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The moderating role of renewable and non-renewable energy in environment-income nexus for ASEAN countries: Evidence from Method of Moments Quantile Regression

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A B S T R A C T

A vast body of studies estimates the impact of energy consumption on the environment. A typical empirical study either use aggregate energy consumption or apply conventional econometric techniques in modelling the nexus of energy, income and environment. To correct these gaps, the objective of the study is to use renewable and non-renewable energy consumption in analyzing energy-income-environment nexus, and to apply the novel Method of Moments Quantile Regression for ASEAN countries. The outcomes indicate that non-renewable energy consumption stimulate carbon emissions across all quantiles (10th to 90th), the value of the 10th quantile is 0.257 which rises to 0.501 till 90th quantile. Whereas, the renewable energy consumption leads to a decrease in CO_2 emissions across all the quantiles (10th to 90th) but this association is statistically insignificant at higher quantiles from 60th to 90th. The empirical outcomes also verify the presence of the environmental Kuznets curve relationship, which is statistically significant from the middle (30th) to higher (90th) quantiles. Moreover, the finding of panel estimation approaches (FMOLS, DOLS, FE-OLS) also verify the existence of the EKC hypothesis in ASEAN countries. Their finding also describes that 1% increase in non-renewable energy consumption increase CO_2 emission by 0.29%, 0.26% and 0.30% whereas 1% increase in the usage of renewable energy reduces CO_2 emission by 0.17%, 0.15% and 0.17% in case of FMOLS, DOLS and FE-OLS respectively. The empirical results conclude that the government should encourage and subsidize the sources of green energy to tackle environmental degradation. More policy implications are further discussed in the study.

1. Introduction

Climate variation is comprehended as one of the major coercions for the living beings on the earth, disturbing extensively sea to atmosphere and land, and from tropical to cold regions. Climate change is primarily credited to the huge consumption of fossil fuels. Among all greenhouse gases (GHG), CO_2 emissions are a major contributor that leads to enhance global-warming and continues to gain academic consideration [1–4]. CO_2 emissions have increased day by day due to increasing economic growth, increasing demand of energy [5–12].

Energy consumption is considered as the foremost device for the progression of economic-development [13–15]. As energy performs a significant part in generating jobs, commerce, transport, agriculture and economic development. It is also the main tool for sustainable human development and eradicating poverty [16]. Energy is also considered as a main factor of production. Traditional causes of energy (i.e., natural gas coal, & oil) are regarded as the best catalysts of economic growth, and their demand has been swiftly increased in the last decades due to economic and social developments [17,18]. The world's energy demand was increased 6264 MTOE to 9791 MTOE from 1990 to 2017. The proportion of coal, natural gas and oil are 10.42%, 15.34% and 40.54% respectively

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to meet this demand in 2017. In other words, traditional energy sources met 66.3% of the world's energy requirements in 2017 [19]. Though, the world's reliance on conventional energy sources has carried several worldwide issues. Today the most fundamental global issues are the nature of coal, natural gas and oil as sources of nonrenewable energy, energy price shocks, energy dependence and security of supply, independence and security of supply, and global warming [20]. Therefore, such issues forced societies to transfer their dependence from the traditional source of energy to alternative or modern energy sources [21]. [16] believed that Millennium Development Goals (MDGs) can also be attained through a sustained and sufficient supply of modern form of energy.

In the current era of energy-based economies, the attention of the rich and poor countries moves towards the topic of renewable energy sources [17,22]. A form of renewable energy sources that is responsible for nominal environment degradation can be classified as wind, waves, rain, geothermal heat, sunlight, etc. [23]. These resources are also known as green energy sources Green energy produces energy in four different sectors. These sectors are categorized as air & water, services in rural areas and transportation. According to World Bank, the contribution of the renewable energy sources (including biomass, tides, solar, biofuels, geothermal and hydro-electric) in the total electricity production of the ASEAN countries (Thailand, Singapore, Indonesia, Malaysia, Philippine, Vietnam) is almost 16% [24].

Economic growth has a momentous impact on economic development as well as on human development [25]. In the current era of development, developing economies have been putting their efforts to boost their industrialization process by enhancing their energy-consumption to produce better goods and services [26–28]. Many emerging economies of the world have deeply indulged themselves to get higher production ranks in the regions but they have failed to get desired protection or safety measures to control CO_2 emissions [29]. Many developing economies are facing crucial challenges such as high unemployment, inflation, poverty level rapid population growth, low per capita, and slower industrialization for the sake of economic development. To cope with these issues, the more efforts to boost production and GDP per capita, the consequences are these efforts are more natural resource depletion, environmental degradation and global warming [25,30]. As a higher level of production requires larger sources of energy. To upsurge economic growth in developing economies, they struggle to use nonrenewable energy resources which is available relatively in higher proportion [31,32].

A fundamental objective of this study is to understand the association between energy consumption, carbon emissions by sources and income for ASEAN countries. The motivation behind the selection of these countries are; first, these economies in terms of the population come after the India and China with a total population of six hundred fifty-four million while the total GDP of ASEAN countries reached to 3.1 trillion US dollars. In this regard, we can realize that three giants are taking the lead, Indonesia with $1111.7 billion, Thailand with $529.2 billion and the Philippine with $365.3 billion. Consequently, the total GDP of Malaysia, Singapore and Vietnam is 362.8, 356.8, 261.6 billion dollars respectively [33]. Consequently, high economic growth is accountable for high-rise emissions of CO_2 [34–36]. Several empirical studies provide evidences that GDP is one of the significant indicators to boost energy demand in the form of electricity [37–42]. The ASEAN nations are in the line of highest energy consumer countries of the world [24]. The abundant natural resources and economic policies of these countries draw the attention of foreign investors. Therefore, ASEAN stands out as one of the rapid regions of emerging economies in the world [43]. In this regard, the eminent economies of ASEAN countries deserve to be studied.

Numerous researchers in their research have studied the association energy-income-environment nexus by considering of several ASEAN nations (Such as, [44–47]. An important drawback of the existing studies is that their findings are mixed. A significant weakness of the prior studies for ASEAN nations is that these studies depend upon the presumption that disturbance terms are independent and no cross-sectional dependence (CD) amongst mentioned variables across the nations. The nature of these variables may be as spillover, common or unobserved shocks, or a combination of all such sources [48–50]; Cerrato, 2001). As a cross-sectional group of ASEAN economies are probably to be commonly dependent to increase economic integration, which makes it imperative to have CD in the study. ASEAN nations are particularly vulnerable to joint shocks that affect economic growth also energy consumption, for instance, international financial crises and oil price shocks [50]. believes that the results of the connection between energy, income and environment will be bias and inconsistent if the CD is ignored in a study.

In light of above-mentioned discussions and considerations, this study contributes to the existing literature in three-fold. First, as far as we are aware, this is the first attempt to study the association between non-renewable energy consumption, renewable energy consumption, income and carbon emissions by using the novel "Method of Moments Quantile Regression" (MMQR) for ASEAN economies. Second, this study contributes to thin body literature that adopts the MMQR [51]. An experiential understanding of the heterogeneity of the association becomes easier by incorporating this methodology with fixed effects. This methodology also permits heterogeneous energy-emissions connections at various conditional quantiles distribution, whereas conventional mean regressions are unable to capture such effects. Subsequently, a detailed analysis of the EKC hypothesis in ASEAN economies is estimated. Third**,** this study uses disaggregated energy consumption in modelling nexus of energy-income-environment in the framework of the EKC hypothesis for the analyzed countries. There are several reasons behind the assessment of Environmental Kuznets's Curve (EKC) hypothesis at several quantiles: i) Contrasting the assessments of conditional-mean. These assessments are susceptible to mislead the impacts of outliers originating from the endogenous variables due to the more vigorous conditional quantiles [52]; ii) Especially in case of panel regression, the quantile regression is particularly attractive because it has an additional intuitive application; iii) Due to the distributional impacts of the exogenous factors on the endogenous factors at various quantile ranges. Conditional mean estimation, on the other hand, unable to describes the full distributional effect of income on emissions. In this manner, it gets simpler to categorize the heterogeneous impacts of the groups of heterogeneous cross-sections.

2. Literature review

Table 1 summarizes the literature review. The importance of energy cannot be denied as it is considered the mainstay of social well-being and development of the economy [53]. Inspected the connection among energy usage and emissions of CO_2 in G-7 nations. The discoveries of Granger causality proposed the way of causality between the factors for the US, runs in the two bearings all the while. Be that as it may, for France, the study found a unidirectional relationship from energy usage to CO_2 emanation [54]. Explored association amid economic growth, energy usage and quality of the environment for Senegal. The empirical outcome shows that usage of energy increases pollution whereas income has a negative impact on environmental deterioration. They recommended that the utilization of green energy can increase the quality of the environment [55]. Explored connection amongst oil usage,

Table 1
A survey of existing literature.

Study	Variables	Country/ies Time Period and Econometric Approach	Findings of the study
[53]	CO_2, GDP, NEC	G-7 states 1960–2010 Time-varying Granger causality approach	Bi-directional causality exists between all the variables.
[8]	Financial Development, electricity energy consumption, urbanization, industrialization, GDP, CO_2.	Senegal 1980–2011 Nonlinear iterative partial least squares (NIPLS)	Financial development, energy consumption and industrialization increase CO_2 whereas urbanization and GDP diminish it.
[55]	Oil consumption, GDP and CO_2.	South Korea, Japan, China 1980–2013 Granger Causality	Oil consumption is a cause of CO_2.
[56]	CO_2, GDP, NEC	Malaysia 1975–2015 ARDL	NEC and GDP increase CO_2.
[1]	REC, CO_2, GDP	United States 1960–2010 ARDL	REC reduces CO_2. EKC exist.
[57]	CO2, REC, Agricultural value-added, Forest area.	Pakistan 1981–2015 FMOLS	REC, Agriculture value added and Forest area reduces CO_2.
[58]	Energy consumption, GDP, CO_2	BRICS countries 1992–2016 Generalized Method of Moments	NEC, the GDP population increases CO_2 and REC decreases CO_2.
[59]	REC, NEC, GDP, agriculture and CO_2.	BRICS countries 1992–2013 Panel OLS, FMOLS, DOLS.	REC and GDP decrease CO_2. NEC increases CO_2.
[60]	REC, NEC, GDP, CO_2	10 MENA countries 1980–2009 FMOLS, DOLS	REC and NEC increases CO_2. EKC exists.
[61]	REC, GDP, CO_2, Oil prices.	11 South American countries 1980–2010 Panel causality	Two-way causality exists between all indicators.
[62]	CO_2, GDP, REC, NEC, International trade	25 OECD countries 1980–2010 FMOLS DOLS	NEC increases CO_2. International trade and REC reduce CO_2 EKC exists.
[63]	GDP, Non-renewable electricity production, Renewable electricity production, international trade, CO2	Italy 1960–2011 ARDL	Renewable electricity production reduces CO_2, international trade increase CO_2, EKC exists
[64]	NEC, REC, GDP, CO_2.	Thailand 1971–2013 Johnsen cointegration Granger Causality	NEC increases CO_2.
[65]	Nuclear energy consumption, REC, GDP, CO_2	9 developed countries 1990–2013 FMOLS, DOLS	Nuclear energy consumption and REC reduces CO_2. GDP increases CO_2.
[66]	Energy consumption, GDP, CO_2.	China 1970–2015 ARDL, FMOLS, DOLS	Energy consumption increases CO_2, EKC exists.
[67]	Energy consumption, GDP, trade openness, CO_2	Pakistan 1971–2009 ARDL	Energy consumption increases CO_2, trade openness decreases CO_2, EKC exists
[68]	GDP, financial development, international trade, tourism expenditure, CO_2.	Greece countries	GDP, financial development, international trade, and tourism expenditure increases CO_2.

		1970–2014 ARDL	
Cai at al. (2018)	Renewable energy consumption, GDP, CO_2.	G-7 countries 1965–2015 Bootstrap ARDL	Green energy reduces CO_2. Cointegration exists only in 2 countries out of seven.
[70]	CO_2, REC, GDP.	Tunisia 1990–2015 ARDL	REC impedes CO_2.
[78]	Foreign direct investment, GDP, energy usage, CO_2.	Turkey 1974–2010 ARDL	EKC exists. Foreign direct investment and energy usage increases CO_2.
[75]	REC, NEC, GDP, CO_2.	42 Developing countries. 2002–2011 Generalized Method of Moments	REC increase CO_2, NEC decreases CO_2.
[79]	Energy consumption, GDP, CO_2.	India 1971–2014 ARDL	EKC exists. Energy Consumption increases CO_2.
[84]	Energy consumption, Financial development, Trade, urbanization, GDP, CO_2.	Turkey 1960–2013 ARDL	EKC exists. Energy usage, Financial development, trade, urbanization increases CO_2.
[80]	Energy consumption, Foreign Direct Investment, GDP, CO_2.	Vietnam 1976–2009 ARDL	EKC exists. Energy consumption increases CO_2. FDI reduces CO_2.
[81]	Energy Consumption, GDP, CO_2.	55 countries 1970–2008 OLS	EKC exists.
[82]	GDP, Population, Energy consumption, CO_2.	SAARC seconomies 1960–2015 FMOLS, DOLS	No EKC.
[83]	GDP, Trade, Energy usage, CO_2.	India, China 1971–2012	No EKC.
[84]	Trade, GDP, Financial development, CO_2.	Iran 1970–2011 ARDL	No EKC.

income and natural environment for three Asian economies over the period 1980–2013. The outcomes of the examination stated that oil usage is a cause of CO_2 in South Korea whereas in China and Japan one-sided causality from oil usage to economic growth exists [56]. Estimated the link between energy utilization, income and environmental pollution in the case of Malaysia from 1975 to 2015. The outcomes concluded that energy utilization and GDP are progressively affected by carbon emissions.

Though, renewable energy is useful to the safe future of the natural environment. It is also vital for sustainable growth, which is only possible in the case of a modern form of energy [1]. documented that usage of renewable energy has an adverse influence on CO2 emissions in the US. By using the Toda Yamamoto technique in a recent examination [57], reported that green energy significantly reduces environmental pollution in Pakistan. The outcomes of the study advised that the government should increase the use of green energy to reduce GHG emissions. Similar results found by Ref. [58] for BRICS economies during 1992–2016. He also found that the utilization of green energy can improve the quality of the environment. He concluded that the policy advisors of BRICS nations should implement such energy policies that support sustainable growth. Subsequently [59],studied linkage amongst renewable energy and non-green, agriculture and pollution for economies of BRICS. The outcomes of the examination verified green energy performs a negative role in pollutant emissions [60]. Analyzed the connection between environmental pollution, output and usage of electricity produced from sources of green and non-green in the case of ten MENA nations. They concluded that electricity from both green and non-green sources contributes to CO2 emissions. Afterward [61],verified the similar outcomes by using the data of 11 South American economies.

Furthermore, there are innumerable studies that explored no connection amongst green energy and environmental pollution. For Instance [62],explored no causation link amongst the utilization of CO_2 emissions and green energy for 25 OECD countries. By using the data of Italy [63],failed to identify any significant result between electricity usage produce from renewable sources and carbon emissions [64].found a neutral association between environmental deterioration and renewable energy utilization for Thailand over the period from 1971 to 2013 [65]. Analyzed that the usage of green and nuclear energy in nine advanced economies has no causal connection with carbon emanation during 1990–2013 [66]. Inspects the link of CO_2 discharges, financial development, and energy utilization in China. The outcomes of the study demonstrated irregularity in the turning point of the EKC. The last's irregularity may be inferable among others to various variable choices and sources of data incorporated in various examinations. In the case of Pakistan during 1971–2009 [67],examine the connection between economic growth, trade openness, discharge of CO_2 and energy usage. The empirical outcomes verify the EKC hypothesis and confirm long-term association amongst variables, in the case of Pakistan [68].explored that economic growth has a progressive influence on environmental pollution in the case of Greece [69]. Examined links amongst economic growth, green energy, and carbon emissions for G-7 economies. The authors found cointegration only in two countries (Japan and Germany) out of seven countries under specific circumstances. After analyzing the annual data of Tunisia [70],suggested that green energy could be utilized as an option in contrast to regular energies to decrease GHG emissions.

The literature provides evidence that association amongst energy usage and economic growth has been extensively examined [71,72]; Rafindadi and Ozturk, 2016 [73,74]; Inglesi-Lotz, 2015) [75]. Analyzed the panel data of 42 underdeveloped economies for 2002–2011. He explored that non-renewable energy negatively whereas renewable energy positively associated with economic growth. By taking the data of 80 economies [76], reported two-way causality among economic growth, utilization of non-green and green energy. While the [77] documented one-sided causality from non-green energy towards economic growth.

When an economy starts to grow then at the preliminary phase of economic development, quality of environment deteriorates due to water and soil contamination, deforestation, air pollution and numerous other factors. But after some time, with further economic development the quality of the environment starting to improve. This phenomenon amongst economic growth and environment is named as EKC hypothesis. The number of studies proved such a hypothesis in different regions and countries [78]. Claimed the presence of EKC during 1974–2010 in the case of Turkey. They also suggested that FDI and usage of energy have a progressive impact on carbon emanation. For India from 1971 to 2014 [79], analyzed that energy usage is positively associated with environmental pollution, they also verify the occurrence of the EKC hypothesis in India. In a study [80], proved the existence of the EKC hypothesis in the case of Vietnam from 1976 to 2009. They also found that energy usage is negatively attached to quality of the environment. By using the panel OLS technique [81],explored the EKC hypothesis in 55 countries. Conversely, numerous studies suggest that the absence of the EKC hypothesis in different countries. Such as, for SAARC countries during 1960–2015 [82], have used FMOLS and DOLS approaches and claimed that there is no EKC hypothesis exists in these countries. Similarly [83], examined the N-shaped association between output and carbon discharge for India and China during 1971–2012. Moreover [84], explored linkage among financial

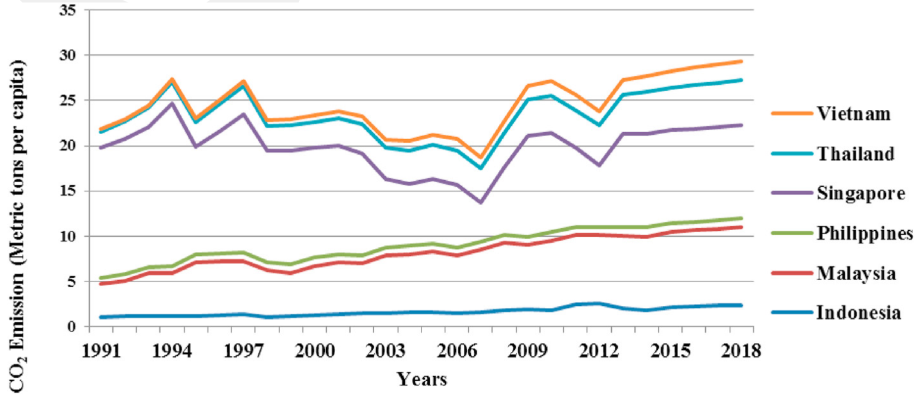

Fig. 1. CO_2 emissions.

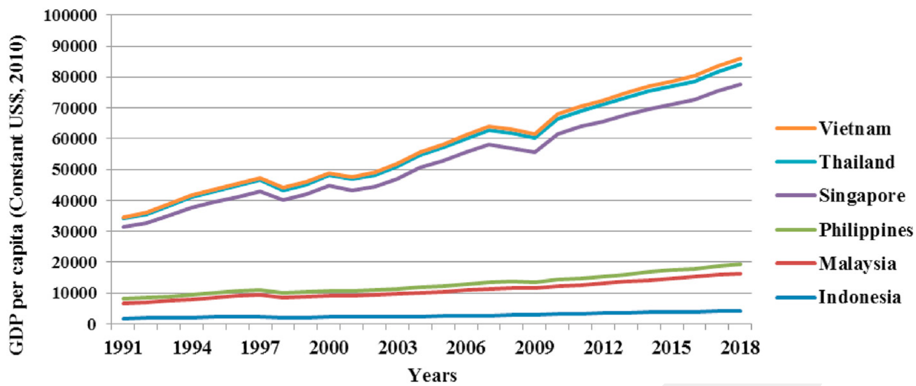

Fig. 2. Gross domestic product.

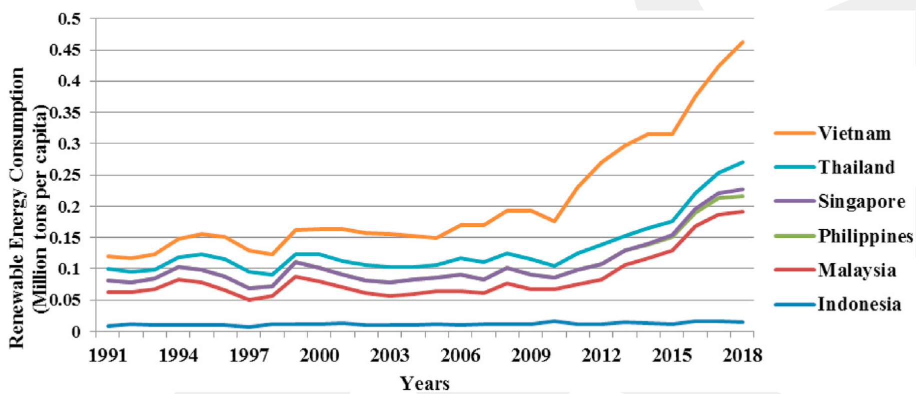

Fig. 3. Renewable energy consumption.

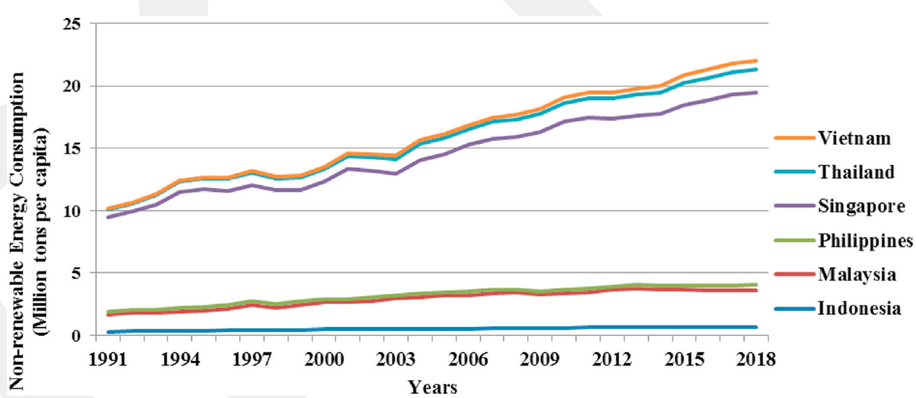

Fig. 4. Non-renewable energy consumption.

development, trade, quality of environment and output, but they unable to found the EKC hypothesis for Iran during 1970–2011.

3. Data and methodology

Inspired by recent studies [85,86]; and [87]; the model is as follow:

$CO_{2it} = f\,(GDP_{it}, GDP^2{}_{it}, NEC_{it}, REC_{it})$

The variables CO_2, GDP and GDP^2 represent carbon dioxide emissions, gross domestic product, and the square of gross domestic product, respectively. Moreover, CO_2 emission is measured in million metric tons while GDP and GDP^2 are in constant US dollars. The data of these variables are acquired from World Development Indicators [24]. The proxy used for renewable energy consumption (REC) is the consumption of hydroelectricity, nuclear, wind and solar whereas the consumption of natural gas, coal and oil are used as a proxy for non-renewable energy consumption (NEC). The data on NEC and REC (measured in million tons per capita) are obtained from the statistical database [88]. The current study uses the data for ASEAN economies over the period from 1990 to 2018. Each variable is taken as real per capita.

Figs. 1 and 2 describing the trend of CO_2 emission and GDP per capita of ASEAN economies. In Fig. 1, it is seen that the CO_2 emission increases with the same pattern in Vietnam. Thailand and

Table-2
Results of descriptive-statistics.

Variables	CO_2	GDP	NEC	REC
Mean	4.085	9696.483	2.689	0.034
Minimum	0.303	449.537	0.074	0.000
Maximum	18.041	58247.870	15.482	0.192
Std. Dev.	3.895	14434.490	4.088	0.039
Observations	174	174	174	174

Source: Author's Calculation

Singapore but Vietnam emit a huge amount of carbon emission as compared to all other ASEAN countries. Fig. 2 shows that Vietnam has the highest GDP per capita whereas Indonesia has the lowest GDP per capita as compared to other ASEAN economies. But all ASEAN countries have a positive increasing trend of GDP per capita.

Figs. 3 and 4 presenting the trend of renewable and non-renewable energy consumption. It is seen that the in both the figures, all ASEAN economies have an increasing trend in renewable and non-renewable energy consumption but Indonesia has a very slow rate of energy consumption in both cases. However, Vietnam is the highest energy-consuming country in both types of energies.

3.1. Panel estimation techniques

Fully Modified Ordinary Least Square (FM-OLS), Dynamic-OLS and Fixed-Effect-OLS methods have been employed for comparative purposes [89]. FM-OLS model comprises individual intercepts that permit for heterogeneous serial-correlation, across distinct members of the panel. The D-OLS was introduced by Ref. [90] to make an unbiased comparison between FMOLS and OLS estimates in restricted samples. The D-OLS method is based on the Monte-Carlo simulation to control endogeneity through the augmented of lag differences. The FE-OLS estimator is amplified as per [91] standard errors (SE). These are useful to robust each cross-sectional dependence and auto-correlation up to the specific lag length. Due to curbs in the above mentioned panel techniques, quantile-regression (QR) estimator was used to assess the heterogeneous and distributional effects across each quantile [92]. This technique was introduced by Refs. [93]. Normally, this methodology is employed to evaluate the conditional-median of various responded quantiles. Therefore, PQR is more vigorous to the prevalence of outliers in the estimations, and are also useful to explain the weak association of conditional means of two variables [94]. However [51], introduced an augmented PQR (known as Methods of Moments-Quantile-Regression (MMQR) technique considering fixed-effects. This is useful to detect the covariance effects under conditional heterogeneity as a determinant of CO_2 emissions. This tool also tolerates the individual-effect to affect the whole distribution instead of fluctuating means amongst the others [52,95]. This technique is also advantageous in that sense where the model possesses endogenous independent variables and entrenches with individual-effect. The following model is used to estimate conditional quantiles $Q_y\,(\delta|\,\ddot{X}'_{it})$:

$$\dot{Y}_{it} = \dot{\alpha}_i + \ddot{X}'_{it}\,\Phi + (\text{ƛ}_i + \text{Ƶ}'_{it}\,\Psi)\,\ddot{U}_{it} \tag{1}$$

where, the probability, $\text{þ}\,\{\text{ƛ}_i + \text{Ƶ}'_{it}\,\Psi > 0\} = 1$, and the parameters $(\dot{\alpha}, \Phi, \text{ƛ}, \Psi)'$ are to be assessed. $(\dot{\alpha}_i, \text{ƛ}_i)$, $i = 1,2,3$ up to n, describes the discrete i fixed-effects whereas Ƶ represents k-vector of recognized modules of $\ddot{X}$, and are distinguishable alterations with j as follow:

$$\text{Ƶ}_j = \text{Ƶ}_j\,(\ddot{X}),\ j = 1,2,\ldots,k \tag{2}$$

$\ddot{X}'_{it}$ and $\ddot{U}_{it}$ are identically dispersed beyond individuals i and time-period (t). According to Ref. [51]standardized momentum conditions $\ddot{U}_{it}$ are orthogonal to $\ddot{X}'_{it}$. Thus, Equation (1) suggests the following;

$$Q_y\,(\delta|\,\ddot{X}'_{it}) = (\dot{\alpha}_i + \text{ƛ}_i\,q(\delta)) + \ddot{X}'_{it}\,\Phi + \text{Ƶ}'_{it}\,\Psi\,q\,(\delta) \tag{3}$$

From the above equation, $\ddot{X}'_{it}$ is a vector of descriptive variable and expressed as the natural logarithm of each observed variable in per capita i.e., nonrenewable energy consumption, renewable electricity consumption, GDP and squared GDP as LNEC, LREC, GDP, LGDP, and $LGDP^2$ respectively. $Q_y\,(\delta|\,\ddot{X}'_{it})$ represents the quantile-distribution of $\dot{Y}_{it}$; LCO_2 which is restrictive on the position of explanatory variable $\ddot{X}'_{it}$. $\dot{\alpha}_i\,(\delta) \equiv \dot{\alpha}_i + \text{ƛ}_i\,q\,(\delta)$; the scalar to reveal quantile-δ' fixed-effects for across individual i. q (δ) designates sample quantile. This is assessed by resolving optimization as follow;

Table-3
Results of Stationary Analysis: IPS-unit root test.

Variable	I(0)		I(1)	
	C	C&T	C	C&T
LCO2	−0.326	−0.358	−6.857***	−7.112***
LGDP	−1.084	−1.189	−9.373***	−9.722***
LNEC	0.261	0.286	−6.849***	−7.104***
LREC	0.884	0.970	−9.254***	−9.598***

***, ** and * represent 1%, 5% and 10% significant level respectively.
Source: Author's Calculation

Table-4
CD and CIPS unit root test.

Variables	CD Test	p-value	CIPS test	
			Level	1st difference
LCO2	13.547	0.000	−0.255	−5.321***
LGDP	17.472	0.000	−0.064	−17.451***
LNEC	22.647	0.000	−0.368	−12.269***
LREC	27.511	0.000	−0.180	−16.711***

***, ** and * describe significant level at 1%, 5% and 10% respectively.
Source: Author's Calculation

Table-5
Panel cointegration in ASEAN countries.

a) Pedroni Cointegration	Stats.	Prob.
$CO2 = f(GDP + GDP^2 + NEC + REC)$- Panel		
ν-statistics	8.481	0.000
ρ-statistics	0.584	0.683
PP-statistics	−7.482	0.000
ADF-statistics	−7.028	0.000
Alternative hypothesis: individual AR coefficient- Group		
ρ −statistic	1.028	0.746
PP-statistic	−7.421	0.000
ADF-statistic	−9.261	0.000

b) [99] bootstrap panel cointegration

Statistics	**Value**	**Z value**	**p-value**	**Robust p-value**
Gt	−20.035	−17.291	0.000	0.000
Ga	−87.897	−71.860	0.000	0.000
Pt	−92.812	−60.197	0.000	0.000
Pa	−98.766	−87.765	0.000	0.000

H_0: no co-integration [101].
H_0: No cointegration by Ref. [99] panel cointegration procedure. The number of one-sided p-value based on normal distribution; replication is 500.
Source: Author's Calculation.

Table-6
Results of panel estimation for ASEAN countries.

Variables	FMOLS			DOLS			FE-OLS		
	Coeff.	t-stats	Prob.	Coeff.	t-stats	Prob.	Coeff.	t-stats	Prob.
LGDP	0.414	5.639	0.000	0.370	5.036	0.000	0.421	5.736	0.000
$LGDP^2$	−0.217	−3.968	0.000	−0.194	−3.543	0.000	−0.221	−4.036	0.000
LNEC	0.298	4.049	0.000	0.266	3.616	0.000	0.303	4.118	0.000
LREC	−0.174	−4.217	0.000	−0.155	−3.766	0.000	−0.177	−4.289	0.000

***, ** and * represent 1%, 5% and 10% level of significant respectively.
Source: Author's Calculation

$$\boldsymbol{Min_q} = \sum_i \sum \boldsymbol{t}\eta_\delta(\ddot{\boldsymbol{R}}\boldsymbol{it} - (ƛ_i + \mathcal{Z}'_{it}\gamma)\boldsymbol{q}) \quad (4)$$

Where $\dot{\eta}_\delta$ $(\ddot{R})= (\delta - 1)\ \ddot{R}\hat{I}\ \{\ddot{R}\leq 0\} + T\ddot{R}\hat{I}\ \{\ddot{R}>0\}$ represents the checked function.

4. Discussion section

In this section, we explain the results, initially, Table 2 shows the statistical properties of all the selected factors (i.e., maximum, minimum, mean, and standard deviation). The value of the mean of CO_2, GDP, NEC and REC are 4.08, 9696.48, 3.68 and 0.034 respectively. All the factors of this study show an impressive level of standard deviation as 3.89, 144434.49, 4.08 and 0.039 for CO_2, GDP, NEC and REC respectively. The descriptive characteristics of the factors allow us to move towards the unit root test.

We employ some of the standard preliminary tests to check the time-series characteristics of variables before approximating unknown parameters. So, we apply [96]; an IPS-unit root test that permits individuals to have their distinct autoregressive parameter. In light of the unpredictability of real economic phenomena, the economic variables are most of the time non-stationary. If regression estimation based on non-stationary data then it will produce spurious results. Accordingly, before assessing the regression model, we tried whether the factors utilized in the model are steady. From Table 3, it's clear that each variable is stationary at first difference instead of the level at a 1% level of significance.

[97] suggested CD-test estimate the dependency of cross-sections within the panel. The CD can disturb the exact parametric values of estimations and may obtain as a consequence of ignored factors that can decrease the efficiency of panel data if neglected [98]. Table 4 describes the outcomes of CD and CIPS tests of a unit root. The outcomes of the CD test reject the null hypothesis. And also verify cross-sectional dependence of variables. Whilst, outcomes of the CIPS test explore that all factors are stationary at first difference. These outcomes verify the occurrence of the cointegration amongst factors.

The panel cointegration technique of [89] and the bootstrapped panel test of [99] are employed to confirm the absence of long-run spurious association amongst variables [89]. suggests a widespread framework for panel cointegration by following Engle and Granger 2-steps process. For the purpose of controlling heterogeneity [97] deterministic trends approach is adopted. After that step, Pedroni determines seven various test-statistics to estimate Pooled (within-dimensions) tests for common processes and grouped (between-dimensions) tests for individual processes. Unlike, Pedroni test [99], technique eases the assumption of common-factor restrictions on tests. Four additional tests (explaining H_0: no co-integration) are suggested by Westerlund. It is necessary to maintain residual's power-based cointegration in structural dynamics [100]. Eliminating this constraint, short and long-run modification processes need not to be equal. By using Westerlund's boot-strapping technique, we can moderate the misleading effects of CD procedure, and hence yield robust critical values.

Table 5 demonstrates the findings of [101] cointegration test that verify association amongst the model's parameters in the long-run. The result clarifies that three tests of within dimension (Panel ADF, PP and *v*-statistics), and two, group statistics of between-dimension (ADF and PP-statistics), support this dismissal. In this manner, five out of seven tests conclude that there exists cointegration in the long run. Moreover, it also represents the findings of bootstrap second-generation [99]test of panel-cointegration. The outcome affirms that under-studied factors are cointegration in the long run after the rejection of the null hypothesis of no cointegration. Overall, a long-run relation is confirmed for non-renewable and renewable energy consumption, income, the square of income and carbon emissions in Model in section 3.

The results of different panel estimation approaches (i.e., FM-OLS, D-OLS, and FE-OLS) are designated in Table 6. These methods provide almost the same coefficient values. The outcome shows that GDP positively and significantly influences CO_2 emissions. 1% growth in GDP raises CO_2 emissions by 0.41%, 0.37% and 0.42% in the case of FM-OLS, D-OLS and FE-OLS respectively. The negative and significant sign of coefficients of GDP square in all three methods confirms the presence of EKC in ASEAN countries. This finding coincides with [102] for BRICS economies [103],for 20 European countries [104], for Russia [105],for Turkey [106],for BRICS economies, who report that at initial stages of development

Table-7
Results of panel quantile estimations.

Method of Moments Quantile regression (MMQR)										
Variables	Location		Quantiles							
		Scale	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
LGDP	0.373***	0.218**	0.332***	0.361***	0.372***	0.389***	0.423***	0.445***	0.463***	0.504***	0.531***
$LGDP^2$	−0.150*	−0.114*	−0.086	−0.111	−0.199*	−0.242**	−0.318***	−0.381***	−0.399***	−0.418***	−0.457***
LNEC	0.247**	0.115*	0.257***	0.275***	0.301***	0.336***	0.389***	0.401***	0.428***	0.474***	0.501***
LREC	−0.476***	−0.292***	−0.387***	−0.343***	−0.318***	−0.235**	−0.232**	−0.162	−0.118	−0.094	−0.071

***, ** and * represent at 1%, 5% and 10% level of significant respectively.
Source: Author's Calculation

the environmental pollution increases as economic growth increases but after threshold point, environmental pollution starts to decline with the upsurge in economic growth. Energy usage is directly correlated with CO2 emissions in all these approaches. As a 1% growth in NEC, upsurges CO2 emissions by 0.29% in the case of FMOLS, 0.26% in the case of DOLS and 0.30% in the case of FE-OLS. This outcome is in line with [107] in the case of Pakistan [108],in the case of 23 top renewable energy countries [109], in case of Pakistan, who claim that non-renewable energy consumption upsurges environmental pollution. The empirical outcomes explain an inverse association between REC and CO_2 emissions. As 0.17%, 0.15% and 0.17% reduction are reported in CO_2 emissions if REC increases by 1% in the case of FM-OLS, D-OLS and FE-OLS respectively. This result corroborated by Ref. [110] for 66 developing countries [102], for BRICS economies [111], for BRICS economies [112], for China and [86] for European Union, who indicate that green energy lessens carbon emissions.

The outcomes of the Method of Movement Quantile regression (MMQR) are shown in Table 7. First of all, the favorable influence of GDP on CO_2 can be verified. For all quantiles, the table clearly describes that upsurge in CO_2 because of GDP is considerable and rises from 0.332 to 0.531 as quantile increases. In the initial stages of economic growth, the primary production rising at a slow rate and getting quicker in the late stages of economic growth. Therefore, upsurge in these economic activities leads towards positive influence on carbon emissions. Conversely, the square of income is negatively affecting carbon emissions for all quantiles; however, the impact is statistically insignificant at lower quantiles. Similarly, the EKC hypothesis can be validated for all quantiles even though the turning point is changing across 10th to 90th quantiles. The validity of inverted U-shaped EKC in ASEAN economies specifies that these economies have touched a certain level of economic growth. And now moving towards environmental-friendly economic growth (Grossman and Krueger, 1995). Moreover, rising economic growth leads towards improvement in technology, promotes sources of alternate energy and for production sources of renewable energy sources for production and expands the tertiary and services sector which helped to contain carbon emissions [113].

Moreover, the outcomes of non-renewable energy consumption (NEC) are significantly and positively correlated with environmental degradation in all the quantiles. Similarly, the size of the effect of NREC is getting larger for higher quantiles. On the contrary, renewable energy consumption (REC) negatively influences the CO_2 emissions in all quantiles but this association is statistically insignificant from quantile 60th to 90th. In opposite to previous cases, the size of the effect of REC is getting smaller through higher quantiles. The upsurge of renewable energy consumption uses in the energy mix verifies that energy consumption from non-renewable energy sources are diminishing and holds true for these economies. The negative results of REC may yield a simple outcome; such as technological innovation particularly related to the production of renewable energy is vital to improve the quality of production as well as deteriorating costs of production. Furthermore, it also fights indirectly against increased environmental pollution.

5. Conclusion & policy implications

Changes in global warming and the number of carbon emissions have kept environmental issues attractive and hot topics to be discussed in the literature. Although countless studies have considered the determinants of the pollution, a typical empirical study either uses aggregate energy consumption or conventional panel estimators. The fundamental objective of this study is to know the role of renewable and non-renewable energy consumption in income-environment nexus for ASEAN economies (Thailand, Singapore, Indonesia, Malaysia, Philippine, Vietnam). Thus, this study for the first time aims to explore the influence of economic growth (GDP), renewable energy consumption (REC), and non-renewable energy consumption (NEC) on CO_2 emissions in the analyzed countries by using novel Method of Moments Quantile Regression (MMQR) over the period from 1990 to 2018. This study applies several preliminary analysis and panel sensitive tests to know about the properties of the dataset and employs several panel estimation techniques alongside quantile regression for robustness check. The outcomes and policy suggestions are listed as follows:

i. The IPS and CIPS unit root tests show that the dataset of each variable becomes stationary even though they are non-stationary at levels.
ii. The Pedroni and the Westerlund bootstrap panel cointegration tests confirm the existence of a long run connection among income, the square of income, renewable and non-renewable energy consumption and carbon emissions.
iii The FMOLS, the DOLS, the FE-OLS report that increases in REC decrease the pollution while increases in NREC stimulate carbon emissions, and the EKC hypothesis is valid. The empirical results report that 1% increase in REC lead to diminishing the carbon emanation by 1.74%, 1.55% and 1.77% in case of FMOLS, DOLS and FE-OLS respectively, While 1% growth in NEC, upsurges CO2 emissions by 0.29% in case of FMOLS, 0.26% in case of DOLS and 0.30% in case of FE-OLS. Moreover, a 1% growth in GDP raises CO_2 emissions by 0.41%, 0.37% and 0.42% in the case of FM-OLS, DOLS and FE-OLS respectively. The negative and significant sign of coefficients of GDP square in all three methods confirms the presence of EKC in ASEAN countries.
iv The result of MMQR demonstrates that income has a positive influence on carbon emissions in all quantiles (10th to 90th). On the other hand, the square of GDP has a negative impact on the pollution across all quantiles while its magnitude increases at higher quantiles (60th to 90th). Thus, outcomes verify the occurrence of the EKC hypothesis in all quantiles.

Moreover, results from MMQR indicate that NEC positively affects environmental pollution in all the quantiles from 10th to 90th, the value of the coefficient lies between 0.27 and 0.50; on the contrary, REC has an inverse relation with CO_2 emissions in all quantiles from 10th to 90th, but it is statistically insignificant from 60th to 90th quantile. The contribution of non-renewable energy consumption to environmental pollution increases with quantile levels; similarly, but conversely, the adverse effects of renewable energy consumption to environmental degradation increases with the levels of the quantile.

Based on the above conclusion, the current study recommends some policy recommendations for the selected sample. ASEAN region should turn to renewable energy to meet increasing energy demand for the sake of less pollution and cleaner environment. Although this is accepted as a general perception, the share of renewable energy consumption in emissions reduction almost doubles at the higher quantile levels compared to the lower quantile levels. This suggests that increases in renewable energy consumption at high levels of carbon emissions result in a reasonable impact on environmental degradation. ASEAN nations should implement regulations and measures to increase public awareness of green energy and environmental concerns. Even though the stimulation of renewable sources in the energy mix is a clear policy implication, dependence on fossil (non-renewable) energy sources is a barrier in terms of applicability. Therefore, the main critical point is to eliminate these obstacles. This is possible with environmentally friendly technologic investments in the long term. Especially in the industrial sector, keeping this priority at every stage of production should be created both consciously and made attractive with some incentives such as tax exemption and subsidies. Finally, this study can be further expanded by adding other variables like tourism, globalization and financial development which also affect the level of energy utilization and environmental degradation in the ASEAN region. Moreover, this study can be done with other regions like BRICS, Group of Seven, or Next 11 countries and by introducing new and advanced econometric methods.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] J. Baek, Do nuclear and renewable energy improve the environment? Empirical evidence from the United States, Ecol. Indicat. 66 (2016) 352–356.
[2] M.S.K. Sarkar, S. Sadeka, M.M.H. Sikdar, B. Zaman, Energy consumption and CO2 emissions in Bangladesh: trends and policy implications, Asia Pacific Journal of Energy and Environment 2 (3) (2015) 175–182.
[3] G.I. Tunç, S. Türüt-Aşık, E. Akbostancı, A decomposition analysis of CO2 emissions from energy use: Turkish case, Energy Pol. 37 (11) (2009) 4689–4699.
[4] S. Paul, R.N. Bhattacharya, CO 2 emissions from energy use in India: a decomposition analysis, Energy Pol. 32 (5) (2004) 585–593.
[5] A. Sharif, S.A. Raza, I. Ozturk, S. Afshan, The dynamic relationship of renewable and nonrenewable energy consumption with carbon emission: a global study with the application of heterogeneous panel estimations, Renew. Energy 133 (2019) 685–691.
[6] A. Sharif, O. Baris-Tuzemen, G. Uzuner, I. Ozturk, A. Sinha, Revisiting the role of renewable and non-renewable energy consumption on Turkey's ecological footprint: evidence from Quantile ARDL approach, Sustainable Cities and Society 57 (2020) 102138.
[7] M. Shahbaz, S. Khan, A. Ali, M. Bhattacharya, The impact of globalization on CO2 emissions in China, Singapore Econ. Rev. 62 (4) (2017) 929–957.
[8] S. Asumadu-Sarkodie, P.A. Owusu, The causal nexus between carbon dioxide emissionss and agricultural ecosystem—an econometric approach, Environ. Sci. Pollut. Control Ser. 24 (2) (2017) 1608–1618.
[9] P.K. Adom, W. Bekoe, F. Amuakwa-Mensah, J.T. Mensah, E. Botchway, Carbon dioxide emissions, economic growth, industrial structure, and technical efficiency: empirical evidence from Ghana, Senegal, and Morocco on the causal dynamics, Energy 47 (1) (2012) 314–325.
[10] C. Zhang, Y. Lin, Panel estimation for urbanization, energy consumption and CO2 emissions: a regional analysis in China, Energy Pol. 49 (2012) 488–498.
[11] C. McAusland, Globalisation's Direct and Indirect Effects on the Environment, 2010.
[12] C.C. Funk, M.E. Brown, Declining global per capita agricultural production and warming oceans threaten food security, Food Security 1 (3) (2009) 271–289.
[13] A. Sharif, R. Jammazi, S.A. Raza, S.J.H. Shahzad, Electricity and growth nexus dynamics in Singapore: fresh insights based on wavelet approach, Energy Pol. 110 (2017) 686–692.
[14] P. Poumanyvong, S. Kaneko, S. Dhakal, Impacts of urbanization on national transport and road energy use: evidence from low, middle and high income countries, Energy Pol. 46 (2012) 268–277.
[15] B.S. Warr, R.U. Ayres, Evidence of causality between the quantity and quality of energy consumption and economic growth, Energy 35 (4) (2010) 1688–1693.
[16] S. Karekezi, S. McDade, B. Boardman, J. Kimani, Energy, poverty, and development, in: Global Energy Assessment–Toward a Sustainable Future, 2012, pp. 151–190.
[17] O. Ellabban, H. Abu-Rub, F. Blaabjerg, Renewable energy resources: current status, future prospects and their enabling technology, Renew. Sustain. Energy Rev. 39 (2014) 748–764.
[18] A. Aslan, N. Apergis, S. Yildirim, Causality between energy consumption and GDP in the US: evidence from wavelet analysis, Front. Energy 8 (1) (2014) 1–8.
[19] IEA, International Energy Agency, 2019. World Energy Outlook.
[20] P. Sadorsky, Renewable energy consumption and income in emerging economies, Energy Pol. 37 (10) (2009) 4021–4028.
[21] F. Bilgili, I. Ozturk, Biomass energy and economic growth nexus in G7 countries: evidence from dynamic panel data, Renew. Sustain. Energy Rev. 49 (2015) 132–138.
[22] X. Wei, J. Liu, T. Wei, L. Wang, High proportion renewable energy supply and demand structure model in 2050, Journal of Clean Energy Technologies 5 (2) (2017) 163–169.
[23] F. Bilgili, E. Kocak, U. Bulut, The dynamic impact of renewable energy consumption on CO2 emissionss: a revisited Environmental Kuznets Curve approach, Renew. Sustain. Energy Rev. 54 (2016) 838–845.
[24] World Bank, World Development Indicators, 2019. Online Database.
[25] I. Hanif, P. Gago-de-Santos, The importance of population control and macroeconomic stability to reducing environmental degradation: an empirical test of the environmental Kuznets curve for developing countries, Environmental Development 23 (2017) 1–9.
[26] R.A. Salim, K. Hassan, S. Shafiei, Renewable and non-renewable energy consumption and economic activities: further evidence from OECD countries, Energy Econ. 44 (2014) 350–360.
[27] S.R. Paramati, A. Sinha, E. Dogan, The significance of renewable energy use for economic output and environmental protection: evidence from the Next 11 developing economies, Environ. Sci. Pollut. Control Ser. 24 (15) (2017) 13546–13560.
[28] S.R. Paramati, N. Apergis, M. Ummalla, 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. Control Ser. 25 (2) (2018) 1375–1387.
[29] T.A. Persson, C. Azar, K. Lindgren, Allocation of CO2 emissions permits—economic incentives for emissions reductions in developing countries, Energy Pol. 34 (14) (2006) 1889–1899.
[30] B. Friedl, M. Getzner, Determinants of CO2 emissionss in a small open economy, Ecol. Econ. 45 (1) (2003) 133–148.
[31] I. Hanif, Impact of economic growth, nonrenewable and renewable energy consumption, and urbanization on carbon emissionss in Sub-Saharan Africa, Environ. Sci. Pollut. Control Ser. 25 (15) (2018) 15057–15067.
[32] S.R. Mudakkar, K. Zaman, M.M. Khan, M. Ahmad, Energy for economic growth, industrialization, environment and natural resources: living with just enough, Renew. Sustain. Energy Rev. 25 (2013) 580–595.
[33] International Monetary Fund, International Financial Statistics Indicators. CD-Rom, 2019. Washington, D.C.
[34] V. Andreoni, S. Galmarini, Drivers in CO2 emissionss variation: a decomposition analysis for 33 world countries, Energy 103 (2016) 27–37.
[35] R. Batool, A. Sharif, T. Islam, K. Zaman, A.M. Shoukry, M.A. Sharkawy, S.S. Hishan, Green is clean: the role of ICT in resource management, Environ. Sci. Pollut. Control Ser. 26 (24) (2019) 25341–25358.
[36] S. Mishra, A. Sinha, A. Sharif, N.M. Suki, Dynamic linkages between tourism, transportation, growth and carbon emission in the USA: evidence from partial and multiple wavelet coherence, Curr. Issues Tourism (2019) 1–23.
[37] M. Balcilar, F.V. Bekun, G. Uzuner, Revisiting the economic growth and electricity consumption nexus in Pakistan, Environ. Sci. Pollut. Control Ser. 26 (12) (2019) 12158–12170.
[38] J. Wang, J. Zhao, H. Li, The electricity consumption and economic growth nexus in China: a bootstrap seemingly unrelated regression estimator approach, Comput. Econ. 52 (4) (2018) 1195–1211.
[39] B. Ameyaw, A. Oppong, L.A. Abruquah, E. Ashalley, Causality nexus of electricity consumption and economic growth: an empirical evidence from Ghana, Open J. Bus. Manag. 5 (2016) 1, 01.
[40] K. Sohag, R.A. Begum, S.M.S. Abdullah, M. Jaafar, Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia, Energy 90 (2015) 1497–1507.
[41] A. Aslan, Causality between electricity consumption and economic growth in Turkey: an ARDL bounds testing approach, Energy Sources B Energy Econ. Plann. 9 (1) (2014) 25–31.
[42] H. Hamdi, R. Sbia, M. Shahbaz, The nexus between electricity consumption and economic growth in Bahrain, Econ. Modell. 38 (2014) 227–237.
[43] H.S. Yu, Explaining the emergence of new East Asian regionalism: beyond power and interest-based approaches, Asian Perspect. 27 (1) (2003) 261–288.
[44] J. Chontanawat, Relationship between energy consumption, CO2 emissions and economic growth in ASEAN: cointegration and causality model, Energy Rep. 6 (2020) 660–665.
[45] Y. Wang, L. Chen, J. Kubota, The relationship between urbanization, energy use and carbon emissionss: evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries, J. Clean. Prod. 112 (2016) 1368–1374.
[46] H. Heidari, S.T. Katircioğlu, L. Saeidpour, Economic growth, CO2 emissionss, and energy consumption in the five ASEAN countries, Int. J. Electr. Power Energy Syst. 64 (2015) 785–791.
[47] B. Saboori, J. Sulaiman, CO2 emissionss, energy consumption and economic growth in Association of Southeast Asian Nations (ASEAN) countries: a cointegration approach, Energy 55 (2013) 813–822.
[48] Alexander Chudik, M. Hashem Pesaran, Large Panel Data Models with Cross-Sectional Dependence: A Survey (2013), CAFE Research Paper No. 13.15. Available at, https://doi.org/10.2139/ssrn.2316333.
[49] J. Breitung, M.H. Pesaran, Unit Roots and Cointegration in Panels, 2005.
[50] D.W. Andrews, Cross-section regression with common shocks, Econometrica 73 (5) (2005) 1551–1585.
[51] J.A. Machado, J.S. Silva, Quantiles via moments, J. Econom. 213 (1) (2019) 145–173.
[52] R. Koenker, Quantile regression for longitudinal data, J. Multivariate Anal. 91 (1) (2004) 74–89.
[53] A.N. Ajmi, S. Hammoudeh, D.K. Nguyen, J.R. Sato, On the relationships

between CO2 emissionss, energy consumption and income: the importance of time variation, Energy Econ. 49 (2015) 629–638.
[54] S. Asumadu-Sarkodie, P.A. Owusu, A multivariate analysis of carbon dioxide emissionss, electricity consumption, economic growth, financial development, industrialization, and urbanization in Senegal, Energy Sources B Energy Econ. Plann. 12 (1) (2017a) 77–84.
[55] B. Saboori, E. Rasoulinezhad, J. Sung, The nexus of oil consumption, CO 2 emissionss and economic growth in China, Japan and South Korea, Environ. Sci. Pollut. Control Ser. 24 (8) (2017) 7436–7455.
[56] C. Sulaiman, A.S. Abdul-Rahim, The relationship between CO 2 emissions, energy consumption and economic growth in Malaysia: a three-way linkage approach, Environ. Sci. Pollut. Control Ser. 24 (32) (2017) 25204–25220.
[57] M.T.I. Khan, Q. Ali, M. Ashfaq, The nexus between greenhouse gas emissions, electricity production, renewable energy and agriculture in Pakistan, Renew. Energy 118 (2018) 437–451.
[58] J.A. Bhat, Renewable and non-renewable energy consumption—impact on economic growth and CO 2 emissionss in five emerging market economies, Environ. Sci. Pollut. Control Ser. 25 (35) (2018) 35515–35530.
[59] X. Liu, S. Zhang, J. Bae, The nexus of renewable energy-agriculture-environment in BRICS, Appl. Energy 204 (2017) 489–496.
[60] S. Farhani, M. Shahbaz, What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO2 emissionss in MENA region? Renew. Sustain. Energy Rev. 40 (2014) 80–90.
[61] N. Apergis, J.E. Payne, Renewable energy, output, carbon dioxide emissionss, and oil prices: evidence from South America, Energy Sources B Energy Econ. Plann. 10 (3) (2015) 281–287.
[62] M.B. Jebli, S.B. Youssef, I. Ozturk, Testing environmental Kuznets curve hypothesis: the role of renewable and non-renewable energy consumption and trade in OECD countries, Ecol. Indicat. 60 (2016) 824–831.
[63] J.P.C. Bento, V. Moutinho, CO2 emissionss, non-renewable and renewable electricity production, economic growth, and international trade in Italy, Renew. Sustain. Energy Rev. 55 (2016) 142–155.
[64] P. Boontome, A. Therdyothin, J. Chontanawat, Investigating the causal relationship between non-renewable and renewable energy consumption, CO2 emissionss and economic growth in Thailand, Energy Procedia 138 (2017) 925–930.
[65] K. Saidi, M.B. Mbarek, Nuclear energy, renewable energy, CO2 emissionss, and economic growth for nine developed countries: evidence from panel Granger causality tests, Prog. Nucl. Energy 88 (2016) 364–374.
[66] J.S. Riti, D. Song, Y. Shu, M. Kamah, Decoupling CO2 emissions and economic growth in China: is there consistency in estimation results in analyzing environmental Kuznets curve? J. Clean. Prod. 166 (2017) 1448–1461.
[67] M. Shahbaz, H.H. Lean, M.S. Shabbir, Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality, Renew. Sustain. Energy Rev. 16 (5) (2012) 2947–2953.
[68] C. Işik, E. Kasımatı, S. Ongan, Analyzing the causalities between economic growth, financial development, international trade, tourism expenditure and/on the CO2 emissionss in Greece, Energy Sources B Energy Econ. Plann. 12 (7) (2017) 665–673.
[69] Y. Cai, C.Y. Sam, T. Chang, Nexus between clean energy consumption, economic growth and CO2 emissionss, J. Clean. Prod. 182 (2018) 1001–1011.
[70] A. Cherni, S.E. Jouini, An ARDL approach to the CO2 emissionss, renewable energy and economic growth nexus: Tunisian evidence, Int. J. Hydrogen Energy 42 (48) (2017) 29056–29066.
[71] E. Koçak, A. Şarkgüneşi, The renewable energy and economic growth nexus in Black Sea and Balkan countries, Energy Pol. 100 (2017) 51–57.
[72] M. Kahia, M.S.B. Aïssa, L. Charfeddine, Impact of renewable and non-renewable energy consumption on economic growth: new evidence from the MENA Net Oil Exporting Countries (NOECs), Energy 116 (2016) 102–115.
[73] A. Alper, O. Oguz, The role of renewable energy consumption in economic growth: evidence from asymmetric causality, Renew. Sustain. Energy Rev. 60 (2016) 953–959.
[74] E. Dogan, Analyzing the linkage between renewable and non-renewable energy consumption and economic growth by considering structural break in time-series data, Renew. Energy 99 (2016) 1126–1136.
[75] K. Ito, CO2 emissionss, renewable and non-renewable energy consumption, and economic growth: evidence from panel data for developing countries, International Economics 151 (2017) 1–6.
[76] N. Apergis, J.E. Payne, Renewable and non-renewable energy consumption-growth nexus: evidence from a panel error correction model, Energy Econ. 34 (3) (2012) 733–738.
[77] H.T. Pao, H.C. Fu, Renewable energy, non-renewable energy and economic growth in Brazil, Renew. Sustain. Energy Rev. 25 (2013) 381–392.
[78] F. Seker, H.M. Ertugrul, M. Cetin, The impact of foreign direct investment on environmental quality: a bounds testing and causality analysis for Turkey, Renew. Sustain. Energy Rev. 52 (2015) 347–356.
[79] A. Ahmad, Y. Zhao, M. Shahbaz, S. Bano, Z. Zhang, S. Wang, Y. Liu, Carbon emissions, energy consumption and economic growth: an aggregate and disaggregate analysis of the Indian economy, Energy Pol. 96 (2016) 131–143.
[80] C.F. Tang, B.W. Tan, The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam, Energy 79 (2015) 447–454.
[81] T. Jobert, F. Karanfil, A. Tykhonenko, Environmental Kuznets Curve for carbon dioxide emissions: lack of robustness to heterogeneity?, 2012.
[82] M.U. Rehman, M. Rashid, Energy consumption to environmental degradation, the growth appetite in SAARC nations, Renew. Energy 111 (2017) 284–294.
[83] D. Pal, S.K. Mitra, The environmental Kuznets curve for carbon dioxide in India and China: growth and pollution at crossroad, J. Pol. Model. 39 (2) (2017) 371–385.
[84] H.E. Moghadam, V. Dehbashi, The impact of financial development and trade on environmental quality in Iran, Empir. Econ. 54 (4) (2018) 1777–1799.
[85] N. Apergis, J.E. Payne, The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states, Energy Pol. 38 (1) (2010) 650–655.
[86] E. Dogan, F. Seker, Determinants of CO2 emissions in the European Union: the role of renewable and non-renewable energy, Renew. Energy 94 (2016a) 429–439.
[87] K.U. Ehigiamusoe, H.H. Lean, R. Smyth, The moderating role of energy consumption in the carbon emissions-income nexus in middle-income countries, Appl. Energy 261 (2020) 114215.
[88] BP Statistical Review, Statistical Review of World Energy, 2019.
[89] P. Pedroni, Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis, Econom. Theor. 20 (3) (2004) 597–625.
[90] C. Kao, M.H. Chiang, On the estimation and inference of a cointegrated regression in panel data, in: Nonstationary Panels, Panel Cointegration, and Dynamic Panels, Emerald Group Publishing Limited, 2001, pp. 179–222.
[91] J.C. Driscoll, A.C. Kraay, Consistent covariance matrix estimation with spatially dependent panel data, Rev. Econ. Stat. 80 (4) (1998) 549–560.
[92] S.A. Sarkodie, V. Strezov, Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissionss in developing countries, Sci. Total Environ. 646 (2019) 862–871.
[93] R. Koenker, G. Bassett Jr., Regression quantiles, Econometrica: journal of the Econometric Society 46 (1) (1978) 33–50.
[94] M. Binder, A. Coad, From Average Joe's happiness to Miserable Jane and Cheerful John: using quantile regressions to analyze the full subjective well-being distribution, J. Econ. Behav. Organ. 79 (3) (2011) 275–290.
[95] I.A. Canay, A simple approach to quantile regression for panel data, Econom. J. 14 (3) (2011) 368–386.
[96] K.S. Im, M.H. Pesaran, Y. Shin, Testing for unit roots in heterogeneous panels, J. Econom. 115 (1) (2003) 53–74.
[97] M.H. Pesaran, General Diagnostic Tests for Cross Section Dependence in Panels, 2004.
[98] P.C. Phillips, D. Sul, Dynamic panel estimation and homogeneity testing under cross section dependence, Econom. J. 6 (1) (2003) 217–259.
[99] J. Westerlund, Testing for error correction in panel data, Oxf. Bull. Econ. Stat. 69 (6) (2007) 709–748.
[100] J.J. Kremers, N.R. Ericsson, J.J. Dolado, The power of cointegration tests, Oxf. Bull. Econ. Stat. 54 (3) (1992) 325–348.
[101] P. Pedroni, Critical values for cointegration tests in heterogeneous panels with multiple regressors, Oxf. Bull. Econ. Stat. 61 (S1) (1999) 653–670.
[102] S.I. Khattak, M. Ahmad, Z.U. Khan, A. Khan, Exploring the impact of innovation, renewable energy consumption, and income on CO2 emissionss: new evidence from the BRICS economies, Environ. Sci. Pollut. Control Ser. (2020) 1–16.
[103] V. Moutinho, M. Robaina, Is the share of renewable energy sources determining the CO2 kWh and income relation in electricity generation? Renew. Sustain. Energy Rev. 65 (2016) 902–914.
[104] X. Yang, F. Lou, M. Sun, R. Wang, Y. Wang, Study of the relationship between greenhouse gas emissions and the economic growth of Russia based on the Environmental Kuznets Curve, Appl. Energy 193 (2017) 162–173.
[105] S.T. Katircioğlu, N. Taşpinar, Testing the moderating role of financial development in an environmental Kuznets curve: empirical evidence from Turkey, Renew. Sustain. Energy Rev. 68 (2017) 572–586.
[106] Danish, M.A. Baloch, N. Mahmood, J.W. Zhang, Effect of natural resources, renewable energy and economic development on CO2 emissionss in BRICS countries, Sci. Total Environ. 678 (2019) 632–638.
[107] M.K. Khan, M.I. Khan, M. Rehan, The relationship between energy consumption, economic growth and carbon dioxide emissionss in Pakistan, Financial Innovation 6 (1) (2020) 1–13.
[108] E. Dogan, F. Seker, The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissionss in the top renewable energy countries, Renew. Sustain. Energy Rev. 60 (2016b) 1074–1085.
[109] M. Javid, F. Sharif, Environmental Kuznets curve and financial development in Pakistan, Renew. Sustain. Energy Rev. 54 (2016) 406–414.
[110] R. Akram, F. Chen, F. Khalid, Z. Ye, M.T. Majeed, Heterogeneous effects of energy efficiency and renewable energy on carbon emissionss: evidence from developing countries, J. Clean. Prod. 247 (2020) 119122.
[111] C. Cheng, X. Ren, Z. Wang, C. Yan, Heterogeneous impacts of renewable energy and environmental patents on CO2 emissions-Evidence from the BRIICS, Sci. Total Environ. 668 (2019) 1328–1338.
[112] K. Dong, R. Sun, H. Jiang, X. Zeng, CO2 emissionss, economic growth, and the environmental Kuznets curve in China: what roles can nuclear energy and renewable energy play? J. Clean. Prod. 196 (2018) 51–63.
[113] D. Kaika, E. Zervas, The Environmental Kuznets Curve (EKC) theory—Part A: concept, causes and the CO2 emissions case, Energy Pol. 62 (2013)

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Nomenclature

CO_2: Carbon Dioxide
GHG: Greenhouse gases
EKC: Environmental Kuznets Curve
REC: Renewable energy consumption
ADF: Augmented Dickey Fuller
ASEAN: Association of Southeast Asian Nations (Thailand, Singapore, Indonesia, Malaysia, Philippine, Vietnam)
G7: Group of Seven
NEC: Non-renewable energy consumption
OECD: Organization for Economic Cooperation and Development
FE-OLS: Fixed Effect Ordinary Least Square
MENA: Middle East and North Africa
IMF: International Monetary Fund
IEA: International Energy Agency
BRICS: Brazil, Russia, India, China, and South Africa
GDP: Gross domestic product
PP: Phillip Perron
IPS: Im, Pesaran and Shin
CIPS: Crossectionally-augmented IPS
DOLS: Dynamic Ordinary Least Square
CD: Cross-sectional dependence
FMOLS: Fully Modified Ordinary Least Square
BRIICS: Brazil, Indonesia, India, Russia, China, South Africa
QR: Quantile Regression
PQR: Panel Quantile Regression
MMQR: Method of Moment Quantile Regression
Coeff: Coefficient
Prob: Probability
t-stat: Test statistics
p-value: Probability value
C: Constant
C&T: Constant and Trend