force and capital). Here, the important finding is the existence of feedback hypothesis between renewable energy consumption and economic growth. This indicates that economic growth in these countries contributes to the renewable energy investment and this in turn facilitates production and economic growth or vice versa. This is a positive sign for taking initiatives for increasing renewable energy investments for sustainable economic growth.

Both GDP and non-renewable energy consumption have bi-directional causality with CO_2 emissions. There is unidirectional causality between renewable energy consumption and CO_2 emissions. The findings indicate that high consumption of non-renewable energy will increase CO_2 emissions. In response to it, GDP can be used to increase investments in renewable energy sector, which will contribute to the reduction of CO_2 emissions in the long-run.

5. Conclusions, Limitations and Further Scope of the Study

At present, renewable energy projects are becoming vital in the energy mixes of most of the countries. The results of this paper also show that, renewable energy can benefit the economic growth and reduce CO_2 emissions in the long run. In order to ensure sustainable economic development, emerging and developing countries should focus on increasing investments in the renewable energy sector. Successful implementation of renewable energy projects depends on adopting a suitable 'policy package', rather than choosing stand-alone policies. At present the popularly practiced renewable energy policies are: subsidy, renewable portfolio standards as a cost-effective option to reduce initial cost of technology installation, low interest loans, green certificates as tradeable assets for electricity generation from renewable sources and feed in tariff offering fixed and guaranteed price for electricity generation from renewable sources [47].

From our findings, the countries where the impact of renewable energy consumption on economic growth is positive and more than that of non-renewable energy consumption have already shifted their investment focus to the renewable energy sector and passed the take-off stage. They can take advanced policy initiatives, e.g., feed-in tariffs, renewable portfolio standards, green certificates and fossil fuel divestment for long-term economic development. Countries like China, India and South Africa have undertaken advanced measures in their renewable energy policy package. For other countries that are in the take-off stage of renewable energy investments, can adopt subsidies, tax incentives, market development initiatives and establish public-private partnership for financing renewable energy projects at low interest rate as the possible policy options. Countries need to increase their allocations in research and development for promoting low-cost innovative technologies.

The real set-up in these emerging and developing economies is surrounded by socio-economic, political and market barriers. In order to facilitate renewable energy sector, it is important to reduce the risk of investment and change the difficult procedures of getting a loan. Governments and the private sector should establish public-private partnership to remove the barriers and reduce the risks in renewable energy investment.

In this paper the authors include the renewable energy sources as defined by the U.S. Energy Information Administration (EIA), e.g., solar, wind, hydropower, biofuel and biomass to analyse the impact of renewable energy consumption on economic growth and CO_2 emissions. This study does not include 'nuclear' in the 'renewable' category following the definition of the EIA. But as a further expansion of the study, the authors would like to analyse 'the nexus between power generation from nuclear energy and economic growth'.

The study takes into account the renewable energy produced from 'biofuels'. Biofuels are derived from corn, palm and other crop-based sources. The main problem of consuming biofuels is deforestation, which has consequences like social dislocation, loss of biodiversity and displacement of food crops (Asian Development outlook 2013: Asia's energy challenge, p-85) [48]. Addressing these problems, 'the efficiency of biofuels in ensuring sustainable development' can be another field of further study.

Finally, this study employs the Cobb–Douglas function, which has its own limitations. Other functional forms e.g., the constant elasticity of substitution (CES) can be more flexible but is not transformable in to log-linear form. This study deals with the log-linear transformation so, we have to use the Cobb–Douglas function.

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References

1. The Renewables 2018 Global Status Report. Available online: http://www.ren21.net/gsr-2018/ (accessed on 3 April 2019).
2. Stern, D.I.; Cleveland, C.J. Energy and Economic Growth. Available online: https://econpapers.repec.org/paper/rpirpiwpe/0410.htm (accessed on 3 April 2019).
3. Tugcu, C.T.; Ozturk, I.; Aslan, A. Renewable and non-renewable energy consumption and economic growth relationship revisited: Evidence from G7 countries. *Energy Econ.* **2012**, *34*, 1942–1950. [CrossRef]

4. Kraft, J.; Kraft, A. On the relationship between energy and GNP. *J. Energy Dev.* **1978**, *3*, 401–403.
5. Soytas, U.; Sari, R.; Ozdemir, O. Energy Consumption and GDP Relations in Turkey: A Co-integration and Vector Error Correction Analysis. *Glob. Bus. Technol. Assoc.* **2001**, *1*, 838–844.
6. Ewing, B.T.; Sari, R.; Soytas, U. Disaggregate energy consumption and industrial output in the United States. *Energy Policy* **2007**, *35*, 1274–1281. [CrossRef]
7. Akinlo, A.E. Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries. *Energy Econ.* **2008**, *30*, 2391–2400. [CrossRef]
8. Lee, C.-C.; Chang, C.-P. The impact of energy consumption on economic growth: Evidence from linear and nonlinear models in Taiwan. *Energy* **2007**, *32*, 2282–2294. [CrossRef]
9. Sadorosky, P. Renewable energy consumption and income in emerging economies. *Energy Policy* **2009**, *37*, 4021–4028. [CrossRef]
10. Apergis, N.; Payne, J.E. Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy* **2010**, *38*, 656–660. [CrossRef]
11. Payne, J.E. Survey of the international evidence on the causal relationship between energy consumption and growth. *J. Econ. Stud.* **2010**, *37*, 53–95. [CrossRef]
12. Apergis, N.; Payne, J.E. The renewable energy consumption-growth nexus in Central America. *Appl. Energy* **2011**, *88*, 343–347. [CrossRef]
13. Menegaki, A.N. Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Econ.* **2011**, *33*, 257–263. [CrossRef]
14. Fang, Y. Economic welfare impacts from renewable energy consumption: The China experience. *Renew. Sustain. Energy Rev.* **2011**, *15*, 5120–5128. [CrossRef]
15. Tiwari, A.K. A structural VAR analysis of renewable energy consumption, real GDP and CO_2 emissions: Evidence from India. *Econ. Bull.* **2011**, *31*, 1793–1806.
16. Shahbaz, M.; Zeshan, M.; Afza, T. Is Energy Consumption Effective to Spur Economic Growth in Pakistan? New Evidence from Bounds Test to Level Relationships and Granger Causality Tests. *Econ. Model.* **2012**, *29*, 2310–2319. [CrossRef]
17. Bildirici, M.E. Relationship between biomass energy and economic growth in transition countries: Panel ARDL approach. *GCB Bio Energy* **2014**, *6*, 717–726. [CrossRef]
18. Bildirici, M.E.; Ozaksoy, F. The relationship between economic growth and biomass energy consumption in some European countries. *J. Renew. Sustain. Energy* **2013**. [CrossRef]
19. Caraiani, C.; Lungu, C.I.; Dascalu, C. Energy consumption and GDP causality: A three step analysis for emerging European countries. *Renew. Sustain. Energy Rev.* **2015**, *44*, 198–210. [CrossRef]
20. Bildirici, M.; Ersin, O. An investigation of the relationship between the biomass energy consumption, economic growth and oil prices. *Proced. Soc. Behav. Sci.* **2015**, *210*, 203–212. [CrossRef]
21. Bloch, H.; Rafiq, S.; Salim, R. Economic growth with coal, oil and renewable energy consumption in China: Prospects for fuel substitution. *Econ. Model.* **2015**, *44*, 104–115. [CrossRef]
22. Paramati, S.R.; Apergis, N.; Ummalla, M. Dynamics of renewable energy consumption and economic activities across the agriculture, industry and service sectors: evidence in the perspective of sustainable development. *Environ. Sci. Pollut. Res.* **2018**, *25*, 1375–1387. [CrossRef]
23. Kaygusuz, K.; Yuksek, O.; Sari, A. Renewable energy sources in the European Union: Markets and capacity. *Econ. Plan. Policy* **2007**, *2*, 19–29. [CrossRef]
24. Menyah, K.; Wolde-Rufael, Y. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy* **2010**, *38*, 2911–2915. [CrossRef]
25. Apergis, N.; Payne, J.E.; Menyah, K.; Wolde-Rufael, Y. On the causal dynamics between emissions, nuclear energy, renewable energy and economic growth. *Ecol. Econ.* **2010**, *69*, 2255–2260. [CrossRef]
26. Odhiambo, N.M. Economic growth and carbon emissions in South Africa: An empirical investigation. *Int. Bus. Econ. Res. J.* **2011**. [CrossRef]
27. Farhani, S. Renewable energy consumption, economic growth and CO_2 emissions: evidence from selected MENA countries. *Energy Econ. Lett.* **2013**, *1*, 24–41.
28. Omri, A. CO_2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy Econ.* **2013**, *40*, 657–664. [CrossRef]

29. Zeb, R.; Salar, L.; Awan, U.; Zaman, K.; Shahbaz, M. Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: Progress towards green economy. *Renew. Energy* **2014**, *71*, 123–132. [CrossRef]
30. Apergis, N.; Payne, J.E. The causal dynamics between renewable energy, real GDP, emissions and oil prices: evidence from OECD countries. *Appl. Econ.* **2014**, *46*, 4519–4525. [CrossRef]
31. Mbarek, M.B.; Ali, N.B.; Feki, R. Causality relationship between CO_2 emissions, GDP and energy intensity in Tunisia. *Environ. Dev. Sustain.* **2014**, *16*, 1253–1262. [CrossRef]
32. Bouznit, M.; Pablo-Romero, M.d.P. CO_2 emission and economic growth in Algeria. *Energy Policy* **2016**, *96*, 93–104. [CrossRef]
33. Mitic, P.; Ivanovic, O.M.; Zravkovic, A. A co-integration analysis of real GDP and CO2 emissions in transitional countries. *Sustainability* **2017**, *9*, 568. [CrossRef]
34. Renewable Energy Explained. Available online: https://www.eia.gov/energyexplained/?page=renewable_home (accessed on 27 July 2019).
35. Sustainable Development 2015. Available online: https://www.sustainabledevelopment2015.org/AdvocacyToolkit/index.php/earth-summit-history/historical-documents/92-our-common-future (accessed on 27 July 2019).
36. Barbier, E.B. The concept of sustainable economic development. *Environ. Conserv.* **1987**, *14*, 101–110. [CrossRef]
37. Asia Leads the Charge in Growth of Renewable Energy. Available online: https://asia.nikkei.com/Economy/Asia-leads-the-charge-in-growth-of-renewable-energy (accessed on 13 May 2019).
38. Cobb, C.W.; Douglas, P.H. A Theory of Production. Available online: http://www.institutodeestudiosurbanos.info/dmdocuments/cendocieu/Especializacion_Mercados/Documentos_Cursos/Theory_Production-Cobb_Charles-1928.pdf (accessed on 22 July 2019).
39. Pesaran, M.H. General diagnostic tests for cross section dependence in panels. *J. Econ.* **2004**, *69*, 1229.
40. Pesaran, M.H. A simple panel unit root test in the presence of cross-section dependence. *J. Appl. Econ.* **2007**, *22*, 265–312. [CrossRef]
41. Pedroni, P. Panel Co-integration: Asymptotic and finite samples properties of pooled time series Tests with an application to the PPP hypothesis. *Econ. Theory* **2004**, *20*, 597–625. [CrossRef]
42. Pedroni, P. Critical values for co-integration tests in heterogeneous panels with multiple regressors. *Oxford Bull. Econ. Stat.* **1999**, *61*, 653–670. [CrossRef]
43. Pedroni, P. Fully Modified OLS for heterogeneous co-integration Panel. *Adv. Econ.* **2001**, *15*, 93–130.
44. Pedroni, P. Fully Modified OLS for Heterogeneous Co-Integrated Panels and The Case of Purchasing Power Parity. Available online: https://web.williams.edu/Economics/pedroni/WP-96-20.pdf (accessed on 27 July 2019).
45. Stock, J.H.; Watson, M.W. A simple estimator of co-integrating vectors in higher Order integrated systems. *Economics* **1993**, *61*, 783–820.
46. Dumitrescu, E.-I.; Hurlin, C. Testing for Granger non-causality in heterogeneous panels. *Econ. Model.* **2012**, *29*, 1450–1460. [CrossRef]
47. Abdmouleh, Z.; Alammari, R.A.M.; Gastli, A. Review of policies encouraging renewable energy integration and best practices. *Renew. Sustain. Energy Rev.* **2015**, *45*, 249–262. [CrossRef]
48. Asian Development Outlook 2013. Available online: https://www.adb.org/sites/default/files/publication/30205/ado2013_1.pdf (accessed on 20 July 2019).