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The Validity of Environmental Kuznets Curve Hypotheis in the Kingdom of Saudi Arabia: ARDL Bounds Testing Approach to Cointegration

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Abstract

The paper aims at estimating the validity of Environmental Kuznets Curves in KSA employing annual data over the period 1971 to 2013 using the Autoregressive Distributed Lagged (ARDL) bounds testing approach to cointegration proposed by Pesaran and Pesaran (1997) and Pesaran et.al, (2001) and Non-Granger Causality within the VECM framework to explores the short-run and long-run causality direction applying the F-statistics of Wald-test. The. The ADF test ensures that the variables are either I(0) or I(1) but not I(2). The ARDL results show that there is a long-run equilibrium relationship among Carbon Dioxide emission (CO_2), economic growth energy consumption, and population density. The results reveal short and long run positive and significant impact of economic growth on CO_2 emission, and that the long run elasticity is less than the short-run elasticity. Following the Narayan (2010) approach, where for the EKC to exist, the long-run elasticity should be less than short-run elasticity, the results provide support for the existence of EKC in KSA. The Non-Granger causality results reveal bidirectional causality between economic growth, energy consumption, population density, and CO_2; economic growth and population density, energy consumption and .population density, whereas, unidirectional causality runs from CO_2 to population density. The Saudi government may help establishing the Environmental Kuznets Curve relationship between air pollution and economic growth by implementing various policies to reduce the emission level. For example, imposing taxes on pollution and increasing the role of renewable and clean energy (nuclear energy) consumption and energy efficiency.

Key Words: *EKC Hypothesis, ARDL, Granger-Causality, VECM, Economic Growth. Pollution.*

Introduction

Every economy wants to achieve a high level of sustainable economic development to improve the well-being of its population. As defined in economic Jargon, sustainable economic development should take into consideration the ecological sustainability. However, as Himani (2010) provided, economic development concentrates on GDP growth and ignoring the associated environmental costs and consequences of sustainable development (in Lingaraj and Shakti, 2015).

The kingdom of Saudi Arabia has been since 1970 pursuing five-year-development plans with the aim of diversifying its economy and reducing dependence on oil revenues. Despite the limited successes in achieving these long-term objectives, there are two recent considerable developments: first, growth of non-oil sector despite the recent fall in oil prices since 2014 has picked up independently from the oil sector. Second, there is growing awareness of the importance of achieving economic development but not at the expense of the environment. These two developments fit well with the newly announced 2030 Vision, which is a roadmap for the kingdom's economic future and hence may succeed in re-enforcing these welcomed developments.

The challenges facing the country remain in having an economic diversification that benefits from greenhouse gas emission avoidances and adaptation to the impacts of climate change, as well as reducing the negative impacts of environmental policies on economic growth. The objective of economic diversification is necessary for sustainability of economic growth and development and increasing the share of non-oil sectors such as industries, energy, mining and tourism. On the other hand, this objective must be met with a reduction in the CO_2 level especially as KSA has agreed to Paris climate agreement in 2015, which demands limiting warming to below 2C degree. Hence, the critical question is whether Saudi Arabia is capable of meeting its environmental obligations without compromising its economic objectives.

The Intended National Determined Contribution (INDC), which was submitted in 2015 to the United Nations Framework Convention on climate change (UNFCC), presented the official position. This official document foresees that integrating climate change objectives and economic diversification will mitigate co-benefits and contribute to economic diversification through a set of measures among them are energy efficiency, renewable energies, and Carbon Capture and storage. The implementation of such plan will be challenging for KSA, but the new economic direction included the establishment of the Council of Economic and Development Affairs, which put forth a very ambitious "2030 Vision" with the aim of tackling these challenges especially as government revenues from oil have dropped considerably. Stevens (2015) noted the fast changes in attitudes and considerable efforts by the Saudi government in implementing these policies towards reducing pollution despite apparent negative impacts to its economy. The inverted U-shaped relationship between per capita income and income inequality Mehmet *et al*., (2016) cited is dated back to the study of Kuznets (1955). Based on (Kuzents, 1955), hypothesis where the relationship between economic development and environmental degradation, as Grossman and Krueger (1991) argue that the inverted U-shaped relationship is also exists between per capita income and environmental degradation. The bottom line of the hypothesis is that the inverted U-shaped relationship between per capita income growth and environmental degradation suggests that as per capita income increases, environmental degradation also increases to maximum point but then decreases and the turning point is the critical high level of income (Lingaraj and Shakti, 2015).

The focus of the present paper is to investigate empirically the validity of Environmental Kuznets Curve hypothesis, which is the effect of income on CO_2 emissions, in KSA. The justification of studying CO_2 emissions has been the core of the debate on environmental protection and development since CO_2 emissions are considered as the source of air pollution and global warming and has been widely used in EKC literature (Jangho, 2015; Lingaraj and Shakti, 2015).The paper contributes to existing literature, especially to KSA case, in many ways. First, it employs the bounds testing approach to cointegration suggested by Pesaran (1997) to avoid and overcome the pitfalls of other approaches. Second, regarding KSA case, the sample is larger than previous studies (Alshehry, 2015). Third, it concentrates on examining the validity of EKC hypothesis in KSA.

The paper is organized as follows. Section 2 reviews the literature on the EKC; section 3 presents the model and data; section 4 is the empirical results; and section 5 provides conclusion and policy implementation.

Literature Review

The origin of the relationship between economic growth and environmental degradation has its roots back to Simon Kuznets who predicted that there is a direct relationship between per capita income increase and income inequality at first stages and then starts declining after a turning point (Halicioglu, 2009). From 1990s onwards, it was observed that the level of environmental degradation and income per capita follows the same relationship as income inequality and income per capita do (Halicioglu, 2009).This phenomenon is known as environmental Kuznets Curve (EKC).

Environmental Kuznets Curve (EKC) postulates that there is a direct relationship an increase between income increase and environmental degradation until some turning point of real per capital income, where the relation reversed, that is an increase in income leads to a reduction in environmental degradation and environmental quality improved (Maria *et al*., 2016; Saboori & Sulaiman, 2013). Then, an inverted U-shaped relationship between environmental degradation (CO_2 emissions indicator) and per capita income exists. Grossman and Krueger (1995, 1993) conducted the first empirical EKC study by using a random city specific effect model, and observed an inverted-U shaped curve for most environmental indicators (Maria *et al*, 2016).

Current literature on environmental Kuznets Curve (EKC) used various indicators to proxy environmental degradation. The use of one indicator may cause biases. However, Luzzati and Orsini (2011) indicate that the use of energy consumption decreases the biases regarding the possible substitution of pollutant for another, non-controllable one, in attempt to reduce environmental degradation. Despite the large volume of applied research investigating the relationship between economic growth and environmental degradation (EKC) using different economic models and econometric approach in different countries and regions (Maria and Jouse, 2016), the results are mixed. This can be attributed to different factors such as data sample and time period, time series characteristics of panel data, and country-specific or regions.

A large volume of empirical research concerning economic growth, environmental degradation, and energy consumption has been conducted (Saboori & Sulaiman, 2013). The empirical methodology utilized different estimation approaches ranging from traditional to modern approaches; such as Johnson cointegration approach, Granger Causality, VECM model, and ARDL bounds testing approach to cointegration using individual country or panel data. One line of research focused on testing the validity of the Environmental Kuznets Curve (EKC) hypothesis, andprovide support for the existence of EKC hypothesis. Jacint and Manuel (2016) employing the ARDL model, provide support the existence of Environmental Kuznets curve (EKC) hypothesis in Spain over the period from 1874 to 2011 by using the variation in oil prices as an indicator for fuel energy consumption.

Jos´e (2016) using the CO_2asindicatorusing the OLS estimation method shows evidence on the existing of the Environmental Kuznets Curve EKC in the Dominican Republic for the period 1960 to 2010. The empirical finding point out that the turning point was at 1991 with income of about $10thousands. Manuel *et al* (2016a) employed ARDL bounds testing to cointegration provide evidence on the existence of long-run Environmental Kuznets Curve (EKC) for Ecuador from 1971 to 2011. The results of Granger causality in the VECM model framework reveal that only GDP Granger causes energy consumption in short-run. Also, Manuel *et al*., (2016b) apply the bounds testing ARDL approach to cointegration, VECM and Granger causality using data over the period 1971-2011to investigate the relationship between CO_2 emissions, economic growth, energy use and electricity for Brazil. Their empirical findings support the existence of an EKC in long-run but not in short-run in Brazil.

Mehmet et al (2016) provide evidence on the existence of EKC in 10 selected Central Eastern European Countries using panel data over the period 1991-2011. In addition, the VECM causality test reveal a bidirectional relationship between CO_2 emissions and both RGDP and Energy consumption. Mohammad and Fatima (2016) empirical findings confirm the existence of EKC in Pakistan over the period 1972-2013 applying the ARDL model. Applying the ARDL estimation for Kenya for the period 1980-2012, Usama et al., (2013) find a support for ECK in Kenya. Ali *et al*., (2015) examine the relationship among CO_2, economic growth, and energy consumption in both short and long run in Pakistan over the period 1980-2012 employing the Johansen co-integration methodology. The empirical results reveal that the environmental Kuznets curve (EKC) hypothesis is a long-run phenomenon but not short-run one. Alshehry and Belloumi (2015) investigated the dynamic relationships between energy consumption and other variables such as economic growth, carbon dioxide and energy prices in KSA by using the Johansen multivariate cointegration approach over the period 1971 to 2010 in KSA. One of the interesting findings is that there is short run unidirectional causality running from CO_2 emissions to energy consumption and economic growth and from energy prices to CO_2 emissions. Balibey (2015) applies Johansen cointegration approach, Granger Causality test, and Impulse response and VDC within the VAR framework for the period 1974 to 2011 in Turkey. His empirical findings verify the existence of EKC hypothesis in Turkey. Fazle *et al*., (2015) examine the short and long run relationships between CO_2 emissions, economic growth, energy consumption, and trade openness for Bangladesh for the period 1972-2012 using Johansen cointegration approach and VECM estimation.

The empirical findings provide evidence on the existence of EKC hypothesis. Jungho (2015) applying the bounds testing (ARDL) approach to cointegration over the period 1960-2010 in Arctic countries, provide little support for the EKC hypothesis. Nicholas& Ilhan (2015) apply the GMM methodology to examine the existence of EKC hypothesis for 14 Asian countries including KSA using panel data for the period 1990-2011.Their empirical findings provide support to the presence of an Environmental Kuznets Curve hypothesis in Asian countries. Shahbaz *et al*. (2015a) provides empirical evidence on the existence of the environmental Kuznets curve (EKC) hypothesis in short and long-run among energy consumption, economic growth, trade openness, urbanization, and carbon emissions in Portugal by applying the ARDL bounds testing to cointegration approach for the period 1971 to 2008. Shahbaz *et al*., (2015b) provide support for Environmental Kuznets Curve (EKC) both in short and long run in Romania over the period 1980 to 2010 by applying the ARDL bounds testing approach to cointegration. O.A. & O. Owoye (2014) examine the applicability of Environmental Kuznets Curve (ECK) in some selected countries over the period 1970 to 2010 using the ARDL bounds testing approach to cointegration. Their empirical results revealed that EKC hypothesis only holds for Japan and South Korea, whereas the N-shaped trajectory holds for the other six countries. Saboor B., and Jamalludin S. (2013) apply the ARDL methodology and the Granger causality test, based on the Vector Error Correction (VECM) Model to examine the validity of EKC in Malaysia for the period 1980-2009. Their empirical results do provide evidence on the existence of EKC for aggregated data, whereas disaggregated data does provide evidence on EKC hypothesis. Khalid and Wei (2013) examine the validity of EKC in Pakistan for the period 1971-2008 using the (ARDL) bound testing approach for cointegration. The empirical findings show support for EKC in long run. Mohamed *et al*. (2012) implement bootstrap panel unit root tests and cointegration techniques to investigate the existence of EKC for 12 Middle East and North African Countries (MENA) over the period 1981–2005. Their empirical findings revealed poor evidence supporting the existence of EKC hypothesis in MENA countries.

Another line found no support to EKC, Aslan & Gozbasi (2016) investigated existence of the environmental Kuznets curve (EKC) hypothesis to the sub-elements of CO_2 emissions in China using fully modified ordinary least squares (FMOLS) and pairwise Granger causality over the period 1977 to 2013. The empirical findings indicate that the validity of the EKC hypothesis results are mixed. It is valid in case of CO_2 emissions from gaseous, liquid fuel, solid fuel and transportation, but not for the rest kinds of emissions. María and Jesús. (2016) empirical findings did not support the existence of EKC in 22 Latin American and Caribbean countries using Panel data for the period 1990-2011. Lingaraj and Shakti (2015) investigated the existence of Environmental Kuznets Curve for SARC countries using panel data for the period 1972-2010 by applying the FMOLS estimation method. The empirical findings did not support the existence of EKC in SAARC countries in the long-run. Miloud *et al*., (2015) examined the validity of Environmental Kuznets Curve for Algeria for the 1971-2009 period employing the (ARDL) model. Their empirical findings reveal that EKC does not exist for Algeria. Usama *et al*. (2015) investigated the validity of EKC for Vietnam for the period 1981-2011 using the ARDL bound testing approach. The empirical findings of Narayan and Narayan (2010) does not provide support for the existence of EKC in Vietnam because there is a positive relationship between GDP and pollution in both the short and the long run.

Econometric Methodology and Data

The concern of environmental impacts of major macroeconomic variables is motivated by the vital role that Carbon Dioxide emissions plays in the environment related issues (Aslan & Gozbasi, 2016). This concern has been the central core of a substantial theoretical and applied research over the past few decades. This section explores the theoretical linkage between EKC hypothesis and its determinants, such as energy consumption, economic growth, trade openness, and financial development …etc. According to EKC hypothesis, the initial stages of income increase are associated with poor environmental conditions, and as income increases more pollution emission in the atmosphere (Khalid & Wei, 2013), however, as soon as income reaches a certain level of growth, the environmental quality improves and starts getting better. The EKC behavior is because at the initial stages the population ignores the pollution since they are more concerned with economic growth rather than with environment quality. However, after attaining the high-income level environment pollution, they become more aware of environment issues and degradation and they begin to pay more attention to environmental quality. This trend in public and economy is considered as the inverted U-shape relationship called EKC hypothesis Manuel *et al*., (2016a, b); Muhammad and Fatima, (2016).

Basic Framework of the Econometric Model

Considerable volume of applied empirical research on environmental degradation and energy consumption-economic growth nexus employed bivariate models. This kind of econometric models may cause an omitted variables problem (Ilhan & Ali, 2010). To avoid this problem, most of the applied researchers resort to using multivariate models that include the square of income (GDP), cubic of income, along with a set of control variables; to name, financial development, foreign direct investment, trade openness test for the existence of EKC: Manuel *et al*., (2016a,b); Muhammad and Fatima, (2016); Aslan & Gozbasi, (2016); María and Josué, (2016); Muhammad and Fatima, (2016); Olugbenga & Oluwole, (2014); Shahbaz, (2015); and Ali *et al*., (2015); Shahbaz *et al*, (2015); Saboori & Sulaiman, (2013). These studies employed a logarithmic functional framework specification which provides an efficient results compared to simple linear model (Manuel *et al.*, 2016 a, b) is expressed as the following:

$$LCO = \alpha_0 + \alpha_1 LY + \alpha_2 (LY)^2 + \alpha_3 (LY)^3 + C_t + \varepsilon_t (1)$$

LCO is an environment degradation indicator proxy by CO_2 per capita emissions, *LY* is per capita of real Gross Domestic Product, income squared (Y^2), cubic income (Y^3) as economic growth indicators, and C_t is a set of control variables. Whereas ε_t is a random error term representing other causes of environmental damage (Jungho, 2015; Mehmet *et al*, 2016). These applied empirical researches employing the standard equation including income (GDP) and square of income as determinant of environmental degradation may suffer from the problem of the presence Multicollinearity arises in the estimation procedure (Usama *et al*., 2016). In econometrics literature, the presence of Multicollinearity leads to large standard errors and wide confidence interval affecting the estimated parameters precision. This situation has motivated researchers to test for the presence of Multicollinearity between income and square of income.

Table (1) reports the result of correlation matrix of proposed variables intended to be included in the estimation model. It is obvious that there is a strong correlation close to perfect correlation among some variables, and hence including them as explanatory variables in the model leads to Multicollinearity problem. As shown in table (3), there is a perfect correlation between income (LY) and square of income$(LY)^2$, population (LPOP) and population density (LDEN), urbanization (LURB), population, and population density, financial development (LFD), trade openness, and population density. Therefore, our model will drop all variables, which suspected of causing Multicollinearity, and will include the rest of the variables. Based on these result the estimation model will include LCO, LEN, LDEN, and LY.

Table 1: Correlation matrix

	LCO	(LY)	$(LY)^2$	LEN	LDEN	LPOP	LURB	LOP	LFD
LCO	1.00	0.16	0.16	0.49	0.46	0.46	0.45	0.35	0.36
LY	0.16	1.00	1.00	-	-0.57	-0.57	-0.58	0.73	-
$(LY)^2$	0.16	1.00	1.00	-	-0.57	-0.57	-0.59	0.73	-
LEN	0.49	-0.54	-0.54	1.00	0.93	0.93	0.94	-	0.92
LDEN	0.46	-0.57	-0.57	0.93	1.00	1.00	1.00	-	0.97
LPOP	0.46	-0.57	-0.57	0.93	1.00	1.00	1.00	-	0.97
LURB	0.45	-0.58	-0.59	0.94	1.00	1.00	1.00	-	0.97
LOP	0.35	0.73	0.73	-	-0.28	-0.28	-0.31	1.00	-
LFD	0.36	-0.68	-0.68	0.92	0.97	0.97	0.97	-	1.00

Narayan and Narayan (2010), due to avoid making the mistake of Multicollinearity between income and square of variables in the estimation results, suggest an alternative procedure of deciding whether EKC exists in developing countries. When long-run elasticity is positive and significant, this procedure rests on comparing the long-run impact of income on carbon dioxide with the short-run impact. If long-run income elasticity is smaller than short-run, this implies that overtime carbon dioxide falls as income increases. Following Narayan and Narayan (2010) and Usama, *et al*., (2016), a logarithmic functional framework specification is expressed as the following:

$$LCO = \alpha_0 + \alpha_1 LY + \alpha_2 LEN + \alpha_3 LDEN + \varepsilon_t (2)$$

Where LCO is an environment degradation indicator proxy by CO_2 per capita emissions (measured in metric tons) stemming from the burning of fossil fuels and manufacturing (Mehmet et al, 2016),$LY$the per capita of real Gross Domestic Product LY(measured in 2000 US $), LEN per capita energy use (measured in KG -Tons- of oil equivalent), and LDEN population density (1000 people/km^2). Whereas ε_t is a random error term representing other causes of environmental damage (Jungho, 2015; Mehmet *et al*., 2016).The data on the selected model variables are taken from the World Development Indicators (WDI) for KSA over the period 1971 to 2013.

Estimation Methodology

To explore the short and long-run relationships between CO_2 emissions, economic growth, energy consumption, and population density; the study uses the vector autoregressive distributed lag (ARDL) bound testing approach for cointegration introduced by Pesaran and Shin (1999) and Pesaran, Shin, and Smith (1997, 2001). The ARDL approach to cointegration has various econometric merits that gained the approach greater acceptance over the well-known residual-based approach proposed by Engle and Granger (1987) and the maximum likelihood-based approach proposed by Johansen and Julius (1990) and Johansen (1992). The Engle and Granger (1987) single equation cointegration approach suffers from problems of endogeniety while the ARDL model is able to distinguish between dependent and the explanatory variables. It also shows appropriate lags in the ARDL capture the data generating process in a general-to-specific modeling framework to correct for both residual correlation and endogeniety (Laurenceson and Chai 2003, p. 28). Moreover, a dynamic error correction model (ECM) can be derived from ARDL through a simple linear transformation (Banerjee *et al*. 1993, p. 51), which allows for inferences of long-run estimates, which is not possible under alternative co-integration procedures (Sezgin and Yildirim, 2002). Moreover, it is also appropriate if all the variables are integrated in different orders I(1) or some in I(0) or they mutually integrated, but not I(2) (Naveed *et al*., 2013; Manuel *et al*., 2016). In addition, the ARDL is relatively more efficient regardless of the sample size applying to small and finite sample data sizes, and applying the ARDL approach to cointegration provides unbiased estimates of the long-run model (Harris and Sollis, 2003). Another important advantage is that estimation is possible even when explanatory variables are endogenous (Alam and Quazi, 2003). The short and long-run parameters with appropriate asymptotic inferences can be obtained by applying OLS to ARDL with an appropriate lag length. Following recent studies concerning EKC hypothesis such as Manuel *et al*., (2016), María and Josué, (2016), Shahbaz *et al*., (2015), Ilhan & Ali (2010) among others, the ARDL -unrestricted error correction model (UECM) - framework of equation (2) is expressed as follows:

$$\Delta LCO = \alpha_0 + \sum_{i=1}^{n} \beta_{1i}\Delta LCO_{t-1} + \sum_{j=0}^{p} \beta_{2i}\Delta LY_{t-j} + \sum_{j=0}^{s} \beta_{3i}\Delta LEN_{t-i} + \sum_{j=0}^{p} \beta_{4i}\Delta LDEN_{t-j} + \delta_1 LY_{t-1} + \delta_2 LDEN_{t-1} + \delta_3 \mathrm{LEN}_{t-1} + \delta_4 LCO_{t-1} + \varepsilon_t \quad (3)$$

The terms $\beta_i \ for \ i = 1, \dots\dots, 4$ are the estimated coefficients of first-differenced variables representing the short-run relationships, while the terms $\delta_i \ for \ i = 1, \dots, 4$are the estimates of the long-run coefficients. Pesaran *et al*. (2001) report two sets of critical values for the significance level when testing for cointegration. The first set of critical values (lower bound) assumes that all variables are I(0), while the other set of critical values (upper bound) assumes that all variables are I(1). The bounds testing procedure is based on the Wald F-statistics test for the existence of the long-run relationship among the variables via the joint significance of the coefficients on the one period lagged levels of the variables included in the model. If, however, the calculated F-statistics is below the lower critical values, then we cannot reject the null hypothesis $(H_0: \delta_i = 0, \ for \ i = 1, .., 4)$of no co-integration. On the hand, if the calculated F-statistics is above the upper critical values, then we can reject the null hypothesis, and hence, accept the alternative hypothesis $(H_a: \delta_i \neq 0, \ for \ i = 1, .., 4)$ indicating the existence of long run relationships. Finally if the calculated F-statistics falls inside these two bounds, then the results are inconclusive. Once co-integration is established, the optimal lag length for each variable can be obtained by using model selection criteria such as the Schwartz Bayesian criteria (SBC) or Akaike's information criteria (AIC).A set of diagnostic tests that examine the serial correlation, functional form using serial autocorrelation (LM) test, normality test, and heteroscedasticity are conducted. Furthermore, the structural stability test is conducted by applying Pesaran *et al*. (2001) cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) to test for the stability of long and short-run estimates.

Vector Error Correction Model (VECM)

Once the long-run relationship among variables is established, then there exists an error correction representation with one lagged period error correction term. The estimation results of the error correction coefficient indicate the speed of adjustment back to the long-run equilibrium after a short-run shock (Masih and Masih, 1997). It is possible to calculate the error correction term (ECT) form the long-run equation proposed by Pesaran *et al*.,(2001) by replacing the lagged level variables in the ARDL equation with ECT_{t-1} and estimate the model after imposing the same optimal lags. The error correction model can be written as follows:

$$\Delta LCO = \alpha_0 + \sum_{i=1}^{n} \beta i \Delta LCO_{t-1} + \sum_{j=0}^{p} \gamma i \Delta LY_{t-j} + \sum_{j=0}^{s} \pi i \Delta \mathrm{LEN}_{t-i} + \sum_{j=0}^{p} \sigma i \Delta LDEN_{t-j} + \lambda_1 ECT_{t-1} + \varepsilon_t \quad (4)$$

The ECT_{t-1} is the lagged error correction term. The existence of the ECM term in the model means that the changes in the dependent variable are a function of the disequilibrium in the cointegration relationship and the changes in the explanatory variables (Manule *et al*., 2016b; Mohammad Zaky, 2015; Shabaz *et al*., 2015). A negative and statistically significant ECT term indicates adjustment of variables towards long-run equilibrium following any short-run disequilibrium. The higher absolute value of the ECT coefficient (λ_1), the faster is the adjustment process.

Non-Granger-Causality test

The evidence on long-run relationship indicates that there is Granger-Causality in at least one direction between the underlying variables (Shabaz *et al*., 2012). Engle-Granger (1987) suggested that if the Granger causality test is conducted at I(1) through VAR framework will be misleading in the presence of cointegration, therefore, an inclusion of additional variable to the VAR method such as the error-correction term would help exploring the long-run relationship (Shahbaz *et al*., 2012;Davoud *et al*., 2013). The causation direction between the underlying variables can be determined by the negative coefficient of the one lagged error-correction term of the long-run effects. The optimal lag length is selected based on the Akiake Information Criterion (AIC), and only cointegrated vectors would be estimated with VECM method, (Davoud *et al*., 2013; Narayan & Singh, 2007; Odhiambo, 2011). VECM model treats all variables as endogenous one by one; hence, the number of equations equals the number of variables included in the model (Ali *et al*., 2015). In VECM method, each dependent variable is a function of its own lags, error-correction term, explanatory variables lags, and a Random variable. Therefore, VECM helps identifying causality among the cointegrated variables and detecting short and long-run relationships. The Granger-Causality test within VECM framework between CO_2 emissions, economic growth, and other variables is as follows:

$$\begin{bmatrix}\Delta lco_t\\ \Delta ly_t\\ \Delta len_t\\ \Delta lden_t\end{bmatrix}=\begin{bmatrix}\mu_1\\ \mu_2\\ \mu_3\\ \mu_4\end{bmatrix}+\begin{bmatrix}\pi_{11,1} & \pi_{12,1} & \pi_{13,1} & \pi_{14,1}\\ \pi_{21,1} & \pi_{22,1} & \pi_{23,1} & \pi_{24,1}\\ \pi_{31,1} & \pi_{32,1} & \pi_{33,1} & \pi_{34,1}\\ \pi_{41,1} & \pi_{42,1} & \pi_{43,1} & \pi_{44,1}\end{bmatrix}\begin{bmatrix}\Delta lco_{t-1}\\ \Delta ly_{t-1}\\ \Delta len_{t-1}\\ \Delta lden_{t-1}\end{bmatrix}$$
$$+\cdots\ldots+\begin{bmatrix}\pi_{11,k} & \pi_{12,k} & \pi_{13,k} & \pi_{14,k}\\ \pi_{21,k} & \pi_{22,k} & \pi_{23,k} & \pi_{24,k}\\ \pi_{31,k} & \pi_{32,k} & \pi_{33,k} & \pi_{34,k}\\ \pi_{41,k} & \pi_{42,k} & \pi_{43,k} & \pi_{44,k}\end{bmatrix}\begin{bmatrix}\Delta lco_{t-k}\\ \Delta ly_{t-k}\\ \Delta len_{t-k}\\ \Delta lden_{t-k}\end{bmatrix}+\begin{bmatrix}\lambda_1\\ \lambda_2\\ \lambda_3\\ \lambda_4\end{bmatrix}+\begin{bmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\\ \varepsilon_{3t}\\ \varepsilon_{4t}\end{bmatrix} \quad (5)$$

Residual terms ε_{it} are assumed to be independently and normally distributed with zero mean and constant variance. The VECM provides three types of causality, the weak and strong short-run and long-run causal relationships (Manuel *et al*., 2016b). Applying Non-Granger-Causality test to equation 5, we can present the three different kinds of causality as follows (Ilhan & Ali, 2011):

1- Short-run or weak Granger causalities are detected through Wald F-statistic test for the joint significance of the coefficients on the first differenced series.

2- The long-run Granger causality can be explored by examining the significance of the error correction terms $\lambda_i$through the t-statistic or Wald test (Menzi, 2014; Odhiambo, 2011; Shabaz *et al*., 2012).

3- Strong Granger causalities are detected by testing the joint hypothesis of ECT_{t-1} terms and the short-run lagged periods of each variable using Wald F-statistics.

Table 2: The results of Granger-Causality

	Short-Run (or Weak) Granger Causality				Long-Run
	ΔLCO	ΔLY	ΔLEN	$\Delta LDEN$	λ_i
ΔLCO	__--	$\pi_{12,1}=\cdots$	$\pi_{13,1}=\cdots$	$\pi_{14,1}=\cdots$	$\lambda_1=0$
ΔLY	$\pi_{21,1}=\cdots$	----	$\pi_{23,1}=..=\pi_{23,k}$	$\pi_{24,1}=\cdots$	$\lambda_2=0$
ΔLEN	$\pi_{31,1}=\cdots$	$\pi_{32,1}=\cdots$	----	$\pi_{34,1}=\cdots$	$\lambda_3=0$
$\Delta LDEN$	$\pi_{41,1}=\cdots$	$\pi_{42,1}=\cdots$	$\pi_{43,1}=\cdots$	-----	$\lambda_4=0$

Empirical Results and Discussion

This section will estimate the empirical model to investigate the short and long-run relationships among CO_2 emissions and considered explanatory variables, the Granger Causality within the VECM framework, and stability tests.

Stationarity test (Unit root tests)

To ensure that all variables are either integrated of order zero or order one but not I(2), according to (Pesaran *et al.*, 2001), the Augmented Dickey-Fuller (ADF) test (1979), Phillip-Perron (1988) test, are employed to determine the integration order for the time series variables. Table 3 reports the unit root tests.

Table3: results of unit roots tests

Variable	ADF results			Phillip-Perron (PP)		
	Constant	Constant & Trend	None	Constant	Constant & Trend	None
LY	-2.367	-0.795	-0.447	-1.517	-1.613	0.284
ΔLY	-3.095**	-5.746*	-3.08*	-3.82*	-3.84**	-3.89*
LEN	-1.79	-2.956	2.270	-1.711	-1.57	1.700
ΔLEN	-3.02**	-3.298** 2.	-3.67**	-4.89*	-5.299*	-4.411*
LCO	-3.153**	-3.257**	0.487	-3.152**	-3.257**	0.742
ΔLCO	***	***	-6.36	****	*****	-6.6*

(*), (**) significant at 1%, 5% respectively

According to these results, all variables are non-stationary at level except (*LCO*), but other variables become stationary at first level, that is all variables are integrated are either I(1) or I(0).

The diagnostics statistical tests of the ARDL (4, 2, 3, 3) estimation results reveal that the model does not suffer from Serial correlation problem as the F-statistic of Breusch-Godfrey which 0.195 with two lags indicating that there is no autocorrelation in the disturbance of the error terms. The ARCH test suggests that the error terms are homoscedastic and independent of the explanatory variables, this is indicated by the F-statistics of Breusch-Pagan-Godfrey test for heteroscedasticity equals to (0.77). Finally, the model passes the Jarque-Bera test suggesting that the error term is normally distributed.

Bounds test approach to Co-integration

The next step is to explore the existence of long-run relationship between the underlying variables using ARDL bounds testing approach to cointegration (Davoud *et al*., 2013, Narayan & Singh, 2007). The first step is to determine the optimal lag length on the first differenced for equation (2) by selecting the minimum AIC. Second step is the application of the bounds F-test in equation (5), to investigate the short-run and long-run relationships among variables.

Table (4) reports the results of ARDL bounds testing to cointegration for equation 5. The results indicate that co-integration is present where F-static is higher than the upper bound critical value at 1% except for LEN equation, and hence, we can reject the null hypothesis of no cointegration for equations 5 except the LEN equation. Based on these cointegration results, we can estimate the VECM model for these cointegrated equations.

Table 4: Results of bounds testing to cointegration

Dep. Var.	Function	F-Statistics	C.V	I(0)	I(1)	Coint.
LCO	F_{LCO}(LCO/ LY, LEN, LDEN)	5.735	1%	4.29	5.61	YES
LY	F_{LY}(LY/LCO, LEN, LDEN)	11.36	1%	4.29	5.61	YES
LEN	F_{LEN}(LY/LCO, LY, LDEN)	2.605	5%	3.23	4.35	No
LDEN	F_{LDEN}(LY/LCO, LEN, LY)	11.24	1%	5.17	6.36	YES

Long-run and short-run estimation

Table 5 shows the short-run estimation results. It shows that the first differenced of all variables are significant in the short-run. These results indicate that these variables have a short-run effect on CO_2 emissions. Economic growth, population density, and energy consumption variables have the expected positive impacts on the level of CO_2 emission in KSA.

Table 5: Short and long-run estimation results (LCO_2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LCO(-1))	1.015140	0.294406	3.448092	0.0022
D(LCO(-2))	0.502047	0.214270	2.343058	0.0281
D(LCO(-3))	0.346784	0.175508	1.975880	0.0603
D(LY)	1.286641	0.392916	3.274593	0.0033
D(LY(-1))	-0.778133	0.411723	-1.889945	0.0714
D(LEN)	0.588892	0.223977	2.629250	0.0150
D(LEN(-1))	-0.358278	0.307048	-1.166846	0.2552
D(LEN(-2))	0.475058	0.246640	1.926118	0.0665
D(LDEN)	-149.836747	57.793918	-2.592604	0.0163
D(LDEN(-1))	271.234692	129.902386	2.087989	0.0481
D(LDEN(-2))	-67.972861	39.868215	-1.704939	0.1017
CointEq(-1)	-1.487543	0.333272	-4.463449	0.0002
Cointeq = LCO - (0.6314*LY + 0.1214*LEN -0.0491*LDEN -3.9973)				

The carbon dioxide emission elasticity with respect to economic growth in the short-run is greater than one (1.286), a 1% increase in economic growth increase carbon emission by 1.286%. Energy consumption has a positive and significant elasticity, a 1% increase in energy consumption increases carbon emission by 0.59%. The error correction term is negative and significant at 1% level indicating that model converges to its long-run equilibrium. The error correction coefficient is about (-1.5) reflecting the high speed of adjustment within less than a year. Table 6 reports the long-run estimation results. The results reveal that only economic growth variable has a significant positive long-run impact on the carbon emission, with income elasticity equals to 0.6315.

To examine the existence of the Environmental Kuznets Curve (EKC) in KSA, we compare the relationship between the short-run and long-run elasticities of carbon emission with respect to economic growth. The short-run and long-run estimation results indicate that the short-run economic growth elasticity is greater than its long-run elasticity, which indicates the validity and the existence of EKC hypothesis in KSA.

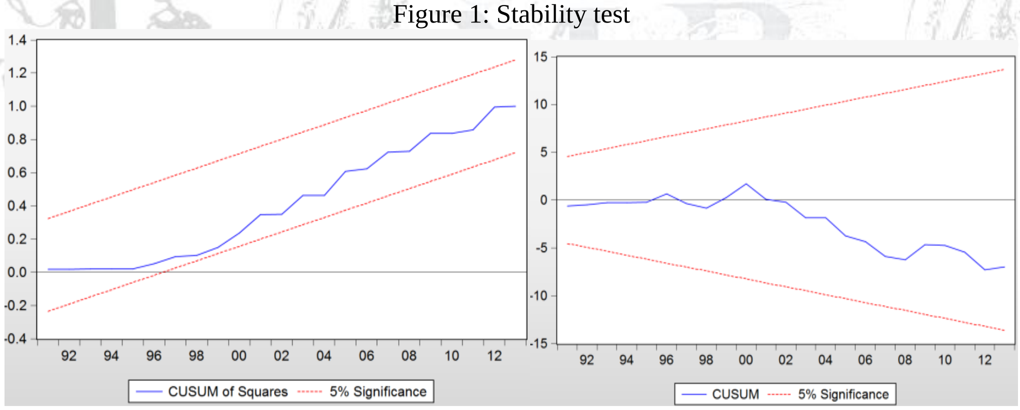
Table 6: Long-run estimation results

Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LY	0.631445	0.109597	5.761540	0.0000
LEN	0.121406	0.128470	0.945014	0.3545
LDEN	-0.049063	0.174524	-0.281126	0.7811
C	-3.997297	1.387589	-2.880749	0.0084

Stability Test

It is more likely that macroeconomic series may experience to one or multiple structural breaks due to the structural changes in developing economies. Therefore, it imperative to check for the stability of the short-run and long-run coefficients through the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests proposed by Brown *et al.*,(1975). The CUSUM and CUSUMSQ tests are quite general tests for structural change that they do not require a prior specifying the structural breaks dates. Whereas, the Chow test requires break point (s) to be specified. If the cumulative sum crosses the 5 per cent critical lines the parameters are not stable. Just like the CUSUM test, the significance of deviation from the mean value line is checked by parallel critical lines around the mean value. If the line passes outside the critical bounds, this is an indication of the instability of the regression parameters. If the plots of these tests statistics stay within the critical bound of 5% level of significance, the null hypothesis of all coefficients of the regression are stable cannot be rejected, therefore, implying that the coefficients in the error-correction model are stable (Bekhet & Mater, 2013). As observed in Figures (1&2), the plots of CUSUM and CUSUMSQ statistics stay within the critical 5% bound for the period, and hence, the coefficients are stable and they do not suffer from structural break in the cumulative sum over the periods.

Figure 1: Stability test



Non- Granger-Causality results

Table (7) reports the short and long-run relationships among CO_2 emissions, economic growth, energy consumption, and population density. The coefficient of ECM when CO_2 emission is the dependent variable is negative and statistically significant implying the existence of long-run causality runs from economic growth, energy consumption, and population density to Carbon Dioxide emissions. The magnitude of ECM term implies that about 149% of the disequilibrium in economic growth of the previous year's shock adjusts back to the long run equilibrium in the current year. In addition, there is a long-run relationship runs from Carbon dioxide, energy consumption, and population density to economic growth. There are no long-run relationships for LEN and LDEN equations since the former did not pass the bounds, while the later has a positive and insignificant ECM term.

Table 7: The results of Granger-Causality (Wald F-statistic test)

	Short-Run (Weak) Causality				Joint Short/Long-run (Strong)				Long-Run
	ΔLCO	ΔLY	ΔLEN	$\Delta LDEN$	ΔLCO	ΔLY	ΔLEN	$\Delta LDEN$	λ_i, i
ΔLCO	-----	6.59	4.59 *	1.85	-----	6.45**	4.10*	2.58 #	(-4.475)*
ΔLY	57.1*	------	1.49	4.3**	45.69*	-----	1.53 #	2.123 #	(-3.62)*
ΔLEN	13.4*	0.19#	-----	6.64*	----	-----	----	----	----
$\Delta LDEN$	16.04	5.75*	131*	-----	------	----	-----	----	0.0007#

Notes: the null hypothesis is that there is no Granger-Causality between variables. Values in parentheses are P-values for Wald-test.

Δ, is the first difference operator. *, **, # denote significance at 1% and 5% level and insignificant respectively.

The short-run causality shows bidirectional causality between economic growth and CO_2, CO_2 and energy consumption, economic growth and population density, and energy consumption and population density. Whereas, a unidirectional causality runs from CO_2 to population density. However, there is no causality between economic growth and energy consumption.

Conclusion

Currently, the increased trend in carbon dioxide and the increased concern in the pollution's impact on environment have triggered a considerable volume of theoretical, applied research, and policy responses. These are due to fact that as a result of government efforts to achieve a high and sustainable economic growth, there is potential adverse damage to the environmental quality (Jos´e, 2016).

The objective of the present paper is to investigate the existence of the Environmental Kuznets Curve (EKC) for KSA. It examines the short and long-run relationships between carbon dioxide, energy consumption, population density, and economic growth over the period 1971 to 2013 employing the Autoregressive distributed lagged (ARDL) bounds testing approach to cointegration posed by Pesaran and Pesaran (1997), and Pesaran *et.al.*, (2001). It also examines the Granger Causality within the VECM framework to explore the short-run and long run causality direction using the F-statistic or Wald-test. The ADF stationarity test show the variables are either I(0) or I(1).

The ARDL bounds test F-statistic provide evidence on the existence of long-run equilibrium relationship between model variables in KSA. The long-run estimation results reveal a positive and a significant elasticity of carbon dioxide emission with respect to economic growth in both short and long run, and that the long run elasticity is less than the short-run elasticity. Following Narayan (2010) methodology, the results provide support for the existence of EKC in KSA. This result indicate that the carbon dioxide emissions decreases as income increases over time. The CUSM and CUSMSQ stability tests show that the estimated parameters are stable and there are no structural breaks over the period. Even though the results indicate that in long-run as income increases the carbon dioxide level falls, still there is a sources of carbon dioxide emission affecting the environmental quality. The Non-Granger causality results reveal bidirectional causality between economic growth, energy consumption, population density, and CO_2; economic growth and population density, energy consumption and .population density, whereas, unidirectional causality runs from CO_2 to population density

There are a number of policy responses that can help reducing the emission level. One of them is imposing taxes on pollution. Another way is to increase the role of renewable and clean energy (i.e. nuclear energy) consumption and energy efficiency can help reducing the air pollution levels. These measures may reduce CO_2 (with reduction in energy consumption) but without considerable negative impact on economic growth which gives strong likely hood for KSA to meets its environmental obligations. Therefore, the government may help establishing the Environmental Kuznets Curve relationship between air pollution and economic growth.

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