Economic Growth And Carbon Dioxide Emissions: The Environmental Kuznets Curve Hypothesis In Yemen

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Abstract
This study investigates the validity of the Environmental Kuznets Curve hypothesis in Yemen and the causal relationships between Carbon dioxide emissions, per capita income, energy consumption, trade openness, and industrial share to GDP. ARDL bounds testing approach to cointegration, Error Correction Model, and Toda-Yamamoto procedure to Granger causality techniques were employed on annual data covering the period from 1990 to 2010. long run relationship between CO2 emissions and its determinants with significant effects for per capita GDP and trade openness, whereas, energy consumption and trade openness appear to be important determinants of CO2 emissions in the short run. Besides, based on Narayan and Narayan (2010) approach, it is found that the EKC hypothesis does not hold in Yemen and therefore the effect of per capita income on CO2 emissions is monotonically increasing. Toda-Yamamoto causality test proved the existence of bidirectional causal relationships between economic growth and CO2 emissions, between energy consumption and economic growth, and between trade openness and energy consumption.
Keywords:CO2 emissions, economic growth, EKC hypothesis, ARDL Cointegration, Yemen

Introduction
The environmental degradation and climate change that associated with the growing human activities has become one of the worldwide most mounting public concerns. Air pollution especially CO2 emissions, as the primary greenhouse gas, is considered a major source for global warming. The combustion of fossil fuels (oil, natural gas, and coal) for electricity, industry, transportation, and other activities constitutes the main human activity that emits CO2. Accordingly, intensive attention has been paid by economists to explore the determinants factors behind CO2 emissions in the context of its relation to economic growth. In this regard, the EKC hypothesis dominates the literature studying the relationship between environmental degradation and economic growth. According to Environmental Kuznets Curve (EKC) hypothesis, the relationship between the level of environmental quality and economic growth takes an inverse U shaped

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pattern, and this pattern has been coined as EKC hypothesis. During the last three decades, intensive attention has been paid to the investigation of the validity of the EKC hypothesis.These investigations were conducted via examining the relationship between several environmental pollutants (such as sulfur dioxide, nitrogen dioxide, nitrates, and CO_2) on the one hand and economic growth and other factors on the other. The fact that CO_2 is a primary greenhouse gas and thus an important source of air pollution, as well as the availability of long time series of CO_2 for most countries, resulted in the focus of most studies on CO_2. However, most of these studies especially earlier ones were cross-country which were applied to either panel or cross-sections data.

As one of the least developed countries, Yemen is facing several socio-economic and environmental challenges. According to World Bank (2017), with per capita income of 1140 US$ and a population of 26.8 million in 2015, about 35% of Yemen population has been estimated to live below the poverty line of 2 US$/day. Oil and gas subtraction activities, constitute around 25% of GDP and about 70% of total public revenue. Agriculture activities represent the mainstay of around two-third of the rural population and employ more than 54% of the total employed workforce, whereas its contribution to GDP does not exceed 15%. Two - thirds of the population live in rural areas and relying on natural resources in their activities of farming, fishing, wooding, and grazing which imposes increasing pressures on these resources and thus jeopardizes the sustainability of development process via environmental degradation. Furthermore, economic activities such as oil and gas subtraction, manufacturing, transportation, and electricity production cause the problems of pollution and climate change and thus affect productivity and public health.

Research Problem

The features of climate change in Yemen have been noted during the last two decades through higher temperatures, extreme changes in rainfall, and flooding (such as that of 1996 and those of 2005-2008), and future projections suggest a steady rise in these events (UNDP, 2012). Accordingly, the problem of this study can be formulated as a question as follows: what is the nature of the relationship between economic growth and the environmental degradation in Yemen and what are the factors affecting environment degradation (proxied by CO2 emissions).

Research Goals

This paper aims at :

1-examining the effects of economic growth, energy consumption, trade openness, and industrial activity on CO2 emissions and thus exploring the validity of EKC hypothesis in the case of Yemen over the period 1990-20109, according to Narayan and Narayan (2010) approach, using advanced econometric techniques

namely, Auto Regressive Distributed Lags (ARDL) bounds testing approach to cointegration and Error Correction Model (ECM).
2- Investigating the causal relationships between Carbon dioxide emissions, economic growth, energy consumption, trade openness, and industrial share to GDP, employing Toda-Yamamoto procedure of Granger causality test.

Research Importance

1- To our knowledge, no econometrical analysis of CO2 emissions determinants and the validity of the EKC hypothesis in Yemen has been done. Accordingly, this study attempts to fill this gap.
2- This study adds evidence to the limited available EKC studies related to least developed countries.

Theoretical Side

Grossman and Krueger (1991) showed that the relationship between the level of environmental quality and economic growth takes an inverse U shaped pattern, and this pattern has been coined as EKC by Panayotou (1993), seeing that it resembles the original and well-known relationship between economic growth and income inequality introduced by Kuzents (1955). It is claimed that development causes environmental quality to deteriorate at the initial stages and tends to improve it at later stages. At earlier stages, priority is given to achieving a rise in income per capita and employment rates, which entails an accelerated growth in various economic activities, especially industrial ones, and accordingly increasing pollution emissions and degradation to natural resources, with little if no attention is paid to environment quality (Dasgupta et al., 2002). Later on and at a high per capita income, people give more consideration to a better environment and cleaner air and public and private institutions become more interested in attaining sustainable development. Besides, at advanced levels of development, economic activity transforms towards information-intensive industries and services sectors and therefore declining environmental degradation and pollution (Panayotou, 1993). Accordingly, a peak level of income distinguishes between the two stages and the second one is referred to as the "de-linking of environmental pressures" (Simonis, 1989).

Empirical Literature Review

As already mentioned, the EKC has received intensive attention in the empirical literature during the last two decades. Despite the availability of a large number of studies, either those used CO2 emissions or other pollutants, their concluding results still conflicting with one another especially cross-country ones. Generally, EKC studies covered different sets of countries and periods, used various pollution indicators, and employed several econometrical techniques and therefore resulted in abroad range of conclusions and leading to sometimes conflicting interpretations (Dinda, 2004: 442). The modern trend in investigating the EKC

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hypothesis emphasizes country-specific (time series) investigations due to criticism and weakness that surround multiple-country researches. It is argued that EKC hypothesis tested from cross-country examinations does not capture dynamic process well enough to justify the relationship between environmental pressure and economic growth in each country included in the sample, and therefore generated a spurious estimate of EKC (Bruyn et al. 1998). In other words, the supposed U inverted relationship between environmental pollutants and income per capita is a static artefact (Galeotte et al. 2006). Moreover, the existing empirical literature on EKC focus on developed and developing economies with enough attention has not been paid to lower-income or least developed ones. For these reasons, and since Yemen is one of the least developed countries, our literature review will be focused on works performed on developing and least developed countries employing CO2 as a pollutant.

As for cross-country studies used panel analysis, Omojolaibi (2010) tested the EKC hypothesis via investigating the relationship between GDP per capita and CO2 emissions in three west African countries using fixed effects and pooled effects regression and found that pooled OLS confirms an inverted U shaped EKC whereas, fixed - effects analysis does not. Arouri et al. (2012) added energy consumption to CO2 emissions and GDP per capita in studying the EKC hypothesis in 12 MENA countries over the period 1981-2005, implementing bootstrap panel cointegration techniques and ECM. Their results showed that turning points were very low in some cases and very high in others which meant, according to them, poor evidence in support of the EKC hypothesis. In evaluating the relationship between energy consumption, economic growth and CO2 emissions, along with trade openness and financial development as control variables, in eight developing Asian economies for the period from 1990 to 2010, Cheema and Javid (2015) applied panel cointegration (Kao and Pedroni) tests and FMOLS technique. Their results support the existence of inverted U shaped Kuznets curve in these countries for all models. Al-Mulali et al. (2015) found an inverted U shaped relationship between GDP and CO2 in the case of Latin-America and Caribbean countries over the period 1980-2010. The renewable energy consumption and financial development included in their models where panel cointegration and FMOLS employed. Hu et al. (2018) confirmed the EKC hypothesis in 25 developing countries during the years 1996-2012, using panel cointegration, FMOLS and DOLS. Beyene and Kotosz (2020) assessed the effects of GDP per capita, globalization, foreign direct investment, population density, and political stability on CO2 emissions for 12 east African countries during 1990-2013. The use of pooled mean group (PMG) approach confirmed the existence of a long run relationship between these variables, but provide evidence to the existence of U-shaped EKC (extended version of EKC).

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Concerning single-based time - series studies, Ahmed and Qazi (2014) examined the effects of economic growth, energy consumption, and trade openness on CO2 emissions for Mongolia, using Johansen cointegration and Granger causality tests during 1996-2014. It is found that the EKC hypothesis exists, and economic growth and energy consumption significantly affect CO2 in both the short and long run. In the case of Ghana, Opoku et al. (2014) provide strong evidence in support of the EKC hypothesis during 1970-2010, via employing the Johansen cointegration procedure. Similarly, Keho (2015) gives support to the economic growth and environment degradation-nexus in Coted'Ivoire for the period from 1970 to 2010, using ARDL. The effects of per capita income, trade openness, and share of the industrial sector in GDP on CO2 emissions were inspected. Al-Mulali et al. (2015) examined the existence of EKC hypothesis in Vietnam for the period 1981-2011, utilizing ARDL. The relationship between per capita GDP and CO2 emissions checked via including the capital, electricity consumption, imports, exports to the model. Their analysis results implied that Vietnam does not fulfil the EKC hypothesis. The study of Rabbi et al. (2015), applying Johansen cointegration test and impulse response analysis on a model that includes CO2, GDP per capita, and energy consumption, shows that EKC does not hold in the case of Bangladesh for the period 1972-2011. On the contrary, empirical evidence for a long run EKC for Ecuador was introduced by Zambrano-Monserrate et al. (2016). In this study, ARDL and Granger causality test was applied to examine the relationship between CO2, economic growth, and energy consumption from 1971 to 2011. The same conclusion was reached regarding the case of Kenya. Al-Mulali et al. (2016) used Narayan and Narayan (2010) approach to test the impacts of per capita income, urbanization, energy consumption, and trade openness on CO2 emissions during 1980-2012. Another investigation by Mikayilov et al. (2018) employed a broad range of econometric techniques (ARDL, Johansen cointegration, FMOLS, DOLS) to check the validity of EKC in Azerbaijan for the period from 1992 to 2013, and concluded that EKC hypothesis does not hold for Azerbaijan.

Econometric Methodology and Data

1- ARDL Bounds test to Cointegration and ECM

According to the theoretical basis of the EKC hypothesis, examining its validity in most empirical studies use the well-known quadratic model as follows :

$$\mathbf{CO2} = \propto_0 + \propto_1 \mathbf{Y} + \propto_2 \mathbf{Y}^2 + \delta_1 \boldsymbol{X}_1 + \delta_2 \boldsymbol{X}_2 + \ldots\ldots + \delta_n \boldsymbol{X}_n + \mathbf{e_t} \,, \qquad (\mathbf{1})$$

where CO2 stands for per capita carbon dioxide emissions as a proxy to environment degradation, Y is per capita income, and $\mathbf{Y^2}$ is per capita income squared. $\boldsymbol{X_1}$ to $\boldsymbol{X_n}$ are controlling variables affecting CO2 emissions However, this model suffers from the problem of multicollinearity between $\mathbf{Y}$ and $\mathbf{Y^2}$,which means unreliable estimates due to the resultant large standard errors and wide

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confidence intervals. The correlation coefficient between $\mathbf{Y}$ and $\mathbf{Y^2}$ from the data of Yemen is 0.99 which indicates about perfect correlation. To overcome this problem, Narayan and Narayan (2010) approach will be employed to evaluate the validity of EKC in Yemen. According to Narayan and Narayan (2010), checking the existence of EKC hypothesis can be performed by using only Y to stand for economic growth or economic activity, and then comparing its elasticity between the short and long run. If the long - run elasticity of per capita GDP is smaller than that of the short run, this means that, over time, an increase in income leads to less CO2 emissions and thus EKC hypothesis holds. This approach looked upon as a new generation of EKC literature and hence applied by many studies such as Jaunky (2011), Arouri et al.(2012) , Al-Mulali et al.(2016), Narayan et al. (2016). So, our model can be formulated as follows:

$$\mathbf{LCO2} = \delta_0 + \delta_1\mathbf{LY} + + \delta_2 \boldsymbol{LEC} + \delta_3\boldsymbol{OP} + \delta_4\boldsymbol{IND} + \mathbf{u_t} \ , (\mathbf{2})$$

where Y is per capita income, EC is energy consumption, OP represents trade openness, IND is the share of industry to GDP, and U is stochastic disturbance term. Concerning a priori expectation, the literature expects the sign of per capita real GDP Y to be positive ($\delta_1 > 0$), as EKC hypothesis assumes CO2 to increase when per capita real GDP increase at early stages of development. The coefficient of EC is supposed to be positive ($\delta_2 > 0$) too, as the increase in energy consumption leads to more economic activity and thus more pollution (CO2 emissions). Similarly, It is predicted that a positive relationship between CO2 and IND exists in developing and least developed countries, since the increase in industrial activities leads to more energy consumption and thus, more pollution emissions. The coefficient of trade openness could either be positive or negative depending on the level of development of the country under study (Halicioglu 2009). From the one hand, the scale effect of international trade states that increasing trade especially exports raise the size of the economy and consequently increases pollution (Dinda 2004 436). In Also, the displacement hypothesis or pollution haven hypothesis (PHH) postulates that increasing trade openness leads to the rapid growth of pollution-intensive industries in less developed countries and thus increasing pollution compared to developed ones where environmental regulations are more strict (Tobey 1990; Rock 1996). On the other hand, it is expected that trade openness coefficient can be negative, meaning that more trade openness can be good for the environment as it raises income levels in developing countries and thus creates demand for the cleaner environment (Liddle 2001).

The EKC hypothesis will be checked using ARDL bounds testing to cointegration, ECM, and Toda-Yamamoto procedure of Granger causality test. ARDL bounds testing and ECM proceed in stages. In the first one, the existence of a cointegration relationship between CO2 and its determinants is tested by estimating a conditional ARDL representation of equation (2) as follows:

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$$dLCO2_t = \delta_0 + \sum_{i=1}^{n} \delta_1\, dLCO2_{t-i} + \sum_{i=0}^{n} \delta_2\, dLY_{t-i} + \sum_{i=0}^{n} \delta_3\, dLEC_{t-i} + \sum_{i=0}^{n} \delta_4\, dOP_{t-i} + \sum_{i=0}^{n} \delta_5\, IND_{t-i} + \delta_6\, LCO2_{t-1} + \delta_7 LY_{t-1} + \delta_8 LEC_{t-1} + \delta_9\, OP_{t-1} + \delta_{10} IND_{t-1} + e_t, \qquad (3)$$

where *d* denotes the first difference operator and *n* is the maximum lag length. The parameters $\boldsymbol{\delta_1}$- $\boldsymbol{\delta_5}$ stand for the short-run dynamics whereas $\boldsymbol{\delta_6}$- $\boldsymbol{\delta_{10}}$ present the long-run relationships. Following the estimation of equation (3), a joint significance test of no cointegration relationship between the variables is implemented with the null hypothesis $\mathbf{H_0}$: $\boldsymbol{\delta_6} = \boldsymbol{\delta_7} = \boldsymbol{\delta_8} = \boldsymbol{\delta_9} = \boldsymbol{\delta_{10}} = 0$ as against the alternative hypothesis $\mathbf{H_1}$: : $\boldsymbol{\delta_6} \neq \boldsymbol{\delta_7} \neq \boldsymbol{\delta_8} \neq \boldsymbol{\delta_9} \neq \boldsymbol{\delta_{10}} \neq 0$.
The bounds test procedure of Pesaran et al. (2001) depends on the Wald test (F statistics) with an asymptotic non- standard distribution. Pesaran et al. (1996) provide two bounds of critical values for different model specifications. If the computed F statistic, at a chosen significance level, exceeds the upper critical bound value, the null hypothesis of no cointegration is rejected. Similarly, if the computed F statistics falls below the lower critical bound value, the null hypothesis of no cointegration is not rejected. When the computed F statistics falls between the two critical bound values, the result is considered inconclusive.

Once a long-run relationship is confirmed, the long-run elasticities are calculated from equation (3) or directly from equation (4) as follows:

$$LCO2_t = \beta_0 + \sum_{i=1}^{n} \beta_1\, LCO2_{t-1} + \sum_{i=0}^{n} \beta_2\, LY_{t-1} + \sum_{i=0}^{n} \beta_3\, LEC_{t-1} + \sum_{i=0}^{n} \beta_5\, OP_{t-1} + \sum_{i=0}^{n} \beta_6\, IND_{t-1} + e_t, \qquad (4)$$

The ECM representation associated with the above long-run equation estimates the short-run coefficients and the speed of adjustment of CO2 to changes in the explanatory variables before converging to its equilibrium level. It can be formulated as follows:

$$dLCO2_t = \mu_0 + \sum_{i=0}^{n} \mu_1\, dLY_{t-i} + \sum_{i=0}^{n} \mu_2\, dLEC_{t-i} + \sum_{i=0}^{n} \mu_3\, dOP_{t-i} + \sum_{i=1}^{n} \mu_4\, dIND_{t-i} + \partial ect_{t-1} + \varepsilon_t, \qquad (5)$$

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where $\boldsymbol{\partial}$ is the speed of adjustment parameter and **ect** is the residuals that are obtained from the estimation of equation (4).

Finally, the structural stability of the parameters of LCO2 model is tested using the cumulated sum of recursive residuals (CUSUM) and cumulated sum of squares of recursive residuals (CUSUMSQ) tests, suggested by Brown et al. (1975).

2- Toda Yamamoto Procedure to Granger Causality test

Toda and Yamamoto (1995) procedure of the Granger causality test is applied to test the causal relationship and bidirectional effects between the study variables. This technique is applicable and does not affect by the degree of the variable integration and whether variables under study is co-integrated or not. Thus, Toda-Yamamoto procedure is the appropriate causality test when variables are mixed of both I(0) and I(0), as the case is in our study. The conventional Granger (1969) causality test from a VAR (vector autoregressive) model relies on the asymptotic theory and supposes zero restrictions on the lag parameters of variables and thus the traditional Wald test (WALD) would lead to spurious Granger causality conclusions (Toda and Yamamoto (1995), Sims et al.(1990), and He and Maekawa (2001)). However,the Toda-Yamamoto procedure avoids these problems via introducing a modified Wald test (MWALD) for restriction on the parameters within an Augmented VAR. It estimates VAR with a lag order of $(k + d_{max})$ instead of its original true lag order k, where d_{max} is the maximum order of integration of the variables. The resulted Toda-Yamamoto representation of our core equation (2) can be introduced as follows:

$$\mathbf{LCO2_t = \partial_0 + \sum_{i=1}^{k} \delta_{1t}\, LCO2_{t-i} + \sum_{i=k+1}^{d_{max}} \alpha_{1t}\, LCO2_{t-i} + \sum_{i=1}^{k} \mu_{1t}\, LY_{t-i} + \sum_{i=k+1}^{d_{max}} \infty_{1t}\, LY_{t-i} + \sum_{i=1}^{k} \beta_{1t}\, LEC_{t-i} + \sum_{i=k+1}^{d_{max}} \varkappa_{1t}\, LEC_{t-i} + \sum_{i=1}^{k} \phi_{1t}\, OP_{t-i} + \sum_{i=k+1}^{d_{max}} \eta_{1t}\, OP_{t-i} + \sum_{i=1}^{K} {}^{3}\sigma_{1t}\, IND_{t-i} + \sum_{i=k+1}^{d_{max}} \varphi_{1t}\, IND_{t-i} + e_{1t}}, \quad (6)$$

$$\mathbf{LY_t = \partial_1 + \sum_{i=1}^{k} \delta_{2t}\, LCO2_{t-i} + \sum_{i=k+1}^{d_{max}} \alpha_{2t}\, LCO2_{t-i} + \sum_{i=1}^{k} \mu_{2t}\, LY_{t-i} + \sum_{i=k+1}^{d_{max}} \infty_{2t}\, LY_{t-i} + \sum_{i=1}^{k} \beta_{2t}\, LEC_{t-i} + \sum_{i=k+1}^{d_{max}} \varkappa_{2t}\, LEC_{t-i} + \sum_{i=1}^{k} \phi_{2t}\, OP_{t-i} + \sum_{i=k+1}^{d_{max}} \eta_{2t}\, OP_{t-i} + \sum_{i=1}^{K} {}^{3}\sigma_{2t} + \sum_{i=k+1}^{d_{max}} \varphi_{2t}\, IND_{t-i} + e_{2t}}, \quad (7)$$

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$$\begin{aligned} LEC_t = \partial_2 &+ \sum_{i=1}^{k} \delta_{3t}\, LCO2_{t-i} + \sum_{i=k+1}^{d_{max}} \alpha_{3t}\, LCO2_{t-i} + \sum_{i=1}^{k} \mu_{3t}\, LY_{t-i} \\ &+ \sum_{i=k+1}^{d_{max}} \infty_{3t}\; LY_{t-i} + \sum_{i=1}^{k} \beta_{3t}\, LEC_{t-i} + \sum_{i=k+1}^{d_{max}} \varkappa_{3t}\, LEC_{t-i} \\ &+ \sum_{i=1}^{k} \phi_{3t}\, OP_{t-i} + \sum_{i=k+1}^{d_{max}} \eta_{3t}\, OP_{t-i} + \sum_{i=1}^{K} {}^{3}\sigma_{3t}\, IND_{t-i} \\ &+ \sum_{i=k+1}^{d_{max}} \varphi_{3t}\, IND_{t-i} + e_{3t}, \qquad (8) \end{aligned}$$

$$\begin{aligned} OP = \partial_3 &+ \sum_{i=1}^{k} \delta_{4t}\, LCO2_{t-i} + \sum_{i=k+1}^{d_{max}} \alpha_{4t}\, LCO2_{t-i} + \sum_{i=1}^{k} \mu_{4t}\, LY_{t-i} \\ &+ \sum_{i=k+1}^{d_{max}} \infty_{4t}\; LY_{t-i} + \sum_{i=1}^{k} \beta_{4t}\, LEC_{t-i} + \sum_{i=k+1}^{d_{max}} \varkappa_{4t}\, LEC_{t-i} \\ &+ \sum_{i=1}^{k} \phi_{4t}\, OP_{t-i} + \sum_{i=k+1}^{d_{max}} \eta_{4t}\, OP_{t-i} + \sum_{i=1}^{K} {}^{3}\sigma_{4t}\, IND_{t-i} \\ &+ \sum_{i=k+1}^{d_{max}} \varphi_{4t}\, IND_{t-i} + e_{4t}, \qquad (9) \end{aligned}$$

$$\begin{aligned} IND_t = \partial_4 &+ \sum_{i=1}^{k} \delta_{5t}\, LCO2_{t-i} + \sum_{i=k+1}^{d_{max}} \alpha_{5t}\, LCO2_{t-i} + \sum_{i=1}^{k} \mu_{5t}\, LY_{t-i} \\ &+ \sum_{i=k+1}^{d_{max}} \infty_{5t}\; LY_{t-i} + \sum_{i=1}^{k} \beta_{5t}\, LEC_{t-i} + \sum_{i=k+1}^{d_{max}} \varkappa_{5t}\, LEC_{t-i} \\ &+ \sum_{i=1}^{k} \phi_{5t}\, OP_{t-i} + \sum_{i=k+1}^{d_{max}} \eta_{5t}\, OP_{t-i} + e_{5t} \qquad (10). \end{aligned}$$

Given that, applying Toda-Yamamoto procedure requires, first, the determination of the maximum order of integration of model variables using known unit root

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tests such as Augmented Dickey - Fuller (ADF), Phillips-Perron (PP), and Ng and Perron (NP). After that, the optimal lag length k is obtained depending on different criteria like Akaike Information Criterion (AIC), and Schwarz Bayesian Criterion (SBC). Following the estimation of the above equations (6-10), the Granger causality test according to Toda-Yamamoto procedure is implemented on levels of the variables, via MWALD test, where the null hypothesis is that there is no causal relationship between variables. Therefore, the rejection of the null hypothesis indicates the existence of a causal relationship and vice versa.

3- Data

In this study, annual time series data for the period 1990 – 2010 are used. The variables employed are defined as follows: CO2 is the per capita carbon dioxide emissions in metric tons as a proxy of environment degradation taken from world bank database. Y is per capita real GDP in US$ (2005=100) from UN database. EC is per capita energy consumption (kg of oil equivalent), whereas OP is a proxy of trade openness measured as the ratio of exports plus imports of goods and services at 2005 prices divided by GDP (2005=100) obtained from UNCTAD database. IND represents the share of industrial sector product to GDP (current prices) from UNCTAD database. The variables CO2, Y, and EC are logged, and thus their coefficients' estimates are interpreted as elasticities. Eviews software was used in various procedures and tests.

Empirical Analysis

1- Unit Root Test

Before implementing the bounds test, an important thing to do is to test the univariate properties of the variables series to identify their degree of integration by making use of both Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests of unit root.

Table 1 Unit Root Tests for Stationarity

variable	ADF Test			PP test		
	intercept	intercept& trend	non	intercept	Intercept& trend	non
LCO2	-1.78	-1.45	-1.745	-3.51**	-4.91*	-2.6**
dLCO2	-2.3	-8.43*	-1,9	-13.31*	-12.19*	-10.6*
LY	-5.33*	-1.83	2.26**	-0.287	-2.28	2.52
dLY	-3.49**	-4.56**	-1.36	-3.42**	-4.68*	-2.4**
LEC	-0.59	-2.35	1.7	-0.23	-2.15	5.8
dLEC	-4.64*	-4.7*	-4.37*	-4.74*	-4.99*	-4.37*
OP	-2	-0.93	-0.13	-1.99	-2.41	0.13
dOP	-5.38*	-5.65*	-5.46*	-6.25*	-6.45	-6.1*
IND	-1.54	-2.09	0.33	-1.33	-2.05	0.18
dIND	-4.5*	-4.49*	-4.52	-5.8*	-8.95*	-4.58*

Note: *, **, * indicate 1%, 5%, and 10% significance level, respectively.**

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Table 1 shows that, except Y which is I(0), all other variables of this study are non-stationary in level and stationary in the first difference or I(1). Consequently, the bounds test procedures can be started.

2- Bounds Test Approach to Cointegration

Table 2 Bounds Tests for LCO2, LY, LEC, OP, and IND models

Dependent Variable	model	F statistic	Lower bound(5%)	Uper bound(5%)	cointegration
LCO2	F_{LCO2} (LCO2/ LY,LEC,OP, IND)	6.45	2.85	4.05	Yes
LY	F_{LY} (LY/ LCO2,LY,LEC,OP, IND)	1.24	2.85	4.05	No
LEC	F_{LEC} (LEC/ LCO2,LY,OP, IND)	3	2.85	4.05	No
OP	F_{OP} (OP/ LCO2,LY,LEC, IND)	8.56	2.85	4.05	Yes
IND	F_{IND} (IND/ LCO2,LY,LEC, OP)	3.83	2.85	4.05	inconclusive

Note: critical values are from Pesaran et al.(2001: 300).

The bounds testing technique is performed on LCO2 model F_{LCO2} (LCO2/ LY, LEC, OP, and IND) and other models of F_{LY} (LY/ LCO2,LY,LEC,OP,and IND), F_{LEC} (LEC/ LCO2,LY,OP, and IND), F_{OP}(OP/ LCO2,LY,LEC,and IND),and F_{IND}(IND/ LCO2,LY,LEC,and OP). Table 2 exhibits that the computed F statistic for LCO2 model (6.45) is higher than the upper bound critical value (5.06) and therefore the null hypothesis of no cointegration between LCO2 and its determinants (LY, LEC, OP, IND)can be rejected at the 5% significance level. As for both models of LY and LEC, the null hypothesis of no long - run relationships between LY and its determinants, and between LEC and its determinants is accepted. Regarding the OP model, F statistics (8.56) is higher than the upper bound value implying that a long - run relationship between OP and its determinants is confirmed. The F statistic value for the last model (IND and its determinants), is 3.83 which lies between the values of the lower and upper bounds and thus the existence of cointegration in this model is inconclusive.

3- Long and Short - Run Dynamics

As the long - run relationship between LCO2 and its determinants is proved, we can follow and estimate the long - run parameters of LEC model as formulated in equation (3). Table (3)shows the estimated long - run elasticities of Y and EC, and the coefficients of OP and IND of the automatically selected model: ARDL(1,2,1,1.0), according to AIC. The resulted signs of long run coefficients of

LY, LEC, IND are positive and in line with expectations. However, the coefficient of OP is positive too, as expected for a least developed country such as Yemen, which evidences the dominance of both the scale and the displacement effects of trade openness on CO2 pollution. Table 3 reveals significant effects of LY and OP on LCO2 at the 5% level and very low and insignificants impacts of both LEC and IND on LCO2 at the same level of significance.

Table 3 Long and short run coefficients for ARDL (1,2,,1,1,0)

Long run coefficients (dependent variable LCO2)		
Regressor	**Coefficient**	**t-ratio [prob]**
LY	0.519	2.83(0.020)
LEC	0.082	0.510(0.622)
OP	1.27	6.79(0.000)
IND	0.0019	1.19(0.266)
INPT	-4.83	-9.75(0.000)
ECM representation of ARDL(1,2,1,1,0) (dependent variable dLCO2)		
dLY	-0.038	-0.128(0.90)
dLY(-1)	0.57	1.43(0.177)
dLEC	-0.49	-2.52(0.027)
dOP	0.69	2.33(0.038)
dIND	0.0035	1.18(0.260)
ECT(-1)	-01.84	-15.22(0.000)
R. squared (0.968) S.E of Regression (0.033) F. statistic (30.09(0.000))		
Diagnostic tests	Autocorrelation (Lagrange Multiplier)=0.044[0.838] Functional form (Ramsey RESET)=0.019[0.893] Normality (skewness and kurtosis)Test=0.084[0.959] Heteroscedacticity(regression of squared residuals on squared fitted values)=0.850[0.369]	

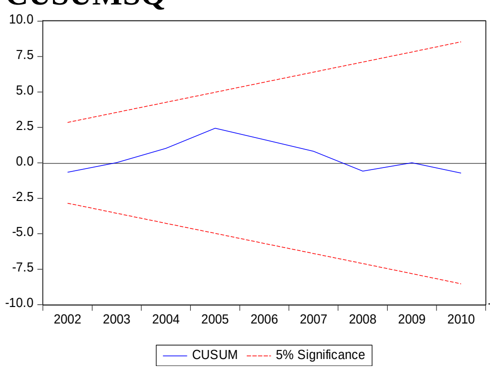
The ECM estimates of the short - run dynamics of the ARDL model, reveal the insignificant impact of IND on LCO2 and thus approve the result found in the long run. A negative and insignificant effect of LY on LCO2 in the short run is evidenced, meaning that an increase of Per capita income decrease CO2 emissions in the short run before reversing this impact in the long run. Likewise, LEC influence appeared to be negative, but significant, in the short run at the 5% level. As demonstrated in the long run, trade openness shows a positive and significant impact on LCO2 in the short run which indicates high importance of OP in explaining variations occurs in LCO2. It can be seen from Table 3 that the coefficient of the lagged error correction term ECT(-1) is negative and highly significant which supports the already evidenced long - run relationship between LCO2 on the one hand and LY, LEC, OP, and IND on the other. In Also, it suggests the existence of causal relationships goes from LY, LEC, OP, IND to LCO2. The value of the coefficient of ECT(-1) is -1.84 which indicates that LCO2 shows a high speed of adjustment (184% a year) to changes in the explanatory variables before converging to its equilibrium value.

To decide about the validity of EKC hypothesis according to Narayan and Narayan (2010) approach, it is clear from Table 3 that short run elasticity of LY is less than the same of the long run thus suggests that EKC hypothesis does not hold in Yemen. Statistical indicators and tests results placed at the end of Table 3 shows a high explanatory power of the model and asserts that the model is free of the key regression problems (serial autocorrelation, heteroskedasticity, misspecification, and error term non - normality).

4- Model Stability Test

The final step of ARDL and ECM techniques is to test the stability parameters of LCO2 model. Figures 1 and 2 of both CUSUM and CUSUMSQ tests prove that our model is stable and well - specified at the 5% level of significance.

Figure 1 : Plot of CUSUM **Figure 2 : Plot of CUSUMSQ**



In performing Toda-Yamamoto test, the optimal lag length of initial VAR model is selected to be 2 according to AIC, SC, HQ (Hannan Quinn information Criterion), and LR(sequential modified LR test). The maximum degree of integration is one since LY is I(0) and all other variables are I(1). Accordingly, the $(k + d_{max})$ order of our augmented VAR model is 3.

5- Toda-Yamamoto Causality Test

Table 4 : Results of Toda –Yamamoto procedure of Granger causality test

Dependent variables	Source of Causation									
	LCO2		LY		LEC		OP		IND	
	Chi-sq	prop	Chi-sq	prop	Chi-sq	prop	Chi-sq	prop	Chi-sq	prop
LCO2	--	--	5.06	(0.08)	6	(0.05)	6.5	(0.04)	1.21	(0.55)
LY	6.66	(0.036)	--	--	6.68	(.035)	4.41	(0.11)	2.48	(0.29)
LEC	3.98	(0.14)	11.75	(0.003)	--	--	7.96	(0.02)	6.7	(0.035)
OP	3.36	(0.19)	1.61	(0.45)	44.69	(.00)	--	--	8.77	(0.013)
IND	1.27	(0.53)	1.52	(0.47)	.56	(.76)	3.64	(0.16)	--	--

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The results of Toda-Yamamoto procedure to granger causality test displayed in Table 4 refer to a bi-directional causal relationship between LCO2 and LY, meaning that LY Granger causes LCO2 and feedback from LCO2 to LY exists as well. It is clear from Table 4 that a unidirectional relationship between LCO2 and LEC running from LEC to LCO2 indicating that energy consumption contributes to the deterioration of the environment. Moreover, in the least developed country such as Yemen energy consumption is inefficient, with very slow technological progress and so consequently, more polluting. The Granger causality relationships between LY and LEC is two way which means that energy consumption stimulates economic activity and economic growth promotes energy consumption. This result means that Yemen economy is more energy - dependent and thus any policy of reducing energy consumption will adversely affect economic growth .One direct causal relationship is also noted between OP and LCO2 running from OP to LCO2 indicating that increases of trade openness leads to the growth of polluting-intensive industries and thus more CO2 emissions.OP and LEC have dependent evolution which refers to the fact that Yemen imports the large part of its energy consumption in the form of oil products and crude oil dominates the structure of its exports. In Besides, Granger causality runs from IND to both LEC and OP. The variables LY and OP showed neutral relationship which may highlight the fact that imports are more important than exports in international trade structure in Yemen and dominated by necessities so their volume not affected by economic growth. Another neutral relationship can be seen between IND and LCO2 which confirms the result of the insignificant effect of IND on LCO2 in the long run from ARDL results and goes in line with the findings of several studies (e.g., the case of CotedIvoire, in Keho (2015), and the case of Uruguay in Piaggio et al. (2017)).

Conclusions

1- A long - run relationship between CO2 emissions and its determinants was found with significant effects for per capita GDP and trade openness.

2- Only energy consumption and trade openness appear to be important determinants of CO2 emissions in the short run.

3- It is found that the EKC hypothesis does not hold in Yemen and therefore the impact of per capita income on CO2 emissions is monotonically increasing.

4- The existence of bidirectional causal relationships between economic growth and CO2 emissions, energy consumption and economic growth, and trade openness and energy consumption.

5- unidirectional causal relationships are running from energy consumption to CO2 emissions, trade openness to CO2 emissions, and from industrial sector share to energy consumption.

6- Yemen economy is more energy - dependent and thus any policy of reducing energy consumption will adversely affect economic growth

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Recommendations

1- The environment preserving consideration has to be taken as a guideline in formulating future economic growth strategies and foreign trade policies.

2- Investment inefficient use of energy and renewable sources of energy must be a cornerstone in any strategy for controlling pollution and promoting economic activity at the same time.

3- Technology dependent and services activities must receive more attention in future development strategies.

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