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Investigating the environmental Kuznets curve hypothesis in seven regions: The role of renewable energy

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ABSTRACT

The aim of this research is to investigate how renewable energy consumption effects pollution and whether the relationship between income and pollution formulates the inverted U-shaped relationship which signals the existence of the environmental Kuznets curve (EKC). To realize the aims of this study, non-stationary panel data techniques were utilized to examine the seven selected regions. According to Pedroni and Fisher type cointegration tests, the variables were cointegrated. Moreover, the dynamic ordinary least square (DOLS) and the vector error correction model Granger causality revealed that renewable energy consumption has a significant negative effect on pollution in Central and Eastern Europe, Western Europe, East Asia and the Pacific, South Asia, and the Americas. However, the tests revealed that renewable energy consumption has no significant effect on pollution in the Middle East and North Africa and Sub-Saharan Africa. In addition, the results in general indicated that the existence of the EKC hypothesis is determined by the significance of the renewable energy consumption. Therefore, the EKC hypothesis was only found in the regions where their renewable energy has a significant correlation with pollution in both the short run and the long run. Furthermore, a number of policy recommendations were provided for the investigated regions.

1. Introduction

It is well known that the fluctuation in fossil fuels energy prices and the increasing environmental pressure that the world is witnessing represent a major dilemma for the lives of the poor in developing countries as well as put the world's foundations of energy security, economic growth, and development at risk. Therefore, many countries are encouraged to implement strategies to reduce their dependency on the imported fossil fuels and to decrease the environmental pressure. Increasing the role of renewable energy sources is a fundamental strategy in decreasing the environmental pressure. These sources of energy can be a key solution in increasing energy security by reducing the countries' dependency on imported fossil fuels. Furthermore, such sources of energy can decrease the environmental damage because renewables represent a clean source of energy. Therefore, the world had witnessed a substantial boost in renewable energy production. During the period of 1980–2012, the world renewable electricity production increased more than 50% (GIMD, 2014). Thus, the boost in renewable energy production indicates that the task of this source of energy in meeting the world energy needs is increasing. Moreover, the boost in renewable energy can increase this type of energy's role as a solution for reducing greenhouse gas emissions. Therefore, this study is set out to examine whether renewable energy consumption has reached a point where it can reduce the environmental pollution as well as whether renewable energy consumption helps to form the inverted U-shaped relationship between income and pollution which resembles the environmental Kuznets Curve (EKC) hypothesis. In this study, seven regions are selected, namely, East Asia and the Pacific, Western Europe, East Europe and Central Asia, the Americas, Middle East and North Africa, South Asia, and Sub Saharan Africa.

The EKC hypothesis explains that during the early stages of economic development, the increase in income will increase the pollution until it reaches to a certain point where the relationship between income and pollution becomes negative. This phenomenon is represented by an inverted U-shaped relationship. In other words, the inverted U-shaped relationship between income and pollution will take place only when the country reaches

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a certain level of economic development where technologies that enhance energy efficiency and renewable energy are available.

The validity of EKC has been examined by a number of studies, which have utilized different econometrics methods and focused on the different regions. The literature can be divided based on the methods, countries or region being studied, the number of variables included in the model and the data span. In this paper, the literature is structured according to the number of countries in each of the studies. The first fold of the literature examines the EKC hypothesis for individual countries. The second strand of the literature examines the EKC hypothesis for multi-country studies. We also try to highlight the particular type of indicator that has been used as a proxy for energy sector in order to show that many studies have focused on using aggregate energy consumption and the use of renewable energy consumption has been very limited.

Starting with the studies that have concentrated on individual countries, Shahbaz et al. (2013a) examined the relationship in CO_2 emission, GDP, GDP square, and energy consumption in Romania for the period, 1980–2010. Using the ARDL bounds testing of Pesaran et al. (2001), the results provided support for EKC hypothesis. Using a similar approach, Ahmed and Long (2012) established the existence of EKC in Pakistan. Yavuz (2014) utilized the data of Turkey to examine the relationship in CO_2 emission, GDP, GDP square and energy consumption. The author used the Johansen and Juselius (1990) cointegration test, and fully modified OLS of Phillips and Hansen (1990) to establish the existence of EKC in Turkey. Ozturk and Al-Mulali (2015) probed the existence of EKC in Cambodia for the 1996–2012 period. Using the Generalized Method of Moments (GMM) of Arellano and Bover (1995) and the two-stage least squares (TSLS), the study fails to observe EKC in the country.

Jalil and Mahmud (2009) employed the data of China to examine the relationship between CO_2 emission, GDP, GDP square, energy consumption and trade openness for the 1975–2005 period. Using the ARDL bounds testing of Pesaran et al. (2001) and the standard Granger causality test, the result provide support for EKC hypothesis and unilateral causality from GDP to emission. While Ang (2007) and Shahbaz et al. (2012) reached the same conclusion for France and Pakistan; Lau et al. (2014) and Saboori et al. (2012) provided similar results for Malaysia. Tan et al. (2014) examined the presence of EKC and the possible causal relationship between the CO_2 emission, energy consumption, GDP, and GDP square in Singapore for the period, 1975–2011. Using the Johansen and Juselius (1990) cointegration test, the results provide evidence for no EKC in the country. However, the causal analysis reveals that there is unidirectional causality from CO_2 emission to GDP, but no causality between CO_2 emission and energy consumption.

Shahbaz et al. (2014a) used the data of Tunisia to examine the existence of EKC in 1971–2010. Using the ARDL bounds testing of Pesaran et al. (2001) and also performing causality tests on variables that include CO_2 emission, GDP, GDP square, energy consumption, and trade openness; the authors observe the presence of EKC and unidirectional causality from GDP to emission. The results further show that there is bidirectional causality between energy consumption and emission. Using similar approach in Tunisia and South Africa, Farhani et al. (2014) and Kohler (2013) provide evidence for EKC and also similar pattern of causality. Ozturk and Acaravci (2013) employed the data of Turkey to probe the relationship in CO_2 emission, GDP, GDP square, energy consumption, trade openness and financial development. The empirical outcome unveils the presence of EKC in addition to unilateral causality flowing from both GDP and energy consumption to emission. Shahbaz et al. (2013b) and Tang and Tan (2015) provide support for EKC and bidirectional causality between GDP and emission; and bidirectional causality between energy consumption and emission in Malaysia and Vietnam, respectively. On the contrary, Pao et al. (2011) failed to find evidence of EKC in Russia but bidirectional causality in GDP and emission; and between energy consumption and emission. Halicioglu (2009) used the data of Turkey to examine the relationship between CO_2 emission, GDP, GDP square, energy consumption and trade openness in Turkey, for the 1960–2005 period. The empirical output unveils support for inverted U-shaped curve in the country as well as bidirectional causality between emission and GDP, but causality from energy consumption to emission. Pao and Tsai (2011a) observed the same pattern of result in a study that involves the dataset of Brazil for the 1980–2007 period.

There are individual country studies that have adopted either sectoral or provincial datasets in their analyses. For instance, Hamit-Haggar (2012) probed the relationship in CO_2 emission, GDP, GDP square and energy consumption in industrial sector in Canada for the 1990–2007 period. The authors adopted the Pedroni (1999, 2004) tests and the standard causality test, the author found support for EKC and the existence of unidirectional causality from both energy consumption and GDP to emission. Haisheng et al. (2005), Guangyue and Deyong (2011) and Llorca and Meunié (2009) employed the dataset of many provinces in China to examine the existence of EKC in the country. While the outputs in the works of Haisheng et al. (2005) and Guangyue and Deyong (2011) show support for EKC, the results in Llorca and Meunié (2009) suggested that EKC does not exist in the country. In the same vein, Wang et al. (2011) used dataset of 28 provinces in China to investigate the existence of EKC and also the pattern of causality in the country. The findings provide evidence for EKC, unidirectional causality from GDP to emission as well as bidirectional causality between energy consumption and emission.

The foregoing individual-country papers have used energy consumption to represent the energy sector. However, there are individual-country studies that have considered other variables beyond energy consumption to proxy the energy sector. For instance, Al-Mulali et al. (2015a) used both fossil fuels energy consumption and renewable energy consumption as indicators of energy sector in Vietnam for the period, 1981–2011. Using the Pesaran et al. (2001) approach to cointegration, the authors were unable to find evidence for EKC. Whilst using similar approach, Al-Mulali et al. (2016) provided evidence for EKC in Kenya. Shahbaz et al. (2014b) investigated the relationship in CO_2 emission, electricity consumption, GDP, and GDP square, urbanization, and exports in United Arab Emirates for the 1975–2011 period. The results support the existence of EKC in the country as well as unilateral causality from GDP to emission and bidirectional causality between energy consumption to emission. Similarly, Shahbaz et al. (2013c) and Tiwari et al. (2013) used coal consumption as proxy for energy sector and found evidence for EKC hypothesis in South Africa and India. In a more detailed study, which includes total energy consumption, coal consumption, gas consumption, electricity consumption, oil consumption as proxy for the energy sector in Malaysia, Saboori and Sulaiman (2013a) established evidence for EKC in addition to bidirectional causality between GDP and emission; and between different energy indicators and emission.

The second part of our literature review focusses on multi-country studies and the first segment of these papers have used energy consumption as a proxy for the energy sector and also utilized time series techniques largely because the number of countries in their sample is finite. The findings provide support for EKC in Indonesia Malaysia and Thailand. Jayanthakumaran et al. (2010) examined the relationship in CO_2 emission, GDP, GDP square, energy consumption, and trade openness in China and India for the period, 1971–2007. Using the Pesaran et al. (2001) approach to cointegration, the results provide evidence for EKC in both countries. In the same vein, Onafowora and Owoye (2014), Lapinskienė et al. (2014), Baek (2015) and Saboori and Sulaiman (2013b) focused on mixed, European, Artic and ASEAN countries, respectively. The results provided mixed evidence for EKC

Table 1
Summary of the literature.

Author	Period	Country/Region/ Organization	Methodology	Variables used in the study	EKC Hypothesis	Causality
Shahbaz et al. (2013a)	1980–2010	Romania	ARDL bounds testing.	CO_2 emission, GDP, GDP square, and energy consumption.	Yes	N/A
Ahmed and Long (2012)	1971–2008	Pakistan	ARDL bounds testing.	CO_2 emission, GDP, GDP square, energy consumption, trade openness and population.	Yes	N/A
Yavuz (2014)	1960–2007	Turkey	Johansen–Jusellius cointegration, fully modified OLS,	CO_2 emission, GDP, GDP square and energy consumption.	Yes	N/A
Ozturk and Al-Mulali (2015)	1996–2012	Cambodia	Generalized Method of Moments (GMM) and the Two-stage Least Squares (TSLS).	GDP, urbanization, trade openness, control of corruption and governance.	No	N/A
Jalil and Mahmud (2009)	1975–2005	China	ARDL bounds testing, and Pair wise Granger causality.	CO_2 emission, GDP, GDP square, Energy consumption, and trade openness.	Yes	Y→C
Ang (2007)	1960–2000	France	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	Yes	Y→C
Shahbaz et al. (2012)	1971–2009	Pakistan	ARDL bounds testing, Gregory–Hansen cointegration test, and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, and trade openness.	Yes	Y→C
Lau et al. (2014)	1970–2008	Malaysia	ARDL bounds testing and VECM Granger causality.	CO_2 emission, foreign direct investment, trade openness, GDP, and GDP square.	Yes	Y→C
Saboori et al. (2012)	1980–2009	Malaysia	ARDL bounds testing, Johansen–Jusellius cointegration, and VECM Granger causality.	CO_2 emission, GDP, GDP square, and Energy consumption.	Yes	Y→C
Tan et al. (2014)	1975–2011	Singapore	Johansen–Jusellius cointegration test and VAR Granger causality.	CO_2 emission, energy consumption, GDP, and GDP square.	No	Y→C E⇹C
Shahbaz et al. (2014a)	1971–2010	Tunisia	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, and trade openness.	Yes	Y→C E↔C
Farhani et al. (2014)	1971–2008	Tunisia	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, trade openness.	Yes	Y→C E↔C
Kohler (2013)	1960–2009	South Africa	ARDL bounds testing, Johansen–Jusellius cointegration, and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, and trade openness.	Yes	Y→C E↔C
Ozturk and Acaravci (2013)	1960–2007	Turkey	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, trade openness, and financial development.	Yes	Y→C E→C
Shahbaz et al. (2013b)	1971–2011	Malaysia	ARDL bounds testing and VECM Granger causality.	CO_2 emission, energy consumption, financial development, financial development square, trade openness, and foreign direct investment.	Yes	Y↔C E↔C
Tang and Tan (2015)	1976–2009	Vietnam	Johansen cointegration and VECM Granger causality	CO_2 emission, GDP, GDP square, energy consumption and FDI.	Yes	Y↔C E↔C
Pao et al. (2011)	1990–2007	Russia	Johansen–Jusellius cointegration, VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	No	Y↔C E↔C
Halicioglu, 2009	1960–2005	Turkey	ARDL bounds testing, and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, and trade openness.	Yes	Y↔C E→C
Pao and Tsai (2011a)	1980–2007	Brazil	Gray prediction model (GM), Johansen–Jusellius cointegration, VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	Yes	Y↔C E→C
Hamit-Haggar (2012)	1990–2007	Canada	Pedroni cointegration, fully modified OLS, and VECM Granger causality	CO_2 emission, GDP, GDP square, industrial energy consumption.	Yes	Y→C E→C
Haisheng et al. (2005)	1990–2002	China	Random and fixed effect model.	Industrial waste water, SO_2 emission, GDP, GDP square, trade openness, and foreign direct investment (FDI).	Yes	N/A

Table 1 (*Continued*)

Author	Period	Country/Region/ Organization	Methodology	Variables used in the study	EKC Hypothesis	Causality
Guangyue and Deyong (2011)	1990–2007	China	Johansen co-integration test and least squares estimation method (PLS).	CO_2 emission, GDP, and GDP square.	Yes	N/A
Llorca and Meunié (2009)	1985–2003	China	Fixed effects model.	SO_2 emission, GDP, GDP square, GDP cubic, FDI, industrial output,	No	N/A
Wang et al. (2011)	1995–2007	China	Pedroni cointegration and VECM Granger causality.	CO_2 emission, GDP, GDP square, and Energy consumption.	Yes	Y→C E↔C
Al-Mulali et al. (2015a)	1981–2011	Vietnam	ARDL bounds testing.	CO_2 emission, GDP, fossil fuels energy consumption, renewable energy consumption, capital, labor, export and imports	No	N/A
Al-Mulali et al. (2016)	1980–2012	Kenya	ARDL bounds testing	GDP, fossil fuel energy consumption, renewable energy consumption urbanization, and trade openness increase	Yes	N/A
Shahbaz et al. (2014b)	1975–2011	United Arab Emirates	ARDL bounds testing and VECM Granger causality.	CO_2 emission, electricity consumption, GDP, and GDP square, urbanization, and exports.	Yes	Y→C E↔C
Shahbaz et al. (2013c)	1965–2008	South Africa	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, trade openness, coal consumption, and trade openness.	Yes	Y→C E→C
Tiwari et al. (2013)	1966–2011	India	ARDL bounds testing, Johansen–Jusellius cointegration, and VECM Granger causality.	CO_2 emission, GDP, GDP square, coal consumption, and trade openness.	Yes	Y↔C E↔C
Saboori and Sulaiman (2013a)	1980–2009	Malaysia	ARDL bounds testing, Johansen–Jusellius cointegration, and VECM Granger causality.	CO_2 emission, GDP, GDP square, and Energy consumption, coal consumption, gas consumption, electricity consumption, oil consumption.	No	Y↔C E↔C
Jayanthakumaran et al. (2010)	1971–2007	China and India	ARDL bounds testing.	CO_2 emission, GDP, GDP square, Energy consumption, and trade openness.	Yes	N/A
Onafowora and Owoye (2014)	1970–2010	Brazil, China, Egypt, Japan, Mexico, Nigeria, South Korea, and South Africa	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, trade openness, and population.	Yes for japan and South Korea.	N/A
Lapinskienė et al. (2014)	1995–2010	Europe	OLS regression	CO_2 emission, GDP, GDP square, and GDP cubic.	Yes for Norway, Switzerland and Ireland.	N/A
Baek (2015)	1960–2010	Arctic countries	ARDL bounds testing.	CO_2 emission, GDP, GDP square, GDP cubic and energy consumption	Yes for Iceland only	N/A
Saboori and Sulaiman (2013b)	1971–2009	ASEAN	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	Yes for Singapore and Thailand	Y↔C Indonesia, Malaysia and Philippines; Y→C for Singapore and Thailand; E↔C
Chandran and Tang (2013)	1971–2008	ASEAN	Johansen–Jusellius cointegration test and VECM Granger causality.	CO_2 emission from transportation, energy consumption, GDP, and GDP square.	Yes in Indonesia Malaysia and Thailand; No for Singapore	Y→C Malaysia; Y↔C Indonesia and Thailand; E↔C for Indonesia Malaysia and Thailand; Y$\nleftrightarrow$C for Philippines Singapore E$\nleftrightarrow$C for Philippines Singapore

Table 1 (*Continued*)

Author	Period	Country/Region/ Organization	Methodology	Variables used in the study	EKC Hypothesis	Causality
Acaravci and Ozturk (2010)	1970–2005	Denmark Germany Greece Iceland Italy Portugal and Switzerland	ARDL bounds testing and VECM Granger causality.	CO_2 emission, GDP, GDP square, and energy consumption.	Yes for Denmark and Italy	Y→C for Denmark Germany Greece Iceland Italy and Portugal and; Y↔C for Switzerland; E→C Denmark Germany Greece, Iceland, Portugal and Switzerland; Y↔C for Italy
Atici (2009)	1980–2002	Bulgaria, Hungary, Romania and Turkey	Random and fixed effects.	CO_2 emission, GDP, GDP square, energy consumption, and trade openness.	Yes	N/A
Osabuohien et al. (2014)	1995–2010	Africa	Pedroni cointegration, dynamic OLS,	CO_2 emission, GDP, GDP square, government effectiveness, and trade openness.	Yes	N/A
Cho et al. (2014)	1971–2000	OECD countries	Pedroni cointegration and fully modified OLS,	CO_2 emission, GDP, GDP square, energy consumption	Yes	N/A
Chow (2014)	1992–2004	132 developed and developing countries	OLS model	CO_2 emission, GDP, and GDP square.	Yes	N/A
Kleemann and Abdulai (2013)	1990–2003	90 developed and developing countries	Fixed effect model	CO_2 emission, GDP, GDP square, GDP cubic, trade openness, and population.	Yes	N/A
Apergis and Ozturk (2015)	1990–2011	14 Asian countries	GMM	CO_2 emission, GDP, GDP square, population density, land, industry shares in GDP, and quality of institutions indicators	Yes	N/A
Pao and Tsai (2010)	1971–2005	Brazil, Russia, India, China (BRIC)	Pedroni, Pedroni cointegration, and VECM Granger causality.	CO_2 emission, GDP, GDP square, and Energy consumption.	Yes	Y⇎C E⇎C
Ozcan (2013)	1990–2008	Middle East	Westerlund panel cointegration test, Pedroni contegration test, fully modified OLS, VECM Granger causality.	CO_2 emission, GDP, GDP square, and Energy consumption.	No	Y→C E→C
Pao and Tsai (2011b)	1992–2007	BRIC	Pedroni cointegration, and VECM Granger causality.	CO_2 emission, GDP, GDP square, energy consumption, and foreign direct investment.	Yes	Y→C E→C
Apergis and Payne (2009)	1971–2004	Central America	Pedroni cointegration, fully modified OLS, and VECM Granger causality.	CO_2 emission, GDP, GDP square, and Energy consumption.	Yes	Y→C E↔C
Apergis and Payne (2010)	1992–2004	Commonwealth of independent states	Pedroni cointegration, fully modified OLS, and VECM Granger causality.	CO_2 emission, GDP, GDP square, and Energy consumption.	Yes	Y→C E↔C
Kasman and Duman (2015)	1990–2010	European Union	Pedroni cointegration, fully modified OLS and VECM Granger causality	CO_2 emission, GDP, GDP square, energy consumption, trade openness and urbanization	Yes	Y↔C E↔C
Shahbaz et al. (2015)	1980–2012	African countries	Pedroni cointegration, fully modified OLS and VECM Granger causality	CO_2 emission, GDP, GDP square, energy intensity	Yes	Y↔C E→C
Govindaraju and Tang (2013)	1965–2009	China and India	Bayer and Hanck cointegration test, VECM and VAR Granger causality.	CO_2 emission, GDP, GDP square, and coal consumption.	No	Y→C E↔C
Shafiei and Salim (2014)	1980–2011	OECD countries	Westerlund panel cointegration test VECM Granger causality	CO_2 emission, GDP, GDP square, renewable energy consumption, non-renewable energy consumption, population, urbanization, GDP from services.	No	Y→C; E→C for renewable energy consumption; E↔C for non-renewable energy consumption
Lean and Smyth (2010)	1980–2006	ASEAN	Johansen Fisher panel cointegration test, dynamic OLS, VECM Granger causality.	CO_2 emission, GDP, GDP square, and electricity consumption.	Yes	Y←C E⇎C
Al-mulali et al. (2015b)	1980–2010	Latin America and the Caribbean countries	Kao cointegration, fully modified OLS and VECM Granger causality	CO_2 emission, GDP, GDP square, renewable energy and financial development	Yes	Y↔C E↔C

→ indicates the direction of causality. ↔ indicates bidirectional causality. ⇎ indicates no causality. N/A indicates the non-availability of causality test. C is CO_2 emission, Y is GDP and E is energy consumption or its components. We have only focussed on the long run causality in these papers.

hypothesis in the sampled countries. Chandran and Tang (2013) used the data of Indonesia, Malaysia, Singapore and Thailand to probe the existence of EKC and also pattern of causality in the CO_2 emission from transportation, energy consumption, GDP, and GDP square. The results provided mixed evidence for EKC hypothesis in the sampled countries as well as differing patterns of causality. Acaravci and Ozturk (2010) provided similar results of mixed evidence of EKC in a sample that involves European countries.

Emission is a global issue and transcends beyond the boundary of a single country or a group of countries. Therefore, it requires global focus. Moreover, one attribute of the foregoing literature is the prevalence of time series techniques in the process of estimation. The power of time series often depends on the span of the data rather than the frequency. Fortunately, panel-based methods provide the opportunity of greater informative data, better degrees of freedom, improved variability, more efficiency in estimation and less susceptible to the problem of multicollinearity (Solarin and Ozturk, 2016).

Hence there are studies that have applied pure panel techniques to examine the possibility of EKC hypothesis as well as the pattern of causality among the variables that include energy consumption as the sole indicator of the energy sector. Atici (2009) employed the random and fixed effect models to probe the relationship between CO_2 emission, GDP, GDP square, energy consumption, and trade openness in Bulgaria, Hungary, Romania and Turkey for the period, 1980–2002. The results support the existence of EKC in these countries. Similarly, Osabuohien et al. (2014), Cho et al. (2014), Chow (2014), Kleemann and Abdulai (2013) and Apergis and Ozturk (2015) provided support for EKC in African countries, OECD countries, 132 countries, 90 countries and 14 Asian countries, respectively. Pao and Tsai (2010) used the dataset of Brazil, Russia, India and China to examine the relationship in CO_2 emission, GDP, GDP square and energy consumption. The results support EKC hypothesis but no causal relationship between GDP emission and between energy consumption and emission.

Ozcan (2013) used the Westerlund (2008) panel cointegration test and Pedroni (2000) approach, among other techniques to examine the relationship in CO_2 emission, GDP, GDP square and energy consumption for the Middle East countries. There is no support for EKC but unidirectional causality from GDP to emission and energy consumption to emission. Pao and Tsai (2011b) examine the relationship between CO_2 emission, GDP, GDP square, energy consumption and foreign direct investment in Brazil, Russia, India and China for the period, 1992–2007. The results show that EKC exists in the country in addition to unidirectional causality from GDP to emission and energy consumption to emission. Studies with similar evidence for EKC within a panel data framework include Apergis and Payne (2009,2010), Kasman and Duman (2015) and Shahbaz et al. (2015) for Central American, Commonwealth of independent states, European Union and African countries, respectively.

There are few multi-country studies that have utilized other forms of energy indicators as a representative of the energy sector. For instance, Govindaraju and Tang (2013) probed the relationship in CO_2 emission, GDP, GDP square, and coal consumption in China and India for the period, 1965–2009. Using the Bayer and Hanck (2013) cointegration test, the findings reveal no evidence for EKC in the two countries, but unilateral causality from GDP to emission. There is also bilateral causality between energy consumption and emission. Shafiei and Salim (2014) used the Westerlund (2007) and the standard causality test to examine the relationship in CO_2 emission, GDP, GDP square, renewable energy consumption, non-renewable energy consumption, population, urbanization, GDP from services and the results suggested no EKC in the OECD countries. Lean and Smyth (2010) used electricity as indicator of energy sector and provided evidence for EKC in ASEAN countries. In the same vein, Al-mulali et al. (2015b) used renewable energy consumption as a proxy for the energy sector. The authors further employed the Kao (1999) cointegration test, Pedroni (2000) approach and standard causality test to support the evidence of EKC in addition to unilateral causality from emission to GDP.

It can be clearly seen from the foregoing papers (and also Table 1) that there is limited empirical studies that examined the effects of renewable energy consumption on pollution despite its remarkable boost over the last three decades. This finite papers on the impact of renewable energy consumption on pollution have either concentrated on single country or a bloc of countries. The authors believe that there is a link between renewable energy consumption and the EKC hypothesis. As we explained earlier, during the initial stages of economic development, the increase in GDP growth will increase pollution as the technologies that enhance energy efficiency and renewable energy are not available and there is a lack of demand for better quality environment. However, as economic development increases (better life quality), it will reach a point where the increase in GDP growth will reduce pollution. This stage of economic development takes place when there is a demand for a better environmental quality and the technologies that enhance energy efficiency and renewable energy become tangible. Therefore, when renewable energy consumption increases the EKC hypothesis might take place.

2. Data and methodology

This study utilized annual data taking the period of 1980–2010. As implemented by the previous literature mentioned in Table 1, this study used CO_2 emission as a pollution indicator and

Table 2
List of countries under investigation categorized by region.

Region	Countries	Time period
East Asia and the Pacific	Australia, China, Indonesia, Japan, Korea, Rep., Malaysia, New Zealand, Philippines, Singapore, Thailand.	1980–2010
Western Europe	Austria, Belgium, Belgium, Cyprus, Denmark, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland.	1980–2010
East Europe and Central Asia	Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Croatia, Czech Republic, Estonia, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova, Romania, Russian Federation, Slovak Republic, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Turkey.	1990–2010
The Americas	Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela, Canada, United States.	1980–2010
Middle East and North Africa	Algeria, Egypt, Iran, Iraq, Israel, Jordan, Lebanon, Malta, Morocco, Syria, Tunisia.	1980–2010
South Asia	Bangladesh, India, Nepal, Pakistan, Sri Lanka.	1980–2010
Sub Saharan Africa	Angola, Benin, Cameroon, Congo, Dem. Rep, Congo, Rep., Cote d'Ivoire, Ethiopia, Gabon, Kenya, Mozambique, Senegal, South Africa, Sudan, Tanzania, Togo, Zambia, Zimbabwe.	1980–2010

GDP, urbanization, trade openness, and financial development as economic indicators. Unlike previous studies, this study added renewable energy consumption to examine whether this source of energy reached the point of reducing pollution. Since this study attempts to investigate the EKC hypothesis, renewable energy consumption was added to examine whether it can help to form the U-shaped relationship between income and pollution. Table 2 reviews the selected 107 countries categorized by their regions.

This study applied panel data methodology because of its ability to perform well with short time series as it increases the degree of freedom. The panel data is also more capable in controlling the heterogeneity and the serial correlation problem compared to the normal time series and cross section data (Baltagi, 2005). To achieve

Table 3
ADF-Fisher Chi-square.

Variables	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Central & Eastern Europe				
LCO2	48.0642	36.9437	58.4604[a]	163.809[a]
LGDP	49.6893	42.6353	129.663[a]	70.3532[a]
LGDP2	30.3648	42.1047	139.413[a]	80.9894[a]
LRE	44.2680	31.2364	99.6567[a]	78.4926[a]
LTD	21.4689	46.7822	71.7956[a]	139.348[a]
LFD	19.2796	25.2079	172.539[a]	109.222[a]
LUR	53.2095	32.9483	66.9534[b]	91.1754[a]
Western Europe				
LCO2	45.6747	37.3653	156.367[a]	125.656[a]
LGDP	28.7733	24.7228	98.2425[a]	72.9466[a]
LGDP2	27.4705	25.3769	99.2995[a]	72.6583[a]
LRE	34.1933	34.3310	153.577[a]	132.771[a]
LTD	17.1620	26.4592	127.939[a]	87.3587[a]
LFD	17.9880	31.6431	80.8127[a]	72.6277[a]
LUR	18.9410	39.8213	72.1034[a]	76.5910[a]
East Asia & the Pacific				
LCO2	17.1923	6.45778	31.6318[b]	45.8627[a]
LGDP	19.5595	16.6863	47.6763[a]	40.7237[a]
LGDP2	18.2905	14.5936	47.8230[a]	40.6002[a]
LRE	25.7029	24.4085	37.8335[a]	60.4097[a]
LTD	0.24508	15.0121	41.8149[a]	42.1122[a]
LFD	14.4996	11.2637	53.7625[a]	35.7116[b]
LUR	24.4592	16.1572	38.7095[a]	35.8507[b]
Middle East & North Africa				
LCO2	21.3160	7.01299	241.049[a]	218.125[a]
LGDP	9.59195	14.0806	46.5524[a]	40.8066[a]
LGDP2	8.27578	13.2041	44.8650[a]	40.3454[a]
LRE	25.6786	22.5703	196.846[a]	150.502[a]
LTD	2.98964	27.7376	95.0503[a]	73.9799[a]
LFD	19.4183	25.7992	31.8960[c]	125.049[a]
LUR	24.1841	9.94472	125.981[a]	90.6802[a]
South Asia				
LCO2	9.00614	8.99058	49.3390[a]	40.5164[a]
LGDP	2.21210	2.14637	41.8320[a]	44.6671[a]
LGDP2	1.84142	2.56136	40.3866[a]	43.9132[a]
LRE	12.5355	15.4792	67.8614[a]	55.0254[a]
LTD	1.14767	6.96105	34.7117[a]	27.0766[a]
LFD	8.99398	8.87140	34.5073[a]	25.9148[b]
LUR	9.08214	11.0448	78.3959[a]	64.4455[a]
The Americas				
LCO2	12.1619	53.6540	279.396[a]	229.008[a]
LGDP	3.40684	47.4333	89.3240[a]	63.0316[b]
LGDP2	13.0029	46.7756	88.2293[a]	62.5428[b]
LRE	45.7757	39.3080	409.374[a]	358.532[a]
LTD	4.56070	53.0884	285.241[a]	232.912[a]
LFD	47.0406	44.6649	201.289[a]	150.155[a]
LUR	52.2424	34.6415	152.607[a]	110.683[a]
Sub Saharan Africa				
LCO2	33.4508	38.9971	100.750[a]	79.7797[a]
LGDP	5.76294	26.9364	87.6033[a]	88.8915[a]
LGDP2	5.70952	25.7030	85.3452[a]	88.4688[a]
LRE	29.6096	35.4460	110.756[a]	84.8340[a]
LTD	16.1658	31.1868	73.9875[a]	53.8639[a]
LFD	28.0385	22.9088	210.735[a]	194.784[a]
LUR	26.7862	43.0752	71.6176[a]	54.3148[a]

The unit root tests were done with individual trends and intercept for each variable.
lag length were selected automatically using the Schwarz Information Criteria (SIC).
[a] Indicates statistical significance at the 1 percent.

the aims of this research, the following model was used to represent pollution:

$$LCO2_{it} = \beta_0 + \beta_1 LGDP_{it} + \beta_2 LGDP2_{it} + \beta_3 LRE_{it} + \beta_4 LTD_{it} + \beta_5 LUR_{it} + \beta_6 LFD_{it} + u_{it} \quad (1)$$

where i represents the cross section (number of countries), t denotes the time series, β_1, β_2, β_3, β_4, β_5, and β_6 denote the slope coefficients, and u_{it} represents the error term. The existence of the EKC hypothesis, which indicates the inverted U-shaped relationship between income and CO_2 emission, can be confirmed if $\beta_1 > 0$ (the slope coefficient of LGDP) and $\beta_2 < 0$ (the slope coefficient of LGDP2). LCO2 is the log of carbon dioxide emissions stemming from the burning of fossil fuels measured in millions of metric tons, LGDP is the log of the gross domestic product measured in millions of 2000 constant US dollars, and LGDP2 is the log of the

Table 4
Im, Pesaran and Shin *W*-statistics.

Variables	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Central & Eastern Europe				
LCO2	−0.91517	0.25674	−2.44377[a]	−9.33423[a]
LGDP	0.07836	−1.14600	−7.08218[a]	−2.47593[a]
LGDP2	1.41572	−1.10989	−7.64243[a]	−3.25546[a]
LRE	0.89335	0.85828	−5.08698[a]	−3.92642[a]
LTD	2.40432	−0.98922	−3.18031[a]	−7.94258[a]
LFD	3.60538	1.99004	−7.63650[a]	−6.53246[a]
LUR	4.46205	1.85361	−1.00852	−2.02904[a]
Western Europe				
LCO2	−0.63575	1.39195	−8.31684[a]	−6.82378[a]
LGDP	1.04041	1.38083	−5.53003[a]	−3.23711[a]
LGDP2	1.20182	1.28469	−5.60076[a]	−3.20472[a]
LRE	4.75180	0.74715	−8.62366[a]	−8.15590[a]
LTD	2.66257	1.49379	−7.20079[a]	−4.85877[a]
LFD	4.32790	1.41422	−4.02719[a]	−3.45091[a]
LUR	5.96578	1.78529	−1.88620[b]	−2.58398[a]
East Asia & the Pacific				
LCO2	0.50929	2.79183	−2.12681[b]	−3.85730[a]
LGDP	1.73367	0.21287	−3.77777[a]	−3.23244[a]
LGDP2	2.17497	0.45015	−3.80220[a]	−3.22234[a]
LRE	0.04054	−1.00043	−2.70732[b]	−5.18640[a]
LTD	10.2484	1.77352	−3.17581[a]	−3.26064[a]
LFD	0.63406	0.62717	−4.52458[a]	−2.91367[a]
LUR	0.97019	1.69220	−1.49400[c]	−1.79058[b]
Middle East & North Africa				
LCO2	−0.26741	0.66717	−17.4138[a]	−15.8915[a]
LGDP	4.35988	0.48539	−3.73120[a]	−2.95686[a]
LGDP2	5.45956	0.65198	−3.59411[a]	−2.90795[a]
LRE	4.43631	−1.20989	−7.58688[a]	−6.18151[a]
LTD	1.63744	−0.31678	−1.77799[c]	−6.20785[a]
LFD	0.06785	0.41110	−8.18274[a]	−3.76042[a]
LUR	6.01068	0.94989	−2.25890[b]	−2.30114[b]
South Asia				
LCO2	0.78904	0.21374	−5.52189[a]	−4.81776[a]
LGDP	6.71393	2.69218	−4.54499[a]	−5.18735[a]
LGDP2	7.15611	2.82459	−4.35028[a]	−5.10402[a]
LRE	−0.21638	−1.34421	−7.41322[a]	−6.49425[a]
LTD	3.82443	0.75720	−3.24804[a]	−1.73744[b]
LFD	2.91486	1.29619	−3.87276[a]	−2.97650[a]
LUR	−0.45855	−0.44428	−8.60122[a]	−7.79182[a]
The Americas				
LCO2	4.25998	−0.93551	−14.9663[a]	−13.0126[a]
LGDP	8.33512	−0.84685	−4.84832[a]	−2.51084[b]
LGDP2	5.51720	−0.73902	−4.78769[a]	−2.48251[b]
LRE	−0.34533	−1.25874	−21.4232[a]	−19.9224[a]
LTD	8.34856	−1.18698	−15.5233[a]	−13.7633[a]
LFD	−0.69287	−0.43588	−11.1103[a]	−8.60740[a]
LUR	−1.09304	2.12405	−8.25845[a]	−5.75485[a]
Sub Saharan Africa				
LCO2	1.80286	−0.86089	−6.36468[a]	−5.12873[a]
LGDP	7.67544	1.48761	−5.06314[a]	−5.34366[a]
LGDP2	7.83560	1.66474	−4.90760[a]	−5.31637[a]
LRE	1.20686	−0.34819	−6.16476[a]	−4.05105[a]
LTD	3.69259	−0.93424	−4.53546[a]	−2.84012[a]
LFD	0.39598	1.68845	−12.4601[a]	−12.2060[a]
LUR	2.13424	−0.47152	−4.84315[a]	−1.34525[c]

The unit root tests were done with individual trends and intercept for each variable.
lag length were selected automatically using the Schwarz Information Criteria (SIC).
[a] Indicates statistical significance at the 1 percent.

Table 5
Levin, Lin and Chu.

Variables	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Central & Eastern Europe				
LCO2	2.12766	3.00615	−12.0142[a]	−10.3307[a]
LGDP	1.31085	−1.80672	−5.00013[a]	−1.17931
LGDP2	4.37221	4.11239	−1.86255[c]	−1.95719[b]
LRE	3.08588	6.06692	−29.2641[a]	−17.9962[a]
LTD	−1.01848	2.24067	−13.5883[a]	−9.70145[a]
LFD	−0.07829	−0.66725	−12.0018[a]	−9.46946[a]
LUR	2.69349	6.78682	−5.86351[a]	−0.12875
Western Europe				
LCO2	−0.94750	12.3751	−17.3732[a]	−16.4201[a]
LGDP	−1.09068	9.19232	−9.67367[a]	−8.57501[a]
LGDP2	−0.72475	9.15909	−9.69373[a]	−8.53150[a]
LRE	2.71678	7.40554	−17.6021[a]	−13.3490[a]
LTD	−1.11465	8.87163	−16.7208[a]	−14.2459[a]
LFD	0.31583	−1.73071	−10.1160[a]	−9.75543[a]
LUR	0.23923	0.23923	−3.08548[a]	−1.97399[b]
East Asia & the Pacific				
LCO2	−1.35660	2.16437	−10.5723[a]	−11.7526[a]
LGDP	−0.87642	−0.10039	−9.26148[a]	−8.39280[a]
LGDP2	−0.09208	0.11183	−9.25506[a]	−8.40158[a]
LRE	−0.38896	−0.73461	−15.8932[a]	−14.2410[a]
LTD	−1.04947	1.28570	−12.5458[a]	−10.9224[a]
LFD	−1.18617	−0.23929	−2.21385[b]	−0.70573
LUR	2.91638	0.21302	−1.60004[c]	−1.82628[b]
Middle East & North Africa				
LCO2	−1.02128	2.47705	−17.9103[a]	−15.2842[a]
LGDP	1.15877	−0.98289	−14.2829[a]	−12.5999[a]
LGDP2	1.60131	−0.70971	−14.2338[a]	−12.5593[a]
LRE	0.80224	6.19021	−15.2582[a]	−11.5944[a]
LTD	1.10182	−1.24251	−12.5721[a]	−10.2424[a]
LFD	−0.12924	3.37951	−8.42004[a]	−5.18370[a]
LUR	−0.05604	−1.23058	−3.42397[a]	−7.82331[a]
South Asia				
LCO2	−0.78773	−0.56003	−10.7982[a]	−7.08623[a]
LGDP	4.33186	0.56698	−3.89666[a]	−4.21684[a]
LGDP2	4.66502	0.76188	−6.14864[a]	−6.68493[a]
LRE	−0.78388	0.51313	−12.8631[a]	−11.7851[a]
LTD	1.79876	0.63783	−6.69334[a]	−3.74684[a]
LFD	0.26163	0.52562	−5.03270[a]	−5.37324[a]
LUR	−0.85378	−1.08555	−1.04806	−4.79571[a]
The Americas				
LCO2	0.88865	−1.23359	−20.6118[a]	−18.2480[a]
LGDP	4.18925	−0.78721	−12.7681[a]	−11.5366[a]
LGDP2	4.49442	−0.97979	−12.6998[a]	−11.5504[a]
LRE	0.34580	9.82965	−19.2787[a]	−17.5063[a]
LTD	1.96966	2.82067	−16.5214[a]	−14.5911
LFD	−0.27679	−0.44619	−18.4546[a]	−17.8163[a]
LUR	−0.87511	−0.74038	−1.11443	−11.1347[a]
Sub Saharan Africa				
LCO2	−0.06311	−0.81082	−20.2781[a]	−18.4262[a]
LGDP	5.38884	−0.10554	−8.55078[a]	−7.61396[a]
LGDP2	5.52463	−0.87180	−5.04332[a]	−5.83885[a]
LRE	0.01105	−0.52349	−8.33528[a]	−6.10243[a]
LTD	2.77495	−1.35171	−7.22442[a]	−5.76250[a]
LFD	−1.08579	1.74803	−6.25001[a]	−5.68379[a]
LUR	−0.76115	−1.03886	−3.59860[a]	1.24541

The unit root tests were done with individual trends and intercept for each variable.
lag length were selected automatically using the Schwarz Information Criteria (SIC).
[a] Indicates statistical significance at the 1 percent.

square of gross domestic product measured in millions of 2000 constant US dollars. The LRE, which includes hydropower, geothermal, solar, tides, wind, biomass, and biofuels measured in millions of kilowatt-hours, is the log of electricity consumption from renewable energy sources. LTD is the log of trade of goods and services as a measure of trade openness measured in millions of 2000 constant US dollars. LUR, which indicates urbanization measured in thousands of individuals, is the log of urban population. LFD is the log of the cross domestic credit to the private sector as an indicator of the financial development measured in millions of 2000 constant US dollars. All the data were retrieved from the World Bank database. The determinants of CO_2 emission, GDP growth, urbanization, trade openness, and financial development, are used by the previous literature. The previous studies reached the conclusion that these variables have a significant effect on pollution in general (see Table 1). Moreover, we included the square of GDP and

Table 6
The results of Pedroni's cointegration tests.

Tests	Statistics	*p*-values
Central & Eastern Europe		
Panel v-statistic	−2.131575	0.9835
Panel ρ-statistic	4.723344	1.0000
Panel PP-statistic	−10.05987[a]	0.0000
Panel ADF-statistic	−4.935300[a]	0.0000
Panel v-statistic (Weighted Statistic)	−4.319844	1.0000
Panel ρ-statistic (Weighted Statistic)	4.813215	1.0000
Panel PP-statistic (Weighted Statistic)	−17.44909[a]	0.0000
Panel ADF-statistic (Weighted Statistic)	−6.698232[a]	0.0000
Group ρ-statistic	6.645572	1.0000
Group PP-statistic	−31.17559[a]	0.0000
Group ADF-statistic	−8.856935[a]	0.0000
Western Europe		
Panel v-statistic	−1.244614	0.8934
Panel ρ-statistic	2.950946	0.9984
Panel PP-statistic	−6.406514[a]	0.0000
Panel ADF-statistic	−5.822229[a]	0.0000
Panel v-statistic (Weighted Statistic)	−2.129769	0.9834
Panel ρ-statistic (Weighted Statistic)	3.319158	0.9995
Panel PP-statistic (Weighted Statistic)	−8.625108[a]	0.0000
Panel ADF-statistic (Weighted Statistic)	−7.205098[a]	0.0000
Group ρ-statistic	4.905702	1.0000
Group PP-statistic	−18.21141[a]	0.0000
Group ADF-statistic	−6.880883[a]	0.0000
East Asia & the Pacific		
Panel v-statistic	−3.409139	0.9997
Panel ρ-statistic	3.154030	0.9992
Panel PP-statistic	−5.364489[a]	0.0000
Panel ADF-statistic	−5.030471[a]	0.0000
Panel v-statistic (Weighted Statistic)	−3.516388	0.9998
Panel ρ-statistic (Weighted Statistic)	3.930391	1.0000
Panel PP-statistic (Weighted Statistic)	−1.455315[c]	0.0728
Panel ADF-statistic (Weighted Statistic)	−3.272908[a]	0.0005
Group ρ-statistic	4.228176	1.0000
Group PP-statistic	−3.371286[a]	0.0004
Group ADF-statistic	−2.522856[a]	0.0058
Middle East & North Africa		
Panel v-statistic	−3.307238	0.9995
Panel ρ-statistic	1.763897	0.9611
Panel PP-statistic	−5.908788[a]	0.0000
Panel ADF-statistic	−4.843465[a]	0.0000
Panel v-statistic (Weighted Statistic)	−3.641072	0.9999
Panel ρ-statistic (Weighted Statistic)	1.207400	0.8864
Panel PP-statistic (Weighted Statistic)	−9.790945[a]	0.0000
Panel ADF-statistic (Weighted Statistic)	−7.572620[a]	0.0000
Group ρ-statistic	2.957279	0.9984
Group PP-statistic	−16.15888[a]	0.0000
Group ADF-statistic	−6.073888[a]	0.0000
South Asia		
Panel v-statistic	−1.340311	0.9099
Panel ρ-statistic	0.663055	0.7464
Panel PP-statistic	−4.662507[a]	0.0000
Panel ADF-statistic	−4.412170[a]	0.0000
Panel v-statistic (Weighted Statistic)	−2.775736	0.9972
Panel ρ-statistic (Weighted Statistic)	0.655392	0.7439
Panel PP-statistic (Weighted Statistic)	−9.872154[a]	0.0000
Panel ADF-statistic (Weighted Statistic)	−6.390176[a]	0.0000
Group ρ-statistic	1.264249	0.8969
Group PP-statistic	−10.05784[a]	0.0000
Group ADF-statistic	−4.841681[a]	0.0000
The Americas		
Panel v-statistic	−4.033058	1.0000
Panel ρ-statistic	3.455496	0.9997
Panel PP-statistic	−10.96784[a]	0.0000
Panel ADF-statistic	−9.550595[a]	0.0000
Panel v-statistic (Weighted Statistic)	−5.733630	1.0000
Panel ρ-statistic (Weighted Statistic)	4.196492	1.0000
Panel PP-statistic (Weighted Statistic)	−8.526773[a]	0.0000
Panel ADF-statistic (Weighted Statistic)	−8.555042[a]	0.0000
Group ρ-statistic	5.112418	1.0000
Group PP-statistic	−13.61197[a]	0.0000
Group ADF-statistic	−8.204104[a]	0.0000
Sub Saharan Africa		
Panel v-statistic	−2.091025	0.9817
Panel ρ-statistic	1.548485	0.9392
Panel PP-statistic	−10.66311[a]	0.0000
Panel ADF-statistic	−9.346097[a]	0.0000
Panel v-statistic (Weighted Statistic)	−5.649812	1.0000
Panel ρ-statistic (Weighted Statistic)	3.568081	0.9998
Panel PP-statistic (Weighted Statistic)	−6.406599[a]	0.0000
Panel ADF-statistic (Weighted Statistic)	−5.267850[a]	0.0000
Group ρ-statistic	4.533847	1.0000
Group PP-statistic	−15.19778[a]	0.0000
Group ADF-statistic	−8.460228[a]	0.0000

[a] denotes significance at the 1 percent level.
[c] denotes significance at 10 percent level.
lag length and bandwidth are selected by Schwarz Information Criterion (SIC) and the Bartlett kernel Newey–West estimator.

renewable energy consumption to examine whether there is a link between renewable energy consumption and the EKC hypothesis.

Testing the stationarity of the variables is essential in the econometric analysis as non-stationary variables cannot be utilized because they will cause erroneous outcomes. Therefore, the panel unit root test was implemented. Three types of panel unit root tests, namely ADF-Fisher (Maddala and Shaowen, 1999), Im, Pesaran and Shin (Im et al., 2003), and Levin, Lin and Chu (Levin et al., 2002) unit root test, were implemented to achieve robustness. The use of panel unit root tests increased among researchers because of their high power compared to the time series unit root tests. Theoretically, the panel unit root tests are multiple time series unit root tests that are modified for panel data structure. The above unit root tests have the same null hypothesis. This explains that if a panel unit root exists in the variables, the variables are deemed not to be stationary, while the alternative hypothesis indicates that if a panel unit root does not exist in the variables, the variables are deemed to be stationary. If the variables are stationary at the first difference, the next step is analyzing the long run relationship between the variables by utilizing the panel cointegration test.

Similar to the panel unit root test, the use of panel cointegration test increased among scholars due to its high power. Therefore, Pedroni (1999, 2004) and Fisher-type (Maddala and Shaowen, 1999) panel cointegration tests were utilized. The Pedroni cointegration test is based on the Engle–Granger (Engle and Granger, 1987) cointegration which implies that if the variables are cointegrated, the residuals are stationary at levels (variables integrated in order 0). However, if the variables are not cointegrated, the residuals are stationary at the first difference (variables integrated in order 1). Pedroni cointegration extended the Engle–Granger idea to work for the panel data structure. Pedroni established a number of tests for cointegration that allow heterogeneous intercepts and trend coefficients across cross-sections. Pedroni cointegration test considers the regression below:

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2\,i,t} + \cdots + \beta_{Mi} x_{Mi,t} + e_{i,t} \quad (2)$$

where x and y are supposed to be integrated in order one I(1), α_i and δ_i are the effects of individual and trend which might be set to zero if preferred, and $e_{i,t}$ represents the residuals.

The null hypothesis for the Pedroni cointegration test explains that if the residuals are integrated in order one I(1), cointegration between the variables does not exist and the null hypothesis cannot be rejected. To test integration of the residuals in Eq. (2), either of the following regressions can be used:

$$e_{it} = \rho_i e_{it-1} + u_{it} \quad (3)$$

$$e_{it} = \rho_i e_{it-1} + \sum_{j=1}^{pi} \psi_{ij} \Delta e_{it-j} + v_{it} \quad (4)$$

For every cross section, Pedroni defines numerous approaches for constructing statistics in order to test the null hypothesis of no cointegration ($\rho_i = 1$). Hence, two alternative approaches were implemented, specifically the homogenous alternative ($\rho_i = \rho$) < 1 for all the cross sections i (refers to the within-dimension test) and the heterogeneous alternative ($\rho_i < 1$) for all I, which refers to the between-dimension or group statistics test.

The Fisher-type cointegration test was proposed by Maddala and Shaowen (1999). They utilize Fisher's results and suggested an approach to test for panel cointegration by uniting the tests from individual cross-sections to get at test statistic for the full panel.

If the cointegration is confirmed, the next step in the econometric analysis is to examine the long run elasticity between the dependent variable, CO_2 emission, and the independent variables, GDP, the square of GDP, renewable energy consumption, trade openness, urbanization, and financial development. Therefore, the panel dynamic ordinary least squares (DOLS), proposed by Kao and Chiang (2000), was utilized. The DOLS involves augmenting the panel cointegrating equation with cross-section specific lags and leads to eliminate the endogenity and serial correlation among the variables. Kao and Chiang (2000) established the pooled DOLS estimator which uses OLS to estimate the augmented cointegrating regression that is presented below:

$$\tilde{y}_{it} = \tilde{X}_{it'}\beta + \sum_{j=-qi}^{r_i} \Delta\tilde{X}_{it'} + j\delta_i - \tilde{v}_{1\,it} \quad (5)$$

where $\tilde{y}_{it}$ and $\tilde{X}_{it}$ are the data removed from the individual deterministic trends and δ_i is the short-run dynamics coefficients which are allowed to be cross-sectional specific. The pooled DOLS estimator can be presented as follows:

$$\begin{bmatrix} \hat{\beta}_{DP} \\ \hat{y}_{DP} \end{bmatrix} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \tilde{W}_{it}\,\tilde{W}_{it'} \right)^{-1} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \tilde{W}_{it}\,\tilde{W}\,\tilde{y}_{it'} \right) \quad (6)$$

where $\tilde{W}_{it'} = (\tilde{X}_{it'}\,\tilde{Z}_{it'})$, $\tilde{Z}_{it'}$ is the regressors molded by relating the $\Delta\tilde{X}_{it+j}$ with the cross section dummy variables.

If a long run relationship between the variables exists, it implies that there might be causal relationships among the variables. In this case, the Granger causality will be utilized. There are two types of Granger causality. The first causality is the Granger causality based on the vector autoregression (VAR) model which captures the short run causality while the second type is the Granger causality based on the vector error correction model (VECM) which captures both the short run and the long run causality. If cointegration is confirmed among the variables, the Granger causality based on the VECM will be implemented. The VECM Granger causality reveals the short run causality based on the F-statistics while the long run causality is revealed through the use of the lagged error corrections term ect(−1). The VECM Granger causality is based on the following regression:

$$\begin{bmatrix} \Delta LCO2_{it} \\ \Delta LGDP_{it} \\ \Delta LGDP2_{it} \\ \Delta LRE_{it} \\ \Delta LTD_{it} \\ \Delta LUR_{it} \\ \Delta LFD_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \end{bmatrix} + \sum_{p-1}^{r} \begin{bmatrix} \beta_{11p} & \beta_{12p} & \beta_{13p} & \beta_{14p} & \beta_{15p} & \beta_{16p} & \beta_{17p} \\ \beta_{25p} & \beta_{26p} & \beta_{27p} & \beta_{28p} & \beta_{29p} & \beta_{30p} & \beta_{31p} \\ \beta_{39p} & \beta_{40p} & \beta_{41p} & \beta_{42p} & \beta_{43p} & \beta_{44p} & \beta_{45p} \\ \beta_{53p} & \beta_{54p} & \beta_{55p} & \beta_{56p} & \beta_{57p} & \beta_{58p} & \beta_{59p} \\ \beta_{67p} & \beta_{68p} & \beta_{69p} & \beta_{70p} & \beta_{71p} & \beta_{71p} & \beta_{72p} \\ \beta_{80p} & \beta_{81p} & \beta_{81p} & \beta_{82p} & \beta_{83p} & \beta_{84p} & \beta_{85p} \\ \beta_{93p} & \beta_{94p} & \beta_{95p} & \beta_{96p} & \beta_{97p} & \beta_{98p} & \beta_{99p} \end{bmatrix} \begin{bmatrix} \Delta LCO2_{it} \\ \Delta LGDP_{it} \\ \Delta LGDP2_{it} \\ \Delta LRE_{it} \\ \Delta LTD_{it} \\ \Delta LUR_{it} \\ \Delta LFD_{it} \end{bmatrix} + \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \\ \varphi_5 \\ \varphi_6 \\ \varphi_7 \end{bmatrix} ect_{it-1} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \\ \varepsilon_{6it} \\ \varepsilon_{7it} \end{bmatrix} \quad (7)$$

The t denotes the time (1980–2010), i denotes the cross sections (1. . .18 Latin America countries), ε_{it} is the error term, and the ect is the lagged error correction term. However, if there is no cointegration between the variables, the following Granger causality based on VAR will be utilized:

$$\begin{bmatrix} \Delta LCO2_{it} \\ \Delta LGDP_{it} \\ \Delta LGDP2_{it} \\ \Delta LRE_{it} \\ \Delta LTD_{it} \\ \Delta LUR_{it} \\ \Delta LFD_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \\ \alpha_7 \end{bmatrix} + \sum_{p-1}^{r} \begin{bmatrix} \beta_{11p} & \beta_{12p} & \beta_{13p} & \beta_{14p} & \beta_{15p} & \beta_{16p} & \beta_{17p} \\ \beta_{25p} & \beta_{26p} & \beta_{27p} & \beta_{28p} & \beta_{29p} & \beta_{30p} & \beta_{31p} \\ \beta_{39p} & \beta_{40p} & \beta_{41p} & \beta_{42p} & \beta_{43p} & \beta_{44p} & \beta_{45p} \\ \beta_{53p} & \beta_{54p} & \beta_{55p} & \beta_{56p} & \beta_{57p} & \beta_{58p} & \beta_{59p} \\ \beta_{67p} & \beta_{68p} & \beta_{69p} & \beta_{70p} & \beta_{71p} & \beta_{71p} & \beta_{72p} \\ \beta_{80p} & \beta_{81p} & \beta_{81p} & \beta_{82p} & \beta_{83p} & \beta_{84p} & \beta_{85p} \\ \beta_{93p} & \beta_{94p} & \beta_{95p} & \beta_{96p} & \beta_{97p} & \beta_{98p} & \beta_{99p} \end{bmatrix} \begin{bmatrix} \Delta LCO2_{it} \\ \Delta LGDP_{it} \\ \Delta LGDP2_{it} \\ \Delta LRE_{it} \\ \Delta LTD_{it} \\ \Delta LUR_{it} \\ \Delta LFD_{it} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \\ \varepsilon_{6it} \\ \varepsilon_{7it} \end{bmatrix} \quad (8)$$

3. Empirical Results

As mentioned previously, the first step of the econometric analysis is to examine the integration of the variables. Thus, the panel unit root test was used. The results of the ADF-Fisher test, the Im, Pesaran and Shin, and Levin, Lin and Chu unit root tests are displayed in Tables 3–5. The results of the tests reveal that all the variables are not significant at levels. Therefore, the null hypothesis of a unit root cannot be rejected. This indicates that the variables are not stationary. However, the results confirm that all the variables are significant at the first difference. This shows that the null hypothesis of a unit root can be rejected. Hence, the variables are stationary at the first difference.

Since the variables are stationary at the first difference, the next step is to investigate the long run relationship between the

Table 7
The results of Fisher's type cointegration tests.

Hypothesized No. of CE(s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-Eigen test)	Prob.
Central & Eastern Europe				
None	5.545	0.6980	5.545	0.6980
At most 1	4.159	0.8425	267.5[a]	0.0000
At most 2	2.773	0.9478	39.61[a]	0.0000
At most 3	0.000	1.0000	10.54[a]	0.0000
At most 4	73.68[a]	0.0000	73.68[a]	0.0000
At most 5	1054.[a]	0.0000	73.68[a]	0.0000
At most 6	60.45[a]	0.0000	60.45[a]	0.0000
Western Europe				
None	788.1[a]	0.0000	480.5[a]	0.0000
At most 1	568.2[a]	0.0000	237.7[a]	0.0000
At most 2	422.2[a]	0.0000	215.4[a]	0.0000
At most 3	312.2[a]	0.0000	166.2[a]	0.0000
At most 4	240.1[a]	0.0000	142.3[a]	0.0000
At most 5	154.0[a]	0.0000	110.0[a]	0.0000
At most 6	110.8[a]	0.0000	110.8[a]	0.0000
East Asia & the Pacific				
None	273.9[a]	0.0000	145.5[a]	0.0000
At most 1	150.3[a]	0.0000	74.02[a]	0.0000
At most 2	90.43[a]	0.0000	41.89[a]	0.0029
At most 3	62.35[a]	0.0000	33.95[b]	0.0265
At most 4	46.52[a]	0.0007	41.38[a]	0.0033
At most 5	33.28[b]	0.0314	33.28[b]	0.0314
Middle East & North Africa				
None	303.3[a]	0.0000	311.9[a]	0.0000
At most 1	236.4[a]	0.0000	127.4[a]	0.0000
At most 2	141.6[a]	0.0000	62.29[a]	0.0000
At most 3	94.07[a]	0.0000	44.46[a]	0.0000
At most 4	60.93[a]	0.0000	35.75[a]	0.0011
At most 5	38.58[a]	0.0004	35.60[a]	0.0012
At most 6	20.43	0.1172	20.43	0.1172
South Asia				
None	179.9[a]	0.0000	86.82[a]	0.0000
At most 1	126.7[a]	0.0000	59.43[a]	0.0000
At most 2	80.15[a]	0.0000	40.40[a]	0.0000
At most 3	48.10[a]	0.0000	32.19[a]	0.0001
At most 4	23.16[a]	0.0032	16.56[b]	0.0350
At most 5	13.46[c]	0.0969	12.03	0.1497
At most 6	12.82	0.1184	12.82	0.1184
The Americas				
None	662.2[a]	0.0000	353.4[a]	0.0000
At most 1	421.1[a]	0.0000	206.8[a]	0.0000
At most 2	257.5[a]	0.0000	125.2[a]	0.0000
At most 3	164.0[a]	0.0000	96.71[a]	0.0000
At most 4	109.3[a]	0.0000	83.55[a]	0.0001
At most 5	93.94[a]	0.0000	93.94[a]	0.0000
Sub Saharan Africa				
None	561.9[a]	0.0000	434.1[a]	0.0000
At most 1	414.4[a]	0.0000	219.6[a]	0.0000
At most 2	295.5[a]	0.0000	170.7[a]	0.0000
At most 3	237.4[a]	0.0000	152.1[a]	0.0000
At most 4	140.3[a]	0.0000	90.17[a]	0.0000
At most 5	82.00[a]	0.0000	70.29[a]	0.0000
At most 6	51.78[a]	0.0080	51.78[a]	0.0080

variables by implementing the Pedroni cointegration test. Table 6 displays the Pedroni cointegration test results. The results reveal that six statistics are significant for all regions, thus, rejecting the null hypothesis of no cointegration. Moreover, Table 7 reveals the Fisher type cointegration test results. The trace statistics confirm the existence of three cointegration equations in Central and Eastern Europe, six cointegration equations in Western Europe and Sub Saharan Africa, five cointegration equations in East Asia and the Pacific, South Asia, and the Americas. In addition, the max-Eigen test statistics reveal six cointegration equations in Central and Eastern Europe, Western Europe, and Sub Saharan Africa. Five cointegration equations are found in East Asia and the Pacific, Middle East and North Africa, and the Americas. Additionally, four cointegration equations are found in South Asia. The results generally indicate the existence of the long run relationship between the variables.

Since the variables are cointegrated, the dynamic OLS (DOLS) was applied. The results are shown in Table 8. The results of Central and Eastern Europe reveal that GDP has a long run positive relationship with CO_2 emission. The increase in GDP by 1 percent will increase CO_2 emission by 4.747569 percent. Moreover, the trade openness has a long run relationship with CO_2 emission. The increase in trade openness by 1 percent will increase CO_2 emission by 0.182095 percent. Moreover, urbanization increases CO_2

Table 8
The results of panel pooled DOLS.

Country	Dependent variable: LCO2					
	LGDP	LGDP2	LRE	LTD	LUR	LFD
Central & Eastern Europe	4.747569[a]	−0.086181[a]	−0.027092	0.182095[a]	1.874838[a]	0.002083[c]
	(3.575885)	(−3.092012)	(−2.695292)	(2.663516)	(3.029516)	(1.966964)
Western Europe	5.397392[a]	−0.084215[a]	−0.134937[a]	−0.145035[b]	0.091875	−0.000460[a]
	(2.739615)	(−2.222045)	(−8.468093)	(−2.458776)	(0.415437)	(−2.443539)
East Asia & the Pacific	6.150363[a]	−0.112293[a]	−0.244477[a]	−0.142200	1.147317[a]	0.003071[a]
	(3.080895)	(−2.861183)	(−3.316413)	(−0.990310)	(2.836862)	(3.550348)
Middle East & North Africa	0.618593[a]	0.011564[a]	−0.008981	−0.043101	1.233369[a]	0.000976
	(4.104664)	(3.780781)	(−0.353317)	(−0.479253)	(5.918370)	(0.885246)
South Asia	7.344507[a]	−0.113480[a]	−0.151474[a]	0.137400[a]	0.516816[a]	0.005864[a]
	(8.691185)	(−6.942812)	(−4.886139)	(2.874855)	(3.996254)	(5.495079)
The Americas	3.739639[a]	−0.069926[a]	−0.100670[a]	0.109547[b]	1.087689[a]	0.000797
	(5.103943)	(−4.628416)	(−3.824657)	(2.253821)	(9.856840)	(1.462135)
Sub Saharan Africa	−0.113479	0.005461	0.025568	0.368726[c]	0.963540	0.019278[a]
	(−0.292438)	(0.395165)	(0.229276)	(1.878339)	(4.049236)	(4.698692)

a, b and c denote significance at the 1, 5 and 10 percent levels, respectively.
Figures in the parenthesis () are the *t*-statistics.

emission in the long run. Its increase by 1 percent will increase CO_2 emission by 1.874838 percent. Furthermore, financial development is found to increase pollution in the long run. The increase in financial development by 1 percent will increase CO_2 emission by 0.002083 percent. Similarly, the square of GDP reduces pollution in the long run. The increase in the square of GDP by 1 percent will reduce CO_2 emission by 0.086181 percent. In addition, renewable energy consumption has a negative significant long run effect on CO_2 emission. The increase in renewable energy consumption by 1 percent will reduce CO_2 emission by -0.027092 percent. Moreover, since GDP has a positive long run effect on CO_2 emission while square of GDP has a negative long run effect on CO_2 emission, the existence of the EKC hypothesis's inverted U-shaped relationship between income and pollution can be confirmed.

For Western Europe, the results reveal that GDP, trade openness, and urbanization increase CO_2 emission while renewable energy consumption and financial development reduce CO_2 emission. The increase in GDP, trade openness, and urbanization by 1 percent will increase CO_2 emission by 5.397392, 2.663516, and 3.029516 percent, respectively, while the increase in renewable energy consumption and financial development will reduce CO_2 emission by 0.134937 and 0.000460 percent, respectively. Therefore, the EKC hypothesis can be confirmed because an inverted U-shaped relationship is formulated from the positive relationship between GDP and CO_2 emission as well as the negative relationship between the square of GDP and CO_2 emission.

The results for East Asia and the Pacific show that GDP, urbanization, and financial development increase pollution in the long run by their positive affect on CO_2 emission. The increase in these variables by 1 percent will increase CO_2 emission in the long run by 6.150363, 1.147317, and 0.003071 percent, respectively. However, renewable energy consumption reduces pollution in the long run. Its increase by 1 percent will reduce CO_2 emission in the long run by 0.244477. In addition, trade openness has no significant long run effect on CO_2 emission. The EKC hypothesis can be confirmed because GDP and its square reveal an inverted U-shaped relationship with CO_2 emission.

Regarding the Middle East and North Africa, the results show that urbanization and GDP increase CO_2 emission in the long run. The increase in urbanization and GDP by 1 percent will increase CO_2 emission by 1.233369 and 0.618593 percent, respectively. Nevertheless, renewable energy consumption, trade openness, and financial development have a negative significant long run effect on CO_2 emission. The EKC hypothesis does not exist as GDP and its square have a positive significant effect on CO_2 emission.

The results for South Asia reveal that the increase in GDP, trade openness, urbanization, and financial development by 1 percent will increase CO_2 emission by 7.344507, 0.137400, 0.516816, and 0.005864 percent, respectively, while the increase in renewable energy consumption by 1 percent will reduce CO_2 emission by 0.151474%. The EKC hypothesis can be confirmed as an inverted U-shaped relationship is found between GDP and its square and CO_2 emission.

The DOLS results for the Americas show that the increase in GDP, trade openness, and urbanization will increase CO_2 emission in the long run by 3.739639, 0.109547, and 1.087689 percent, respectively. On the other hand, the increase in renewable energy consumption by 1 percent will reduce CO_2 emission in the long run by 0.100670 percent. Moreover, financial development has no significant long run effect on CO_2 emission. Since GDP has a positive relationship with CO_2 emission and the square of GDP has a negative relationship with CO_2 emission, the EKC hypothesis can be confirmed.

The results for Sub Saharan Africa show that only trade openness has a significant positive long run relationship with CO_2 emission. The increase in trade openness by 1 present will increase CO_2 emission by 0.368726 percent. However, the rest of the variables are not significant, therefore, the EKC hypothesis cannot be confirmed.

Since the variables are cointegrated, the Granger causality based on the VECM was implemented. The results are presented in Table 9. The Granger results for Eastern and Central Europe reveal, based on the ect(−1), the existence of a bi-directional long run causal relationship among all the variables with the exclusion of urbanization. The short run causality results show that a bi-directional causal relationship exists between CO_2 emission and GDP, CO_2 emission and the square of GDP, CO_2 emission and trade openness, and between trade openness and the square of GDP. However, a unidirectional causality was found from renewable energy consumption to CO_2 emission, trade openness to GDP, financial development to GDP, renewable energy consumption to the square of GDP, and from financial development to the square of GDP.

For Western Europe, bi-directional long run causality between CO_2 emission, GDP, and renewable energy consumption exists. Moreover, a bi-directional causal relationship is found between renewable energy consumption and CO_2 emission, urbanization and CO_2 emission, GP and the square of GDP, trade openness and the square of GDP, and between trade openness and urbanization. However, a one directional causality is concluded from GDP to CO_2 emission, trade openness to GDP, GDP to financial

Table 9
The results of panel Granger causality tests.

	LCO2	LGDP	LGDP2	LRE	LTD	LUR	LFD	ect(−1)
Central & Eastern Europe								
LCO2	–	3.775433[a]	3.563781[a]	5.515820[a]	4.732170[a]	0.498990	0.652333	−1.862655[c]
LGDP	2.162117[c]	–	0.268188	0.774661	44.33772[a]	0.344829	6.831305[a]	−3.477938[a]
LGDP2	2.455860[b]	0.657900	–	3.545151[a]	36.76850[a]	0.381404	2.968274[b]	−3.236539[a]
LRE	0.319396	0.939409	1.024776	–	0.618279	0.915813	1.016335	−3.385933[a]
LTD	6.910465[a]	1.068224	1.961307[c]	0.824375	–	0.347800	0.200516	−2.030509[c]
LUR	0.933698	0.498811	0.378589	0.613031	0.093526	–	1.329753	−0.376542
LFD	0.446687	0.533694	0.643835	0.353483	0.806231	1.511175	–	−3.700077[a]
Western Europe								
LCO2	–	0.575211	0.763645	8.326045[a]	0.923660	3.695917[b]	0.431820	−1.980347[b]
LGDP	6.731916[a]	–	2.789481[b]	0.347319	106.9228[a]	1.364250	1.855939	−0.371606
LGDP2	0.525193	20.78360[a]	–	0.487506	5.119893[a]	1.740410	3.443940	−1.694704[c]
LRE	11.62889[a]	0.547367	0.601952	–	1.313885	0.406844	1.725395	−7.885666[a]
LTD	0.708985	1.649239	2.981033[b]	0.186908	–	3.799426[a]	0.781679	−1.489034
LUR	2.436907[b]	0.685671	0.184407	1.336973	11.52454[a]	–	11.47632[a]	−0.934227
LFD	0.889584	2.660277[b]	2.126749[c]	2.643052[b]	1.786890	1.637273	–	−1.318593
East Asia & the Pacific								
LCO2	–	1.434007	1.284242	6.164287[a]	0.772117	1.259405	0.493322	−1.690143[c]
LGDP	0.794481	–	99.58455[a]	1.633238	0.782910	0.678957	1.013759	−1.144240
LGDP2	0.514895	119.4174[a]	–	0.712719	0.637563	0.710631	0.755548	−1.483082
LRE	2.294301[b]	0.908145	0.726656	–	1.055142	1.954632[c]	0.780349	−1.949381[c]
LTD	0.660723	0.437833	1.659754	0.244665	–	0.328643	0.177357	−3.666233[a]
LUR	7.133365[a]	1.093291	0.938047	0.943442	0.956394	–	−1.144414	−0.786516
LFD	0.602944	1.426026	1.391321	0.880930	1.229681	2.358085[c]	–	−2.804527[a]
Middle East & North Africa								
LCO2	–	1.118063	1.267481	0.911059	0.949217	0.388492	0.682614	−1.680034[c]
LGDP	1.064103	–	2.864692[b]	2.281817[c]	11.12368[a]	2.214462[c]	1.393515	−2.114335[b]
LGDP2	1.466760	171.0819[a]	–	0.530464	3.741789[a]	9.987002[a]	0.622534	−0.706600
LRE	1.073656	0.134901	0.014804	–	1.329288	0.944413	0.878242	−1.885204[c]
LTD	1.524056	2.753453[b]	3.026096[a]	3.352793[a]	–	1.829921	1.178177	−3.750067[a]
LUR	1.630474	4.362356[a]	4.037121[a]	0.168994	1.730500	–	0.705558	−1.716937[c]
LFD	2.842497[b]	1.172650	1.318290	1.296317	0.797485	4.819568[a]	–	−3.906657[a]
South Asia								
LCO2	–	1.289796	1.354451	3.973818[a]	1.263192	0.175057	0.498758	−4.324894[a]
LGDP	1.563145	–	53.72122[a]	1.054807	1.790702	4.184395[a]	0.694042	−0.336930
LGDP2	1.690161	47.61982[a]	–	1.316577	1.693768	3.131929[a]	0.930469	−0.991382
LRE	5.404056[a]	0.651728	0.379686	–	1.307150	0.115886	0.934560	−2.215079[b]
LTD	1.179025	0.798477	1.053778	3.206692[b]	–	0.423577	0.172366	−0.635277
LUR	1.215736	2.081565[c]	1.953636[c]	0.966203	0.112157	–	0.584932	−0.103694
LFD	4.806313[a]	1.525372	1.778043	1.117004	0.571877	0.765838	–	−1.519037
The Americas								
LCO2	–	5.025496[a]	4.990589[a]	9.044840[a]	1.588238	3.764917[a]	0.580997	−2.528296[b]
LGDP	3.542490[a]	–	1.841267	3.491094[a]	85.21917[a]	0.184014	0.325556	0.482902
LGDP2	0.286870	21.46971[a]	–	0.888774	0.522732	2.863779[c]	0.899914	0.072525
LRE	9.678777[a]	0.455540	0.393788	–	2.988893[c]	1.195404	0.273543	−2.434519[b]
LTD	0.992746	2.107125[a]	2.874220[b]	1.351962	–	0.478709	1.406212	−4.784797[a]
LUR	3.009077[a]	2.748354[c]	1.949554	1.044483	0.619389	–	0.721785	−1.416101
LFD	1.347410	1.532980	2.047625[c]	0.894479	1.538832	0.084152	–	−3.658966[a]
Sub Saharan Africa								
LCO2	–	0.833471	0.945583	0.152772	1.147337	0.571035	0.571906	−2.175234[b]
LGDP	0.713307	–	35.07824[a]	6.108991[a]	1.091874	3.043050[a]	0.660628	−2.024242[a]
LGDP2	0.755004	58.76972	–	4.187747[a]	2.608199[b]	0.826650	1.634851	−1.654164[c]
LRE	0.564202	2.601912[b]	2.584051[b]	–	0.107964	0.632587	1.417860	−0.458903
LTD	0.322206	2.611375[b]	2.731567[b]	0.497604	–	2.120364[c]	0.926788	−2.347018[b]
LUR	0.862587	0.609710	0.649752	0.487959	0.383071	–	0.446207	−0.109335
LFD	0.414399	2.879846[b]	1.578804	0.623117	0.795375	1.717458	–	−2.363547[b]

[a] denote significance at the 1 percent levels.
[b] denote significance at the 5 percent levels.
[c] denote significance at the 10 percent levels.

development, the square of GDP to financial development, renewable energy consumption to financial development, and from financial development to urbanization.

The results for East Asia and the Pacific indicate the existence of a bi-directional long run causal relationship between CO_2 emission, renewable energy consumption, trade openness, and financial development. In addition, a bi-directional short run causal relationship is found between CO_2 emission and renewable energy consumption, GDP and the square of GDP, and between urbanization and trade openness. A unidirectional causality is also found from trade openness to GDP, GDP to financial development, trade openness to the square of GDP, the square of GDP to financial development, CO_2 emission to urbanization, and from renewable energy consumption to financial development.

The Granger causality results for the Middle East and North Africa reveal the existence of a long run bi-directional causality between CO_2 emission, GDP, renewable energy consumption, trade openness, urbanization, and financial development. The outcome for the short run causality confirms the existence of a bi-directional causal relationship between GDP and the square of GDP, trade openness and GDP, urbanization and GDP, trade openness and the square of GDP, and between urbanization and the square of GDP. Moreover, a unidirectional causality is also found from CO_2 emission to financial development, renewable energy consumption to

GDP, renewable energy consumption to trade openness, and from urbanization to financial development.

The results for South Asia reveal the existence of a short run bi-directional causality between renewable energy consumption and CO_2 emission, GDP and the square of GDP, urbanization and GDP, and between urbanization and the square of GDP. Moreover, a unidirectional causality from CO_2 emission to financial development and renewable energy consumption to trade openness is also confirmed. In addition, based on the lagged error correction term, bi-directional long run Granger causality between CO_2 emission and renewable energy consumption is confirmed.

For the Americas, the results show a short run bi-directional causal relationship between GDP and CO_2 emission, the square of GDP and CO_2 emission, renewable energy consumption and CO_2 emission, urbanization and CO_2 emission, and between trade openness and GDP. Moreover, a one way causal relationship is found from trade openness to CO_2 emission, GDP to the square of GDP, renewable energy consumption to the square of GDP, GDP to urbanization, the square of GDP to trade openness, urbanization to the square of GDP, the square of GDP to financial development, and from trade openness to renewable energy consumption. In addition, a long run causality between CO_2 emission, renewable energy consumption, trade openness, and financial development is also confirmed.

The results from the Sub Saharan Africa reveal the existence of bi-directional long run causality between CO_2 emission, GDP, the square of GDP, Trade openness, and financial development. Moreover, a bi-directional causal relationship is confirmed between GDP and renewable energy consumption, renewable energy consumption and the square of GDP, and between the square of GDP and trade openness. Furthermore, a one way causality from the square of GDP to GDP, the square of GDP to trade openness, urbanization to GDP, GDP to financial development, and from urbanization to financial development is also confirmed.

4. Conclusion and policy implications

The aim of this research is to investigate how renewable energy consumption effects pollution and whether the relationship between income and pollution formulates the inverted U-shaped relationship which signals the existence of the EKC hypothesis. To investigate this relationship, a panel model that represents pollution was established to examine the seven selected regions during the period of 1980–2010. Moreover, this study utilized CO_2 emission as an indicator of pollution and the gross domestic product, renewable energy consumption, total openness, urbanization, and financial development as economic indicators.

The results retrieved from the Pedroni cointegration revealed the existence of a long run relationship among the variables which confirms cointegration in all the investigated regions. In addition, the DOLS and the VECM Granger causality (focusing on the short run causality) results showed that renewable energy consumption has a significant and negative effect on CO_2 emission in Central and Eastern Europe, Western Europe, East Asia and the Pacific, South Asia, and the Americas. The results also revealed that renewable energy consumption has no significant effect on CO_2 emission in the Middle East and North Africa and Sub Saharan Africa. Moreover, the results indicated that the existence of the EKC hypothesis is determined by the significance of the renewable energy consumption because the EKC hypothesis only existed in the regions where their renewable energy consumption has a significant effect on CO_2 emission. In other words, EKC hypothesis is confirmed in five regions except Middle East and North Africa and Sub Saharan Africa in where renewable energy consumption has no significant effect on CO_2 emission.

Based on the results of this study, the following policy implications are suggested: (i) For the regions (Central and Eastern Europe, Western Europe, East Asia and the Pacific, South Asia, and the Americas) that renewable energy consumption has a significant and negative effect on CO_2 emission, it is important to utilize policies that help establish new projects and implement green technologies that promote renewable energy and energy efficiency. In addition, the increase in energy efficiency and the role of renewable energy from total energy consumption can help increase energy security by reducing the region's dependency on imported fossil fuels. Moreover, the reduction in the consumption of fossil fuels can also be a key solution for reducing greenhouse gas emission as fossil fuels represent its main source. (ii) For the Middle East and North Africa, renewable energy consumption has no significant effect on CO_2 emissions because at present renewables contribute only a mere one percent to the region's primary energy mix. Subsidies for fossil fuels pose a significant barrier to renewable energy and thus ought to be phased out in these countries to increase the level of renewable energy in order to reduce the high level of CO_2 emissions. Also we suggest that natural gas is the best-suited nonrenewable energy carrier to accompany the introduction of renewables due to the both environmental and economic reasons. In addition, we recommend for urban planners to utilize policies that will allow them to improve urban planning by controlling sewage, industrial waste, and solid waste which are some of the major causes for the environmental deterioration in these countries. (iii) For Sub Saharan Africa, since only trade openness has a significant positive effect on CO_2 emissions, these countries should implement pollution and trade-related actions and strategies to increase the environmental protection from trade.

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