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Does moving towards renewable energy cause water and land inefficiency? An empirical investigation

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HIGHLIGHTS

- The effect of renewable energy production on water and land footprint is studied.
- 58 developed and developing countries were examined for the period of 1980–2009.
- Eight different models were constructed to achieve robustness in the outcomes.
- GDP, urbanization, and trade openness increase the water and land footprint.
- Renewable energy production increases the water and land inefficiency.

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ABSTRACT

This study investigates the effect of renewable energy production on water and land footprint in 58 developed and developing countries for the period of 1980–2009. Utilizing the ecological footprint as an indicator, the fixed effects, difference and system generalized method of moment (GMM) approaches were employed and eight different models were constructed to achieve robustness in the empirical outcomes. Despite the use of different methods and models, the outcome was the same whereby GDP growth, urbanization, and trade openness increase the water and land footprint. Moreover, renewable energy production increases the water and land inefficiency because of its positive effect on ecological footprint. Additionally, based on the square of GDP it is concluded that the EKC hypothesis does not exist while the square of renewable energy production indicates that renewable energy production will continue to increase water and land footprint in the future. From the outcome of this study, a number of recommendations were provided to the investigated countries.

1. Introduction

The increase in environmental pressure that the globe is witnessing (due to the consumption of fossil fuels in the world) is forcing countries to adopt renewable energy as an alternative to fossil fuels. It is well known that renewable energy can play a significant role in reducing air pollution and increasing the countries' energy security by reducing their dependency on fossil fuels. On the other hand, if the world replaces fossil fuels energy with renewables, it is important to take into consideration the use of water and land. Similar to fossil fuels, renewable energy sources, such as biofuels, solar, wind and geothermal energy, require substantial amount of water and land. The rapid increase in world population increased the scarcity of water and land availability, thus the global move towards renewable energy sources may escalate water and land insufficiency (Hoekstra, 2015). Since renewable energy sources require substantial amounts of land and water resources, given the limitation of land and water availability, therefore, these energy scenarios may be feasible and important in the long run.

There is a considerable number of empirical literature regarding the influence of renewable energy consumption on the gross domestic product (GDP) (Aguirre and Ibikunle, 2014; Apergis and Payne, 2011a, 2011b; Shahbaz et al., 2015; Inglesi-Lotz, 2015; Tugcu et al., 2012; Omri et al., 2015; Lin and Moubarak, 2014; Bloch et al., 2015; and so forth) and air pollution (Sebri and Ben-Salha, 2014; Menyah and Wolde-Rufael, 2010a, 2010b; Jaforullah

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and King, 2015; Özbuğday and Erbas, 2015; Shafiei and Salim, 2014; Jebli and Youssef, 2015; and so forth). The outcome of these studies reached the conclusion that renewable energy consumption plays a significant effect in increasing GDP growth and reducing air pollution. However, there is a lack of empirical literature that examined the influence of renewable energy production on water and land footprint.

The global production of renewable energy escalated especially after the first adoption of Kyoto Protocol in Japan in 1997. The researchers of this study believe that this large escalation in renewable energy production that the world is witnessing over the last three decades may cause water and land inefficiency. Therefore, this study will examine the influence of renewable energy production on water and land footprint. Table 1 reviews the literature that investigated the relationship between environmental degradation, economic activities, and energy consumption. Most of the previous studies found that GDP growth and energy consumption are the main factors that increase air pollution (Zhang and Cheng, 2009; Menyah and Wolde-Rufael, 2010a, 2010b; Pao and Tsai, 2011a, 2011b; Hossain, 2011; Chandran and Tang, 2013; Kohler, 2013; Saboori and Sulaiman, 2013a, 2013b; Shahbaz et al., 2013a, 2013b; Ozturk and Al-Mulali (2015); Al-Mulali et al., 2015a, 2015b, 2015c, 2015d, 2015e; Ajmi et al., 2015; Heidari et al., 2015; Bastola and Sapkota, 2015; Kasman and Duman, 2015; and so forth). Moreover, other important air pollution determinants were found such as urbanization (Hossain, 2011; Omri, 2013; Al-Mulali, 2014; Al-Mulali et al., 2015a, 2015b, 2015c, 2015d, 2015e; and Kasman and Duman, 2015), trade openness (Jayanthakumaran et al., 2012; Omri, 2013; Kohler, 2013; Shahbaz et al., 2013a, 2013b; Farhani et al. 2014; Ozturk and Al-Mulali, 2015; Kasman and Duman, 2015; and Halicioglu, 2009), financial development (Al-Mulali et al., 2015a, 2015a; Shahbaz et al., 2013a, 2013b), foreign direct investment (FDI) (Al-Mulali, 2012; Chandran and Tang, 2013; Al-Mulali and Tang, 2013; and Pao and Tsai, 2011a, 2011b), and so forth.

In addition, most of the studies used CO_2 emission as an indicator of environmental degradation (see Table 1). However, there is a lack of studies that investigated the effect of renewable energy on the environmental degradation. The aim of this study is to address this gap in the energy economics literature.

This study, therefore, examines the effect of renewable energy production on water and land footprint in 58 developed and developing countries for the period of 1980–2009. The ecological footprint as an indicator, the fixed effects, as well as difference and system generalized method of moment (GMM) approaches were employed and eight different models were constructed to achieve robustness in the empirical outcomes. The rest of the paper is organized as follows: methodology and data are presented in Section 2, empirical results are presented in Sections 3 and 4 provides the conclusion and policy implication.

2. Methodology

The same factors responsible for CO_2 emissions are also the determinants of ecological footprint. Since the main goal of this study is to examine the influence of renewable energy on water and air footprint, the ecological footprint is the optimal choice because water and land footprint are included in this variable. The existing literature has modelled the determinants of emission by using several variables; for instance, aggregate and disaggregate energy production (or consumption) series have been used by the existing literature as determinants of emission (Ang, 2007, 2008). Also, standard theories such as STRIPAT (which stands for *Stochastic Impacts by Regression on Population, Affluence and Technology)* have argued that the level of environmental degradation is determined by a nation's level of affluence, its demographic characteristics, and the available technology (Dietz and Rosa, 1994, 1997; Suh, 2013). While affluence and demography can be easily represented by macroeconomic indicators, representing technology is not straight forward. Real GDP can proxy affluence, while urbanization can be utilized to proxy the demographic characteristics of a country. The technology term represents all other factors other than population and affluence (Suh, 2013). Therefore, we use trade openness to represent the level of technology in a country. Moreover, we examine the determinants of ecological footprints with the following model:

$$Y = f(RE, GDP, URB, TRA) \tag{1}$$

Here, Y is ecological footprints, RE is electricity production from renewable sources, excluding hydroelectricity, GDP is real GDP, URB is the total urban population, and TRA is real trade openness (real exports of goods and services plus real imports of goods and services). The data of ecological footprint were retrieved from the Global Footprint Network (2015), while the data for the remaining variables were obtained from the World Development Indicators (WDI) (2015) for the period of 1980–2009. The number of investigated countries in this paper is 58.[1] We transformed all the variables into logarithmic form, which produces better result compared to the linear functional form (Shahbaz and Lean, 2012). The empirical equation of the model is given as follows:

$$\ln Y_{it} = \alpha_1 + \alpha_2 \ln RE_{it} + \alpha_3 \ln GDP_{it} + \alpha_4 \ln URB_{it} + \alpha_5 \ln TRA_{it} + \varepsilon_{it} \tag{2}$$

where, $\ln Y$ is natural log of ecological footprints, $\ln RE$ is natural log of electricity production from renewable sources, excluding hydroelectricity, $\ln GDP$ is natural log of real GDP, $\ln URB$ is natural log of total urban population, $\ln TRA$ is natural log of real trade openness, and ε is error term with the assumption of normal distribution.

We utilize the system generalized method of moment (GMM) procedure to estimate the determinants of ecological footprints. Introduced by Hansen (1982), GMM is perceived as an internal instrument estimator because it relies on previous values of the regressors. The method offers several advantages over the traditional panel estimation techniques. As contrary to the older panel techniques, GMM relaxes the assumptions of both serial correlation and heteroscedasticity. Therefore, under weak distributional assumptions, the methods of moments are ideal in obtaining parameter estimators that are unbiased and consistent. The estimator is known to produce unreliable estimates when employed in dynamic models. Extant papers illustrate that in dynamic panels, within group method may produce coefficients that are likely to be biased downwards, while OLS may produce coefficients that are likely to be biased upwards. According to Baum et al. (2003), GMM estimator produces more efficient output than the simple instrumental variable technique. Given the dimension of the data, the econometric method is also suitable. This research use a panel data with finite time span *(T)* and a sizeable number of cross-sectional units *(N)*. The system GMM estimator is appropriate to this kind of data structure (Arellano and Bover, 1995; Blundell and Bond, 1998). The method works with the notion that regressors

[1] Argentina, Australia, Austria, Belgium, Bolivia, Brazil, Canada, Chile, China, Colombia, Costa Rica, Denmark, Dominican Republic, Egypt, El Salvador, Finland, France, Gabon, Germany, Greece, Guatemala, Honduras, Hungary, Iceland, India, Indonesia, Iran, Italy, Japan, Jordan, Kenya, Korea, Luxembourg, Mexico, Morocco, Netherlands, New Zealand, Nicaragua, Norway, Panama, Peru, Philippines, Poland, Portugal, Romania, Senegal, Singapore, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Togo, Trinidad and Tobago, Turkey, United States of America and Uruguay.

Table 1
Summary of the literature on the environmental Kuznets curve.

Author	Period	Country/region/organization	Methodology	The indicator for environmental degradation	The economic variables indicators	Empirical results
Ozturk and Al-Mulali (2015)	1996–2012	Cambodia	Generalized Method of Moments (GMM) and the Two-stage Least Squares (TSLS).	CO_2 emission.	GDP, urbanization, trade openness, control of corruption and governess.	Energy consumption and trade openness increase the environmental degradation while GDP the control of corruption decreases it.
Al-Mulali et al., (2015e)	1980–2008	93 countries classified by income.	Panel fixed effects and Generalized Method of Moments (GMM).	Ecological footprint.	GDP, urbanization, trade openness, energy consumption and financial development.	GDP, urbanization, trade openness energy consumption increase ecological footprint in most of the countries.
Bella et al. (2014)	1965–2006	OECD countries	Henceforth LLL and vector error correction model (VECM) Granger causality.	CO_2 emission.	GDP and energy consumption.	CO_2 emission, energy consumption and GDP are cointegrated. GDP has a causal effect on CO_2 emission.
Hossain (2011)	1971–2007	Newly industrialized countries	Johansen panel cointegration and VECM Granger causality.	CO_2 emission.	GDP, energy consumption, urbanization and trade openness.	GDP, energy consumption, urbanization and trade openness are cointegrated. GDP and energy consumption have causal effect on CO_2 emission.
Al-Mulali and Ozturk (2015)	1996–2012	MENA (Middle East and North African) region	Pedroni cointegration, fully modified lease square (FMOLS) and VECM Granger causality.	Ecological footprint	Urbanization, trade openness, industrial output and political stability.	Urbanization, trade openness, and industrial output increase ecological footprint in the long run while political stability reduces it. All the variables have a causality effect on the ecological footprint.
Zhang and Cheng (2009)	1960–2007	China	Toda and Yamamoto Granger causality and generalized impulse response	CO_2 emission.	GDP, urbanization, capital and energy consumption	Energy consumption Granger causes CO_2 emission while income Granger causes GDP.
Chandran and Tang (2013)	1971–2008	Association of Southeast Asian Nations (ASEAN)–5economies	Johansen cointegration and VECM Granger causality.	CO_2 emission.	Energy consumption from road transportation, GDP, foreign direct investment (FDI).	CO_2 emission, GDP, transport energy consumption and foreign direct investment are cointegrated for Indonesia, Malaysia, and Thailand. GDP and transport energy consumption have a positive long run effect on CO_2 emission. CO_2 emission, transport energy consumption and GDP Granger cause each other in the mentioned above countries.
Al-Mulali and Sheau-Ting (2014)	1990–2011	189 countries by region.	Panel FMOLS.	CO_2 emission.	Energy consumption, Imports, exports and trade openness.	Trade variables increase both energy consumption and CO_2 emission in most of the investigated regions.
Al-Mulali et al. (2015c)	1980–2010	Latin America and the Caribbean countries.	Kao cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP, energy consumption and financial development.	GDP and energy consumption increase CO_2 emission in the long run while financial development reduces it. Renewable energy has no significant long run effect on CO_2 emission. Bidirectional causality was found among CO_2 emission, energy consumption, GDP, and financial development.
Menyah and Wolde-Rufael (2010a, 2010b)	1965–2006	South Africa	Autoregressive distributive lag (ARDL) and Toda and Yamamoto Granger causality.	CO_2 emission.	GDP, energy consumption, capital and labor.	CO_2 emission, GDP, energy consumption, labor and capital are cointegrated. GDP increases CO_2 emission in the long run. Unidirectional causality was found from CO_2 emission to GDP, energy consumption to GDP, and from energy consumption to CO_2 emission.
Hamit-Haggar (2012)	1990–2007	Canada	Pedroni cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	Energy consumption and GDP increase CO_2 emission in the long run, bidirectional causality was found between the variables.
Omri (2013)	1990–2011	MENA countries.	GMM model.	CO_2 emission.	GDP, energy consumption, urbanization, trade openness.	GDP, energy consumption, and urbanization increase CO_2 emission while trade openness has no significant effect on CO_2 emission.
Ajmi et al. (2015)	1970–2010	G-7 countries.	Time variation dynamic Granger causality.	CO_2 emission.	GDP and energy consumption.	Unidirectional causality running from GDP to energy consumption for Italy, bidirectional

Table 1 (*continued*)

Author	Period	Country/region/ organization	Methodology	The indicator for environmental degradation	The economic variables indicators	Empirical results
						causality between GDP and energy consumption for Japan, unidirectional causality running from energy consumption to GDP for the resource country Canada. bidirectional causality Between energy consumption and CO_2 emissions for the United States, causality from energy consumption to CO_2 emissions for France. One way causality from GDP to CO_2 emissions for Italy and Japan.
Heidari et al. (2015)	1980–2008	ASEAN.	Panel smooth transition regression (PSTR) model	CO_2 emission.	GDP and energy consumption.	GDP and energy consumption increase CO_2 emission.
Al-Mulali (2014)	1990–2010	30 major nuclear producer countries.	Pedroni cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP, fossil fuels energy consumption, nuclear energy consumption and urbanization.	CO_2 emission, fossil fuel energy consumption, nuclear energy consumption, urbanization are cointegrated. GDP and fossil fuel energy consumption increase CO_2 emission in the long run while nuclear energy consumption and urbanization have no significant effect on CO_2 emission. Bi-directional causality between fossil fuel energy consumption, nuclear energy consumption and CO_2 emission. Feedback causality was also found between GDP and CO_2 emission and between urbanization and GDP. Unidirectional causality was found from urbanization to CO_2 emission.
Ang (2007)	1971–1999	Malaysia	Johansen cointegration and VECM Granger causality.	CO_2 emission.	GDP and energy consumption	CO_2 emission, energy consumption and GDP are cointegrated. Energy consumption and GDP increase CO_2 emission in the long run. One way causality was found from GDP to CO_2 emission and GDP to energy consumption. Bidirectional causality was found between GDP and energy consumption.
Jafari et al. (2012)	1971–2007	Indonesia	TY Granger causality.	CO_2 emission.	GDP, energy consumption, capital and labor.	No causality was found between GDP, CO_2 emission and energy consumption. One way causality was found from urbanization to energy consumption.
Farhani et al. (2014)	1971–2008	Tunisia	Autoregressive distributive lag (ARDL) and VECM Granger causality.	CO_2 emission.	GDP, energy consumption and trade openness.	GDP and energy consumption increase CO_2 emission while trade openness has no in both short and long run. Significant effect on CO_2 emission. Bidirectional causality was found between energy consumption and CO_2 emission while the causality was unidirectional from GDP to CO_2 emission.
Kasman and Duman (2015)	1992–2010	European Union	Pedroni and Kao cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP, energy consumption, urbanization and trade openness.	All the variables are cointegrated. GDP, energy consumption, urbanization and trade openness increases CO_2 emission in the long run. Bidirectional causality was found between CO_2 emission, GDP, energy consumption and trade openness. One way causality was found from urbanization to CO_2 emission.
Halicioglu (2009)	1960–2005	Turkey	Autoregressive distributive lag (ARDL) and VECM Granger causality. Johansen cointegration	CO_2 emission.	GDP, energy consumption and trade openness.	All variables are cointegrated. GDP, energy consumption and trade openness increase CO_2 emission in the long run. Bi-directional causality

						was found between CO_2 emission, energy consumption and GDP. One way causality was found from trade openness to CO_2 emission.
Apergis and Payne (2010)	1992–2004	Commonwealth of independent states	Pedroni cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	All the variables are cointegrated. GDP and energy consumption increase CO_2 emission in the long run. Bi-directional causality was found between CO_2 emission and energy consumption and between energy consumption and GDP. Unidirectional causality was found from GDP to CO_2 emission.
Pao and Tsai (2010)	1971–2005	Brazil, Russia, India and China (BRIC).	Pedroni, Kao and Johansen Fisher cointegration. OLS regression and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	All the variables are cointegrated. GDP and energy consumption increase CO_2 emission in the long run. Bi-directional causality was found between all the variables.
Wang et al. (2011)	1995–2007	China	Pedroni cointegration, OLS regression and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	All the variables are cointegrated. Energy consumption increases CO_2 emission in the long run while GDP has no significant effect on CO_2 emission. Bi-directional causality between CO_2 emission and energy consumption.
Jayanthakumaran et al. (2012)	1971–2007	China and India	Autoregressive distributive lag (ARDL).	CO_2 emission.	GDP, energy consumption and trade openness.	GDP and energy consumption increase CO_2 emission in the long run and short run while trade openness has neither short nor long run effect.
Alam et al. (2012)	1972–2006	Bangladesh	Johansen cointegration, Autoregressive distributive lag (ARDL), and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	All the variables are cointegrated. GDP and energy consumption increase CO_2 emission in the long run. Bi-directional causality was found between energy consumption and CO_2 emission. One way causality was found from energy consumption to GDP and from CO_2 emission to GDP.
Al-mulali and Tang (2013)	1980–2009	Gulf cooperation council (GCC) countries	Pedroni cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP, energy consumption and FDI.	All the variables are cointegrated. GDP and energy consumption increase CO_2 emission in the long run while FDI has a negative long run effect on CO_2 emission. Bi-directional causality was found between all the variables.
Saboori and Sulaiman (2013a, 2013b)	1980–2009	Malaysia	Autoregressive distributive lag (ARDL) and VECM Granger causality.	CO_2 emission.	GDP and energy by type.	Energy by type and GDP increase CO_2 emission in both the long run and the short run. Bi-directional causality relationship was found among all the variables.
Kohler (2013)	1960–2009	South Africa	Autoregressive distributive lag (ARDL) and VECM Granger causality. Johansen cointegration.	CO_2 emission.	GDP, energy consumption and trade openness.	All the variables are cointegrated. GDP and energy consumption increase CO_2 emission in the long run and the short run while trade openness reduces CO_2 emission in the short run and the long run. Bi-directional causality was found between all the variables.
Azlina et al. (2014)	1975–2001	Malaysia	Johansen cointegration and VEC, Granger causality.	CO_2 emission.	GDP, road sector energy consumption, renewable energy consumption and structural change in the economy.	All the variables are cointegrated. GDP and road sector energy consumption increase CO_2 emission in the long run while renewable energy and structural change in the economy reduce CO_2 emission in the long run. Bi-directional causality was found between renewable energy and road energy consumption. One way causality was found from CO_2 emission and road sector energy consumption to GDP, from GDP and structural chance in the economy to renewable energy consumption, and from GDP to road sector energy consumption.
Chang (2010)	1981–2006	China	Johansen cointegration and VECM Granger causality.	CO_2 emission.	GDP and energy consumption by type.	All the variables are cointegrated. One way causality was found from natural gas and electricity consumption to GDP, all types of energy consumption to CO_2 emission, GDP to CO_2

Table 1 (*continued*)

Author	Period	Country/region/ organization	Methodology	The indicator for environmental degradation	The economic variables indicators	Empirical results
						emission, and from GDP to oil and coal consumption.
Hatzigeorgiou et al. (2011)	1977–2006	Greece	Johansen cointegration and VECM Granger causality.	CO_2 emission.	GDP and energy intensity.	All the variables are cointegrated. GDP and energy intensity increase CO_2 emission in the long run. One way causality was found from GDP to energy intensity and from GDP to CO_2 emission. Bi-directional causality was found between energy intensity and CO_2 emission.
Acaravci and Ozturk (2010)	1970–2005	Europe	Autoregressive distributive lag (ARDL) and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	Energy consumption increases CO_2 emission in the long run in most of the investigated countries while GDP increases CO_2 emission in few of the countries. In the short run, energy consumption increases CO_2 emission in all of the countries while GDP increases CO_2 emission only in few countries.
Pao and Tsai (2011a, 2011b)	1980–2007	BRIC	Perdoni, Kao and Fisher type johansen cointegration, OLS regression and VECM Granger causality.	CO_2 emission.	GDP, energy consumption and FDI.	All the variables are cointegrated. GDP energy consumption and FDI increase CO_2 emission in the long run. Bi-directional causality between FDI, energy consumption and CO_2 emission. One way causality was found from CO_2 emission and energy consumption to GDP.
Pao and Tsai (2011a, 2011b)	1980–2007	Brazil	Johansen cointegration, Grey prediction model and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	All the variables are cointegrated. GDP and energy consumption increase CO_2 emission in the long run. Bi-directional causality was found between GDP and CO_2 emission
Al-Mulali (2011)	1980–2009	MENA	Pedroni, Kao and Fisher Johansen cointegration, VECM Granger causality.	CO_2 emission.	Oil consumption and GDP.	All the variables are cointegrated. Bi-directional causality was found among the variables.
Al-Mulali and Che Sab (2012a, 2012b)	1980–2008	Sub Saharan African (SSA) countries.	Pedroni cointegration, VECM Granger causality.	CO_2 emission.	GDP, energy consumption and financial development.	All the variables are cointegrated. Bi-directional causality was found among the variables.
Al-Mulali (2012)	1990–2009	Middle East.	Pedroni cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP, energy consumption, FDI and trade openness.	All the variables are cointegrated. GDP, energy consumption, FDI, and trade openness increase CO_2 emission in the long run. Bi-directional causality was found among the variables.
Saboori and Sulaiman (2013a, 2013b)	1971–2009	ASEAN	Autoregressive distributive lag (ARDL) and VECM Granger causality.	CO_2 emission.	GDP and energy consumption.	All the variables are cointegrated. Energy consumption increases CO_2 emission in the long run for all ASEAN countries while GDP increases CO_2 emission in the long for all ASEAN except for Malaysia. In the short run energy consumption increases CO_2 emission for all ASEAN countries while GDP increases CO_2 emission in Indonesia, Philippines and Thailand. Bi-directional causality was found between all the variables in Indonesia, Malaysia and the Philippines. Bi-directional causality was found between CO_2 emission and energy consumption in Singapore and Thailand.
Bastola and Sapkota (2015)	1980–2011	Nepal	Autoregressive distributive lag (ARDL), VECM Granger causality and Johansen cointegration.	CO_2 emission.	GDP and energy consumption.	All the variables are cointegrated. Bi-directional causality was found between energy consumption and CO_2 emission.
Ozturk and Acaravci (2010)	1968–2005	Turkey	Autoregressive distributive lag (ARDL) and VECM Granger causality.	CO_2 emission.	GDP, energy consumption and total labor force.	All the variables are cointegrated. GDP and energy consumption increase CO_2 emission in the long run while labor force reduces CO_2 emission in the long run. Unidirectional causality was

						found from energy consumption, GDP and total labor force to CO_2 emission.
Alam et al. (2011)	1971–2006	India	Vector autoregression (VAR) Granger casualty.	CO_2 emission.	GDP, energy consumption, labor and capital.	A one way causality was found from capital to GDP, CO_2 emission and labor. Bidirectional causality was found between CO_2 emission and energy consumption.
Al-Mulali and Che Sab (2012a, 2012b)	1980–2009	Countries that are highly developed financially.	Pedroni cointegration and VECM Granger causality.	CO_2 emission.	GDP, energy consumption and financial development.	All the variables are cointegrated, bi-directional causality was found among the variables.
Shahbaz et al. (2013a)	1975–2011	Indonesia	Autoregressive distributive lag (ARDL) and VECM Granger causality.	CO_2 emission.	GDP, energy consumption, financial development and trade openness.	All the variables are cointegrated. Financial development increases CO_2 emission in the short while its effect is negative on CO_2 emission in the long run. Energy consumption, GDP, and trade openness increase CO_2 emission in both the long run and the short run. Bi-directional causality was found among the variables.
Ara et al. (2015)	1970–2009	Malaysia	Autoregressive distributive lag (ARDL) and DOLS.	CO_2 emission.	GDP, energy consumption and population.	Electricity consumption has a significant long run positive effect on CO_2 emission while GDP has a significant negative long run effect.
Alshehry and Belloumi (2015)	1970–2010	Saudi Arabia	Johansen cointegration and VECM Granger causality.	CO_2 emission.	GDP, energy consumption and energy price.	All the variables are cointegrated. Unidirectional causality from energy consumption to economic growth, CO_2 emission, energy price to economic growth and CO_2 emission and from CO_2 emission energy consumption and GDP and from energy price to CO_2 emission. Bidirectional causality between CO_2 emissions and economic growth
Al-Mulali et al. (2015a)	1990–2013	European Union countries.	Pedroni cointegration, FMOLS and VECM Granger causality.	CO_2 emission.	GDP, trade openness, urbanization, financial development and renewable energy consumption by type.	All the variables are cointegrated. GDP, urbanization and financial development increase CO_2 emission in the long run while trade openness, renewable energy from waste generation, hydroelectric generation and nuclear generation reduce CO_2 emission. GDP, financial development, urbanization, renewable energy from waste generation, hydroelectric generation and nuclear generation have causal effect on CO_2 emission.
Al-Mulali et al., (2015d)	1980–2011	129 countries by income.	Pedroni cointegration, DOLS and VECM Granger causality.	CO_2 emission.	GDP, urbanization, trade openness, petroleum energy consumption, financial development.	All the variables are cointegrated. Urbanization and trade openness increase CO_2 emission in the long run Lower-middle, Upper-middle and high income countries. Petroleum energy consumption increases CO_2 emission in the long run for all countries. However, financial development reduces CO_2 emission in all countries. GDP increases CO_2 emission in the long run in the upper-middle and the high income countries. Bi-directional causality between the variables was found in most of the income grouped countries.

and regressands' past values do not correlate with the error term (Wooldrigde, 2001). The relevant equation can be expressed as follows:

$$y_{it} = \eta_i + \beta_1 y_{it-1} + \beta_2 Z_{it} + \varepsilon_{it} \quad (3)$$

where Z_{it} is the row vector of the explanatory series (including ecological indicators), y_{it-1} is the lag of y_{it} (which is the dependent variable, ecological footprints), η_i is a country-specific effect that is unobserved and time-invariant, and ε_{it} is the error term. In line with Arellano and Bond (1991), the first differencing process removes the country specific effect as follows:

$$y_{it} - y_{it-1} = \beta_1 \Delta y_{it-1} + \beta_2 \Delta Z_{it} + \Delta\varepsilon_{it} \quad (4)$$

The differencing process eliminates the time-invariant effect, but it also generates another bias because the newly-created error term $\Delta\varepsilon_{it}$ is by default correlated with the lagged dependent variable Δy_{it-1} (since $y_{i,t-1}$ is correlated with $\varepsilon_{i,t-1}$). Under the premise of the independent series' exogeneity, Arellano and Bond (1991) introduced the following moment conditions:

$$E[y_{it-s}\,\Delta\varepsilon_{it}] = 0 \quad for\ s \geq 2; \quad t = 3, \ldots, T \quad (5)$$

$$E[Z_{it-s}\,\Delta\varepsilon_{it}] = 0 \quad for\ s \geq 2; \quad t = 3, \ldots, T \quad (6)$$

However, this difference estimator does have shortcomings. Blundell and Bond (1998) demonstrated that when the regressors exhibit persistency, the lagged levels of these series are likely to produce inadequate instruments for the models in differences because previous levels provide inadequate representation about the changes in the future. This flaw impairs the performance of the difference estimator in the case of limited sample size (Arellano and Bover, 1995; Blundell and Bond, 1998; Beck and Levine, 2004).

Since the current study deals with a finite sample, we employ a method that combines the regression in levels and the regression in differences (see Arellano and Bover (1995) and Blundell and Bond (1998)). The instruments for the regression in differences are the same as the ones in the preceding discussion. However, the instruments for the regression in levels are the lagged differences of the corresponding series. On the basis of no relationship between the unobserved country-specific effect and the series' differences, Arellano and Bover (1995) introduced the following additional moments:

$$E[\Delta y_{it-s}\,(\eta_i + \varepsilon_{it})] = 0 \quad for\ s = 1 \quad (7)$$

$$E[\Delta Z_{it-s}(\eta_i + \varepsilon_{it})] = 0 for s = 1 \quad (8)$$

Building on these four moment conditions, (5)–(8), it is possible to either employ the one-step GMM system method, or the two-step method. In this paper, the two-stage method is adopted.[2] To evaluate the robustness of our results, we look at two specification tests. The first test is the Sargan test of over-identifying restrictions to consider the reliability of the instruments in the system.[3] The second test is to examine the existence of autocorrelation. In doing this, we undertake autoregressive tests to check whether the errors exhibit autocorrelation. Similar to past studies, we examine the presence of first-order and second-order autocorrelation. The inability to reject the null hypotheses of no second-order autocorrelation corroborates the model.

3. Empirical results

We start the analysis by estimating the determinants of ecological footprints with the fixed effects model in Table 2. The baseline regression, which contains renewable electricity as the sole determinant of ecological footprints is reported in Column (1). The estimates suggest that renewable electricity has positive effect on ecological footprints at 1% significance level. Due to the possibility of omission variable bias and following the works of Lean and Smyth (2010) and Ang (2007, 2008), we incorporate real GDP into the model in Column (2). We observe that both renewable electricity and real GDP positively lead to more ecological footprints at 1% significance level. Consistent with the works of Shahbaz et al. (2013b), Solarin (2014), and Liddle (2014), we include urbanization and trade indicators into the regression. The estimates show that all the variables positively influence ecological indicators at 1% significance level.

As a robustness check, we divide the sample into 1980–1997 and 1998–2009 periods, consistent with the adoption of the Kyoto Protocol in 11 December 1997. On the premise that developed countries are mainly responsible for the growing volume of greenhouse gases, the protocol puts the obligation to reduce current emissions on developed countries. Moreover, developing nations are allowed to comply with the terms of the protocol on voluntary basis. Consequently, the protocol has partly led to the growing popularity of renewable energy. We report the results for 1980–1997 in Column (4), while the findings for 1998–2008 phase is reported in Column (5). The results suggest that all the variables have significant positive effect on ecological indicators at 1% significance level.

We examine the existence of environmental Kuznet curve (EKC) in Column (6) by introducing the square of GDP in the regression. The level of GDP is found to have negative impact on ecological footprints and the square of GDP has a positive effect on ecological footprints. Therefore, there is no evidence of EKC as we could not find an inverted U-shape relationship from the findings. In Column (7), we consider a situation where there will be a higher level of renewable electricity relative to the current level. It is observed that higher renewable electricity has insignificant negative effect on ecological indicators. In Column (8), we introduce a dummy for the high-income members of the sample. The results suggest that the dummy is insignificant, although it is positive. Considering the estimates' validity, we observe that with the exception of equations in Column (1) and Column (2), the Adjusted-R^2 is very high as they are well above 90%. For instance in Column (4), it is shown that the regressors collectively determine about 95.3% of variation in ecological indicators.[4] Despite the revealing information derived from the foregoing estimates, inference with the fixed effects estimator is potentially more sensitive to non-normality, heteroscedasticity, and serial correlation in idiosyncratic errors (Wooldrigde, 2009).

The results from the difference GMM is reported in Table 3. With the equation involving renewable electricity as the sole determinant of ecological indicators in Column (1), the estimates indicate that renewable electricity enhances ecological footprints indicators. The positive impact remains when GDP, urbanization, and trade are included as control variables. When the GDP square is introduced into the model, we observe that renewable electricity has adverse influence on ecological footprints in Column (6). In the same equation, it is observed that the EKC hypothesis does not exist because the square of GDP produce a positive sign.

[2] The major issue with the two-step method is that it is biased downwards. Windmeijer (2005) introduced corrected standard errors to correct for small sample bias. In the process of estimation, we employ the Windmeijer's (2005) corrected standard errors.

[3] This is also necessary because we are using all the available instruments.

[4] An alternative approach to the fixed effects estimate is the random effects estimates. We have conducted the Hausman test and observe that we could reject the null hypothesis of consistency of the random effects estimates. Therefore, fixed effect is superior to random effects method in our case.

Table 2
Determinants of ecological footprints, fixed effect model.

Regressors	1	2	3	4	5	6	7	8
Constant	3.278 (0.000)***	0.873 (0.008)**	1.460 (0.000)***	1.473 (0.000)***	0.956 (0.000)***	9.960 (0.000)***	1.721 (0.369)	1.346 (0.001)***
Renewable electricity	0.381 (0.000)***	0.302 (0.000)***	0.020 (0.005)***	0.024 (0.013)**	0.049 (0.000)***	−0.011 (0.568)	−0.006 (0.975)	0.022 (0.283)
GDP		0.158 (0.000)***	0.027 (0.000)***	0.018 (0.021)**	0.024 (0.008)***	−0.689 (0.000)***	0.027 (0.105)	0.032 (0.023)**
Urbanization			0.679 (0.000)***	0.665 (0.000)***	0.645 (0.000)***	0.579 (0.000)***	0.679 (0.000)***	0.690 (0.000)***
Total trade			0.194 (0.000)***	0.230 (0.000)***	0.212 (0.000)***	−0.003 (0.945)***	0.193 (0.000)***	0.176 (0.000)***
GDP square						0.020 (0.000)***		
Square renewable electricity							−0.001 (0.892)	
High income								0.064 (0.517)
Adjusted R	0.359	0.452	0.926	0.933	0.941	0.947	0.926	0.925
F (*p*-value)	0.000***	0.000***	0.000***	0.000	0.000***	0.000***	0.000***	0.000***

The p-value reported in the parentheses are heteroscedasticity and autocorrelation consistent (HAC).
*** Denote significance at 1% level.
** Denote significance at 5% level.

Although there is similarity between the results obtained here with the findings of fixed effects model, the estimates obtained here are sharper and more significant. We also found more positive impacts of renewable electricity relative to the fixed effects estimates. In examining the validity of the estimates, we could generally accept the null hypothesis that the errors display no second order serial correlation. Moreover, the Sargan test shows that our model does not suffer from over-identifying restrictions as we are unable to reject the null hypothesis that the instruments used are not correlated with the residuals (Beck and Levine 2004).

Since it has been argued that GMM difference instruments are often weak, thus causing biases (Arellano and Bover, 1995), we further utilize the system GMM to examine the factors of ecological indicators (Table 4). It is shown in Column (1) that renewable electricity has positive influence on ecological indicators. In the remaining equations, the positive impact of renewable electricity does not change. Variables such as GDP, urbanization, and total trade are also shown to have positive impact on ecological footprints. There is no evidence for EKC hypothesis as the regression in Column (6) suggests that there is a monotonic relationship between GDP and ecological indicators. Although the results are not materially different from those produced by the difference GMM, there are some slight variances. For instance, we observed that renewable electricity has positive influence on ecological footprints, in all the equations, unlike the output obtained from difference GMM, which produced (although very limited) evidence for the negative impact of renewable electricity on ecological footprints. The diagnostics tests reveal that the entire models do not face the problem of neither second-order serial correlation nor over-identification restriction, as suggested by the Sargan test.

The positive impact of GDP on ecological indicators is consistent with the studies of Shahbaz et al. (2015), Al-Mulali and Ozturk (2015) and Ozturk and Al-Mulali (2015). The positive impact of urbanization on ecological indicators is consistent with the studies of Zhang and Lin (2012), Solarin (2014), Al-Mulali and Ozturk (2015), Ozturk and Al-Mulali (2015). The positive impact of trade on ecological indicators is consistent with the studies of Al-Mulali and Ozturk (2015) and Ozturk and Al-Mulali (2015) but dissimilar to the study conducted by Shahbaz et al. (2013a, 2013b).

The outcome of the econometric results from the fixed effects, difference GMM, and system GMM of this research reached to the same conclusion that GDP growth, urbanization, and trade openness increase the level of water and land use by their positive effect on ecological footprint. From this outcome, it is obvious both renewable or non-renewable sources energy requires abundant amount of land and water sources which result into environmental degradation. Moreover, renewable energy production increases water and land inefficiency especially after the Kyoto Protocol in 1997; this outcome was the same despite the different regressions and models that was utilized in this study. Moreover, based on the square of GDP growth, there is no evidence that supports the existence of the EKC hypothesis. However, the square of renewable energy production, which is significant and positively related to water and land footprint, indicates that renewable energy production will cause more land and water inefficiency not only in the present but in the future as well. Therefore, the rising production of renewable energy will increase the environmental degradation in the future.

4. Conclusion

This study examines the influence of renewable energy production on water and land inefficiency using ecological footprint as an indicator in 58 countries for the period of 1980–2009. Moreover, other determinants for ecological footprint were included namely urbanization, GDP growth, and trade openness. To achieve the aims of this study, the fixed effects as well as difference and system GMM methods were utilized. Additionally, eight models were formulated to achieve robustness. The outcome of the empirical results of all regressions reached to the same conclusion that urbanization, GDP growth, and trade openness increase water and land inefficiency by their positive influence on the ecological footprint. Moreover, the increase in renewable energy production will increase water and land footprint as it has a positive effect on the ecological footprint particularly after the Kyoto Protocol in 1997.

Furthermore, the EKC hypothesis does not exist in the investigated countries. However, the square of renewable energy production indicates that renewable energy will also cause more water and land inefficiency in the future. Since economic activities, urbanization, and trade openness are important to achieve a better economic development, sacrificing them is not a good policy despite their positive influence on the environmental degradation. Nonetheless, increasing the energy efficiency of these components can be a good solution to reduce the amount of energy needed to fuel them. Moreover, replacing fossil fuels to renewable energy can be a good solution in reducing air pollution as it was proved by the previous literature. However, renewable energy increases the water and land inefficiency as it has a positive influence on ecological footprint which is verified by this study.

Table 3
Determinants of ecological footprints, difference GMM.

Regressors	1	2	3	4	5	6	7	8
Constant	0.007 (0.000)***	0.0183 (0.000)***	−0.038 (0.000)***	0.007 (0.000)***	0.004 (0.059)*	0.020 (0.000)***	−0.001 (0.000)***	0.024 (0.000)***
Renewable electricity	0.363 (0.000)***	0.287 (0.000)***	0.045 (0.000)***	0.056 (0.000)***	0.059 (0.000)***	−0.017 (0.000)***	0.003 (0.000)***	0.013 (0.000)***
GDP		0.154 (0.000)***	0.028 (0.000)***	0.024 (0.000)***	0.028 (0.000)***	−0.680 (0.000)***	0.024 (0.000)***	0.016 (0.000)***
Urbanization			0.691 (0.000)***	0.611 (0.000)***	0.614 (0.000)***	0.577 (0.000)***	0.699 (0.000)***	0.750 (0.000)***
Total trade			0.212 (0.000)***	0.221 (0.000)***	0.220 (0.000)***	0.009 (0.051)*	0.144 (0.000)***	0.189 (0.000)***
GDP square						0.020 (0.000)***		
Square renewable electricity							0.008 (0.000)**	
High income								0.074 (0.000)***
Sargan test	57.971 (0.999)	57.953 (0.999)	22.904 (0.999)	45.519 (0.253)	46.390 (0.5780)	57.464 (0.999)	57.062 (0.999)	57.258 (0.999)
AR(1) test	−5.761 (0.000)***	−6.327 (0.000)***	−4.213 (0.000)***	−4.422 (0.000)***	−5.157 (0.000)***	−5.713 (0.000)***	−4.996 (0.000)***	−4.907 (0.000)***
AR(2) test	0.099 (0.921)	−0.360 (0.719)	0.215 (0.830)	0.971 (0.331)	1.603 (0.109)	−0.758 (0.449)	−0.077 (0.710)	−0.616 (0.538)

The p-value are presented in brackets.
*** Denote significance at 1% level.
* Denote significance at 10% level.
** Denote significance at 5% level.

Table 4
Determinants of ecological footprints, system GMM.

Regressors	1	2	3	4	5	6	7	8
Constant	4.661*** (0.000)	0.022*** (0.000)	1.497*** (0.000)	1.274 (0.350)	3.464*** (0.000)	11.527*** (0.000)	1.689*** (0.000)	2.216*** (0.000)
Renewable electricity	0.396*** (0.000)	0.361*** (0.000)	0.016*** (0.005)	0.020* (0.067)	0.047*** (0.000)	0.004* (0.067)	0.009*** (0.007)	0.010*** (0.001)
GDP		0.124*** (0.000)	0.037*** (0.000)	0.037*** (0.001)	0.015*** (0.005)	−0.656*** (0.000)	0.014*** (0.000)	0.016*** (0.000)
Urbanization			0.714*** (0.000)	0.725*** (0.000)	0.617*** (0.000)	−0.003 (0.641)	0.700*** (0.000)	0.722*** (0.000)
Total trade			0.163*** (0.000)	0.215*** (0.000)	0.223*** (0.000)	0.019*** (0.000)	0.162*** (0.000)	0.197*** (0.000)
GDP square						0.019*** (0.000)		
Square renewable electricity							0.001*** (0.000)	
High income								0.085*** (0.000)
Sargan test	57.958 (0.999)	57.650 (0.999)	55.592 (0.999)	35.410 (0.999)	44.711 (0.568)	57.302 (0.999)	57.287 (0.999)	57.727 (0.999)
AR(1) test	−6.620*** (0.000)	−5.640*** (0.000)	−4.475*** (0.000)	−4.189*** (0.000)	−4.435*** (0.000)	−5.550*** (0.000)	−5.795*** (0.000)	−5.028*** (0.000)
AR(2) test	−1.125 (0.261)	−1.028 (0.304)	−1.291 (0.197)	0.022 (0.983)	1.123 (0.262)	−0.916 (0.360)	−0.864 (0.388)	−0.531 (0.596)

The p-value are presented in brackets.
**Denote significance at 5% level.
*** Denote significance at 1% level.
* Denote significance at 10% level.

As a result, the best suggestion that the researchers of this study can offer is that the countries should replace current renewable energy technologies with new ones that enhance the efficiency of water and land use. When these technologies are available, it can make renewable energy a perfect replacement for fossil fuels since it can reduce air pollution (Sebri and Ben-Salha, 2014; Menyah and Wolde-Rufael, 2010; Jaforullah and King, 2015; Özbuğday and Erbas, 2015; Shafiei and Salim, 2014; Jebli and Youssef, 2015) and GDP growth (Aguirre and Ibikunle, 2014; Apergis and Payne, 2011, 2012; Shahbaz et al., 2015; Inglesi-Lotz, 2015; Tugcu et al., 2012; Omri et al. 2015; Lin and Moubarak, 2014; Bloch et al., 2015) and it is more efficient to the use of water and land.

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References

Aguirre, M., Ibikunle, G., 2014. Determinants of renewable energy growth: A global sample analysis. Energy Policy 69, 374–384.

Apergis, N., Payne, J.E., 2012. Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. Energy Economics 34, 733–738.

Acaravci, A., Ozturk, I., 2010. On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. Energy 35 (12), 5412–5420.

Ajmi, A.N., Hammoudeh, S., Nguyen, D.K., Sato, J.R., 2015. On the relationships between CO_2 emissions, energy consumption and income: the importance of time variation. Energy Econ. 49, 629–638.

Alam, M. Jahangir, Ara Begum, I., Buysse, J., Van Huylenbroeck, G., 2012. Energy consumption, carbon emissions and economic growth nexus in Bangladesh: cointegration and dynamic causality analysis. Energy Policy 45, 217–225.

Alam, M.J., Begum, I.A., Buysse, J., Rahman, S., Van Huylenbroeck, G., 2011. Dynamic modeling of causal relationship between energy consumption, CO2 emissions and economic growth in India. Renew. Sustain. Energy Rev. 15 (6), 3243–3251.

Al-mulali, U., 2011. Oil consumption, CO_2 emission and economic growth in MENA countries. Energy 36 (10), 6165–6171.

Al-mulali, U., 2012. Factors affecting CO_2 emission in the Middle East: a panel data analysis. Energy 44 (1), 564–569.

Al-mulali, U., 2014. Investigating the impact of nuclear energy consumption on GDP growth and CO_2 emission: a panel data analysis. Progress. Nucl. Energy 73, 172–178.

Al-mulali, U., Che Sab, C.N. Binti, 2012a. The impact of energy consumption and CO_2 emission on the economic growth and financial development in the Sub Saharan African countries. Energy 39 (1), 180–186.

Al-mulali, U., Che Sab, C.N. Binti, 2012b. The impact of energy consumption and CO_2 emission on the economic and financial development in 19 selected countries. Renew. Sustain. Energy Rev. 16 (7), 4365–4369.

Al-mulali, U., Tang, C. Foon, 2013. Investigating the validity of pollution haven hypothesis in the gulf cooperation council (GCC) countries. Energy Policy 60, 813–819.

Al-mulali, U., Sheau-Ting, L., 2014. Econometric analysis of trade, exports, imports, energy consumption and CO_2 emission in six regions. Renew. Sustain. Energy Rev. 33, 484–498.

Al-mulali, U., Saboori, B., Ozturk, I., 2015a. Investigating the environmental Kuznets curve hypothesis in Vietnam. Energy Policy 76, 123–131.

Al-mulali, U., Tang, C.F., Ozturk, I., 2015a. Estimating the environment Kuznets curve hypothesis: evidence from latin America and the caribbean countries. Renew. Sustain. Energy Rev. 50, 918–924.

Al-mulali, U., Tang, C.F., Ozturk, I., 2015a. Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries. Environ. Sci. Pollut. Res. 22 (19), 14891–14900.

Al-mulali, U., Weng-Wai, C., Sheau-Ting, L., Mohammed, A.H., 2015b. Investigating the environmental Kuznets curve (EKC) hypothesis by utilizing the ecological footprint as an indicator of environmental degradation. Ecol. Indic. 48, 315–323.

Al-Mulali, U., Ozturk, I., 2015. The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. Energy 84, 382–389.

Al-Mulali, U., Ozturk, I., Lean, H.H., 2015a. The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. Nat. Hazards 79 (1), 621–644.

Alshehry, A.S., Belloumi, M., 2015. Energy consumption, carbon dioxide emissions and economic growth: the case of Saudi Arabia. Renew. Sustain. Energy Rev. 41, 237–247.

Ang, J.B., 2007. CO_2 emissions, energy consumption, and output in France. Energy Policy 35 (10), 4772–4778.

Ang, J.B., 2008. Economic development, pollutant emissions and energy consumption in Malaysia. J. Policy Model. 30 (2), 271–278.

Apergis, N., Payne, J.E., 2010. The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. Energy Policy 38 (1), 650–655.

Apergis, N., Payne, J.E., 2011a. The renewable energy consumption–growth nexus in Central America. Appl. Energy 88, 343–347.

Apergis, N., Payne, J.E., 2011b. The renewable energy consumption–growth nexus in Central America. Energy Econ. 34, 733–738.

Ara, R., Sohag, K., Mastura, S., Abdullah, S., Jaafar, M., 2015. CO_2 emissions, energy consumption, economic and population growth in Malaysia. Renew. Sustain. Energy Rev. 41, 594–601.

Arellano, M., Bond., S., 1991. Some tests of specification for panel data: Monte-carlos evidence and an application to employment equations. Rev. Econ. Stud. 58, 277–297.

Arellano, M., Bover., O., 1995. Another look at the instrumental-variable estimation of error components models. J. Econom. 68, 29–52.

Azlina, A.A., Law, S.H., Mustapha, N.H. Nik, 2014. Dynamic linkages among transport energy consumption, income and CO_2 emission in Malaysia. Energy Policy 73, 598–606.

Bastola, U., Sapkota, P., 2015. Relationships among energy consumption, pollution emission, and economic growth in Nepal. Energy 80, 254–262.

Baum, C.F., Schaffer, M.E., Stillman, S., 2003. Instrumental variables and GMM: estimation and testing. Stata J. 3 (1), 1–31.

Beck, T., Levine, R., 2004. Stock markets, banks, and economic growth: panel evidence. J. Bank. Financ. 28 (3), 423–442.

Bella, G., Massidda, C., Mattana, P., 2014. The relationship among CO_2 emissions, electricity power consumption and GDP in OECD countries. J. Policy Model. 36 (6), 970–985.

Bloch, H., Rafiq, S., Salim, R., 2015. Economic growth with coal, oil and renewable energy consumption in China: prospects for fuel substitution. Econ. Model. 44, 104–115.

Blundell, R., Bond, S.S., 1998. Initial conditions and moment restrictions in dynamic panel data models. J. Econ. 87, 115–143.

Chandran, V.G.R., Tang, C.F., 2013. The impacts of transport energy consumption, foreign direct investment and income on CO_2 emissions in ASEAN-5 economies. Renew. Sustain. Energy Rev. 24, 445–453.

Chang, C.-C., 2010. A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. Appl. Energy 87 (11), 3533–3537.

Dietz, T., Rosa, E.A., 1994. Rethinking the environmental impacts of population, affluence and technology. Hum. Ecol. Rev. 1, 277–300.

Dietz, T., Rosa, E.A., 1997. Effects of population and affluence on CO_2 emissions. Proc. Natl. Acad. Sci. USA 94, 175–179.

Esteve, V., Tamarit, C., 2013. Is there an environmental Kuznets curve for Spain? Fresh evidence from old data. Econ. Model. 29 (6), 2696–2703.

Farhani, S., Chaibi, A., Rault, C., 2014. CO_2 emissions, output, energy consumption, and trade in Tunisia. Econ. Model. 38, 426–434.

Global Footprint Network, 2015. Ecological footprint. Oakland, USA; [Online] (Available from) September 2013; http://www.footprintnetwork.org/en/index.php/GFN/. (acessed 15.04.15).

Halicioglu, F., 2009. An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 37, 1156–1164.

Hamit-Haggar, M., 2012. Greenhouse gas emissions, energy consumption and economic growth: a panel cointegration analysis from Canadian industrial sector perspective. Energy Econ. 34 (1), 358–364.

Hansen, L., 1982. Large sample properties of generalized method of moments estimators. Econometrica 50 (3), 1029–1054.

Hatzigeorgiou, E., Polatidis, H., Haralambopoulos, D., 2011. CO_2 emissions, GDP and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977–2007. Appl. Energy 88 (4), 1377–1385.

Heidari, H., Turan Katircioğlu, S., Saeidpour, L., 2015. Economic growth, CO_2 emissions, and energy consumption in the five ASEAN countries. Int. J. Electr. Power Energy Syst. 64, 785–791.

Hoekstra, A.Y., 2015. Switching to biofuels could place unsustainable demands on water use. [Online] (acessed 12.06.15) Available from June 2015; http://www.theguardian.com/sustainable-business/2015/may/28/switching-to-biofuels-would-place-unsustainable-demands-on-water-use.

Hossain, M. Sharif, 2011. Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energy Policy 39 (11), 6991–6999.

Inglesi-Lotz, R., 2015. The impact of renewable energy consumption to economic growth: a panel data application. Energy Econ. http://dx.doi.org/10.1016/j.eneco.2015.01.003.

Jafari, Y., Othman, J., Nor, A.H.S.M., 2012. Energy consumption, economic growth and environmental pollutants in Indonesia. J. Policy Model. 34 (6), 879–889.

Jaforullah, M., King, A., 2015. Does the use of renewable energy sources mitigate CO_2 emissions? A reassessment of the US evidence. Energy Econ. 49, 711–717.

Jayanthakumaran, K., Verma, R., Liu, Y., 2012. CO_2 emissions, energy consumption, trade and income: a comparative analysis of China and India. Energy Policy 42, 450–460, June 2011.

Jebli, M.B., Youssef, S.B., 2015. The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. Renew. Sustain. Energy Rev. 47, 173–185.

Kasman, A., Duman, Y.S., 2015. CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis. Econ. Model. 44, 97–103.
Kohler, M., 2013. CO_2 emissions, energy consumption, income and foreign trade: A South African perspective. Energy Policy 63, 1042–1050.
Lean, H.H., Smyth, R., 2010. CO_2 emissions, electricity consumption and output in ASEAN. Appl. Energy 87 (6), 1858–1864.
Liddle, B., 2014. Impact of population, age structure, and urbanization on carbon emissions/energy consumption: evidence from macro-level, cross-country analyses. Popul. Environ. 35 (3), 286–304.
Lin, B., Moubarak, M., 2014. Renewable energy consumption – economic growth nexus for China. Renew. Sustain. Energy Rev. 40, 111–117.
Menyah, K., Wolde-Rufael, Y., 2010a. Energy consumption, pollutant emissions and economic growth in South Africa. Energy Econ. 32 (6), 1374–1382.
Menyah, K., Wolde-Rufael, Y., 2010b. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy 38, 2911–2915.
Omri, A., 2013. CO_2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models. Energy Econ. 40, 657–664.
Omri, A., Mabrouk, N., Sassi-Tmar, A., 2015. Modeling the causal linkages between nuclear energy, renewable energy and economic growth in developed and developing countries. Renew. Sustain. Energy Rev. 42, 1012–1022.
Özbuğday, F.C., Erbas, B.C., 2015. How effective are energy efficiency and renewable energy in curbing CO_2 emissions in the long run? A heterogeneous panel data analysis. Energy 82, 734–745.
Ozturk, I., Acaravci, A., 2010. CO_2 emissions, energy consumption and economic growth in Turkey. Renew. Sustain. Energy Rev. 14 (9), 3220–3225.
Ozturk, I., Al-Mulali, U., 2015. Investigating the validity of the environmental Kuznets curve hypothesis in Cambodia. Ecol. Indic. 57, 324–330.
Pao, H.T., Tsai, C.M., 2011. Multivariate Granger causality between CO_2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. Energy 36 (1), 685–693.
Pao, H.-T., Tsai, C.-M., 2010. CO_2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy 38 (12), 7850–7860.
Pao, H.-T., Tsai, C.-M., 2011. Modeling and forecasting the CO_2 emissions, energy consumption, and economic growth in Brazil. Energy 36 (5), 2450–2458.
Saboori, B., Sulaiman, J., 2013a. CO_2 emissions, energy consumption and economic growth in association of Southeast Asian Nations (ASEAN) countries: a cointegration approach. Energy 55, 813–822.
Saboori, B., Sulaiman, J., 2013b. Environmental degradation, economic growth and energy consumption: evidence of the environmental Kuznets curve in Malaysia. Energy Policy 60, 892–905.
Sebri, M., Ben-Salha, O., 2014. On the causal dynamics between economic growth, renewable energy consumption, CO_2 emissions and trade openness: fresh evidence from brics countries. Renew. Sustain. Energy Rev. 39, 14–23.
Shafiei, S., Salim, R.A., 2014. Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: a comparative analysis. Energy Policy 66, 547–556.
Shahbaz, M., Lean, H.H., 2012. Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. Energy Policy 40, 473–479.
Shahbaz, M., Tiwari, A.K., Nasir, M., 2013b. The effects of financial development, economic growth, coal consumption and trade openness on CO_2 emissions in South Africa. Energy Policy 61, 1452–1459.
Shahbaz, M., Hye, Q.M.A., Tiwari, A.K., Leitão, N.C., 2013a. Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. Renew. Sustain. Energy Rev. 25, 109–121.
Shahbaz, M., Loganathan, N., Zeshan, M., Zaman, K., 2015. Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. Renew. Sustain. Energy Rev. 44, 576–585.
Solarin, S.A., 2014. Tourist arrivals and macroeconomic determinants of CO_2 emissions in Malaysia. Anatolia 25 (2), 228–241.
Suh, J., 2013. Does Buddhism have much to offer in terms of reduction in global CO_2 emissions? A panel data analysis. Soc. Econ. 35 (2), 209–225.
Tugcu, C.T., Ozturk, I., Aslan, A., 2012. Renewable and non-renewable energy consumption and economic growth relationship revisited: evidence from G7 countries. Energy Econ. 34, 1942–1950.
Wang, S.S., Zhou, D.Q., Zhou, P., Wang, Q.W., 2011. CO_2 emissions, energy consumption and economic growth in China: a panel data analysis. Energy Policy 39 (9), 4870–4875.
Windmeijer, F., 2005. A -nite sample correction for the variance of linear e!cient two-step GMM estimators. J. Econom. 126, 25–51.
Wooldrigde, J., 2001. Application of generalized methods of moments estimation. J. Econ. Perspect. 15, 87–100.
Wooldrigde, J., 2009. Introductory Econometrics: A Modern Approach, Fourth edition.. South-Western College Publishing, Austrialia.
Zhang, C., Lin, Y., 2012. Panel estimation for urbanization, energy consumption and CO_2 emissions: a regional analysis in China. Energy Policy 49, 488–498.
Zhang, X.-P., Cheng, X.-M., 2009. Energy consumption, carbon emissions, and economic growth in China. Ecol. Econ. 68 (10), 2706–2712.