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Using the Environmental Kuznets Curve to Study the Mutual Effects between CO_2 Emissions and Economic Growth in Jordan

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Abstract: This study analyzes the dynamic relationship between economic growth and CO_2 emissions in Jordan using the Environmental Kuznets Curve. The study looks at the direction of the causal relationship both in the long and short-run to determine the mutual effects between the two variables during the 1980-2010 period. Using the ARDL bound testing approach and the Vector Error Correction Model (VECM), the study shows that the results are consistent with the Environmental Kuznets Curve (EKC) hypothesis. Furthermore, the study shows the existence of a bidirectional causal relationship, both in the long and short run, between economic growth and CO_2 emissions. Based on that, the authors conclude that environmental issues must be taken into consideration when formulating economic policies, as well as using environmentally friendly technologies in the manufacturing and transportation sectors.

Keywords: Environmental Kuznets Curve, CO_2 Emissions, Economic Growth, Jordan

Introduction

The focus on environmental issues started in the early 1970 s when the first environmental conference, which was organized by the United Nations, was held in Amsterdam. That was the first worldwide attempt by the international community to address the relationship between the environment and development. Other environmental conferences, like the Earth Summit in Rio de Janiro in 1995 and the World Summit for Sustainable Development in Johannesburg in 2002, came later. The most recent conference of that type was the Copenhagen Conference for Climate Change in 2009. Because of the intertwined relationship between economic activities and the environment, economists started paying more attention to that relationship, both on macro and micro levels.

In economics, the environment is considered a compound source that provides a group of goods and services. This source has a unique place in providing the environmental system that guarantees the sustainability of life. The environment provides the economy with raw materials that are transformed into consumer goods through the production process. These raw materials and the energy used in the production process go back to the environment as waste. Therefore, the relationship between the environment and the economy is a closed relationship (Pungetti and Romano, 2003).

The research problem arises from the nature of the concomitance relationship between economic growth and environmental issues on one hand and their contradictory relationship on the other hand. The question is that: does the production expansion come at the expense of the environmental quality? Does maintaining the environment require the sub-optimal use of energy sources to reduce the emission of air pollutants to preserve the public health and achieve the required growth rates?

This paper traces the environmental index and its behavior, represented by the CO_2 emission, during the economic growth stages in Jordan. Also, the study analyzes the relationship between economic indicators like economic growth and energy consumption with the environmental index using the Environmental Kuznets Curve (EKC). The goal is to derive the Turning Point (TP); the TP is the point where the pollution level starts to decline as the level of income starts increasing. Furthermore, we want to test the causal relationship, in the long and short-run, between the economic indicators and the CO_2 emission variables and determine the direction of that relationship. To the best of the authors' knowledge, this issue hasn't been discussed in the literature for the Jordanian economy. We believe that the methodology utilized in this paper is unique for such a subject. We also believe that the importance of this subject along with its methodology should add to the literature of this area.

Literature Review

Economists have been more interested in studying the relationship between economic growth and environmental pollution since the 1990 s. The EKC hypotheses arose from this research trend. Studies in the field took two general directions. Initially, studies analyzed the relationship for different countries. An example are the studies of (Acaravci and Ozturk, 2010; Pao and Tsai, 2010; Zilio and Recalde, 2010). The second direction studies took was analyzing a single country. Ang (2007) tested the long-run dynamic relationships between CO_2 emissions, energy consumption and GDP in France for the period 1960-2000. Ang found that there is a strong, long-run relationship among the variables and the relationship between CO_2 emissions and GDP in the long run takes a quadratic functional form. The Turning Point (TP) happens at an income level of 9.31 French Franc, in logarithmic form. The causal relationship is from energy consumption to output in the short-run and the output causes CO_2 emission and energy consumption in the long-run.

Pao and Tsai (2011) studied the balanced long-run relationship between CO_2 emissions, energy consumption and real GDP in Brazil for the period 1980-2007. The results showed that the relationship takes an inverted U shape in logarithmic form with the TP at an income level of $7.30. The results also showed that there is a strong bi-directional causal relationship between the real GDP, energy consumption and the emission of the pollutants.

Pao *et al*. (2011) tested the dynamic relationship between CO_2 emissions, energy consumption and real GDP in Russia for the period 1990-2007. The authors showed that output had a significant effect on the emission of pollutants, but this research does not support the EKC hypotheses. Also the authors showed the existence of a strong, bi-directional causal relationship between output and energy consumption on one side and the emission of the pollutants on the other side.

Shahbaz *et al*. (2012) analyzed the relationship between CO_2 emission, energy consumption and economic growth in Pakistan for the period 1971-2009. The study showed the existence of a strong long-run relationship among all the variables, supporting the EKC hypothesis and the existence of one direction causal relationship from economic growth to CO_2 emissions.

Tiwari *et al*. (2013) provided an analysis of the relationship between the consumption of coal, economic growth, trade openness and CO_2 emissions in India for the period 1966-2011. The results supported the EKC hypotheses both in the short and long-run, in addition to the existence of a short and long-run causal relationship from income and energy consumption to CO_2 emissions.

Srinivasan (2015) demonstrated the use of a real-option model to encourage the planting of new biologically-diverse forests and to help conserve existing forests standing on private land. The incentive structure is simplified to include the interest foregone on the terminal value, reduced by the existential value derived from such delay. The real-option model employing bounded random walk projections is applied to a registered Clean Development Mechanism (CDM) project. Vatn (2015) aimed to clarify what is meant by 'markets for Ecosystem Services (ES)'. Two main dimensions are identified as basis for classifying markets in ES: (markets with and without intermediaries) and (markets created by defined liabilities like caps on emissions). Regarding Payments for Ecosystem Services (PES), most are not markets, not even incomplete. This is so as most resources are raised through taxes or fees-command not trade. Moreover, most payments are best characterized as subsidies.

Finally, Sgroi *et al*. (2016) showed the relationship between humans and the forest has always been an important element, sometimes characterizing in the history of man himself. Through a survey conducted in a wooded area of Sicily where recently was established a typical example of PES (Ecocampus), it aimed at determining the actual satisfaction by users of the various services provided by forest, the reasons that lead them to visit it and their willingness to pay.

Following the second objective of the research, this study focuses on using the data of a single country, Jordan, to show the characteristics of the environmental issues related to CO_2 emissions and the relationship of those emissions with the economic growth in that country.

Variables used in the Study

The model used in this study depends on two types of indicators. The economic indicator is represented by the real GDP and energy consumption. The environmental indicator is represented by the level of CO_2 emissions.

Figure 1 shows the changes in the GDP in constant prices (1994 = 100) across time. From this, we can see that it has been increasing over the period of the study 1980-2010, except for the span of 1988-1991 when real GDP declined. The dip in GDP is related to the economic crisis in the Jordanian economy that came from the reduction of the exchange rate of the Jordanian dinar.

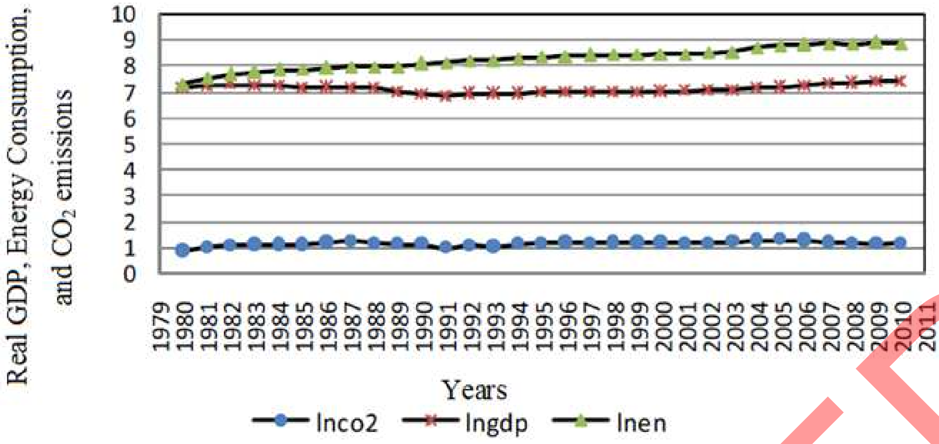

Fig. 1. Real GDP (1994 = 100), Energy Consumption and CO_2 emissions in the logarithm forms for the period (1980-2010)

Fig. 2. The percentage of CO_2 Emissions from the Various Sectors in Jordan for the period (1994-2009) Source: Prepared by researchers depending on the data available from the Department of Statistics, Statistics Environment Bulletin (2000-2009)

The increasing pattern of the real GDP reflects the growth of the production of goods and services during the period of the study. The real GDP grew by 3.8% during that period. Much of that growth resulted from the increase in the demand for goods due to the three percent growth in population during the same period.

Energy resources are considered a major input for economic activities. It is the main driver for the different sectors of the economy, since energy resources are a requirement for economic development. Jordan has very limited local sources of energy. The local production of crude oil and natural gas constitutes a small proportion of the total energy sector. In the period 2007-2011, the local production of crude oil and natural gas was about 3.2% of the total energy consumption in the country. Therefore, Jordan depends largely on the imports of energy resources, like crude oil, oil products and natural gas to meet the needs of the economy (MENR, 2012). Figure 1 also shows that energy consumption in Jordan grew at about four percent annually for the period 1980-2010. This reflects the increasing demand on energy resources by economic sectors and the importance of those resources for the economic development process.

CO_2 emission is defined by the US Carbon Dioxide Information Analysis Center (CDIAC) as the emissions from burning fossil fuel and cement industry and the consumption of fuels whether solid, fluid, or gaseous. In Jordan, the emission of CO_2 comes from multiple economic sectors, such as the manufacturing, agricultural, commercial, transportation and household sectors. CO_2 emissions constitute the largest proportion of all gas emissions as a result of energy used in the different sectors. It constitutes about 97% of total emissions on average for the period 1994-2009. The manufacturing sector produces the largest share of CO_2 emissions, averaging 60% between 1994 and 2009. The transportation sector is the next largest producer of CO_2 emissions, averaging 21% during that period (Fig. 2).

During the study period, the structure of the Jordanian economy changed. The manufacturing sector's share of the GDP grew at 2.1% annually. The natural result of this growth was the increase in the use of industrial inputs,

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especially the energy resources, which is known as Composition Effect. Hence, CO_2 emissions increased. This is illustrated in Fig. 1 where the annual rate of CO_2 emission increased during the 2007-2010 period. This figure shows a drop in 2010, possible attributable to the increase of the oil prices worldwide or the international financial crisis, both of which are associated with a decline in the demand for energy resources resulting in fewer CO_2 emissions. The decline might be attributable to the trend toward using natural gas, which produces less CO_2 emission. In 2006, natural gas consumption represented 28% of total energy consumption and it increased to 40% in 2009 (MENR, 2012).

Methodology

In studies such as this, researchers test for stationarity of the time series. We are using the Augmented Dickey-Fuller test (ADF) and the Phillips-Perron Test (PP) to test stationarity.

To check for the existence of cointegration among the variables, the Engle and Granger (1987) and Johansen and Juselius (1990) can be used. To perform these tests, the variables must be integrated at the same degree. If the variables are integrated at different degrees, then these tests will not work. In that instance, the Autoregressive Distributed Lag (ARDL) bounds testing approach is used to do test for cointegration.

The ARDL approach differs from the classical ways to test for cointegration in a few ways. First, the ARDL can be used regardless of the degrees of integration of the variables. Second, it gives efficient results and coefficients in the case of small samples. Third, this approach is preferred when the integration of the variables is not clear (Hoque and Yusop, 2010).

In this study, we will test the cointegration of the variables in the three models of the study within the framework of the Unrestricted Error Correction Model (UECM) (Baranzini *et al*., 2013), in the following format:

$$\Delta y_t = \alpha + \sum_{i=1}^{m}\beta_i \Delta y_{t-i} + \sum_{i=0}^{n}\lambda_i \Delta x_{t-i} + \varphi y_{t-1} + \delta x_{t-1} + \eta_t \quad (1)$$

where, y is the dependent variable and x is the independent variable vector. Δ represents the first difference, m and n represent the lags in the first difference and η is the random error.

The cointegration test among the variables in Equation 1 is done by testing the following:

- H_0: $\varphi = \delta = 0$, means no cointegration
- H_1: $\varphi \neq \delta \neq 0$, means there is cointegration

After estimating Equation 1, the calculated F-statistic is compared to the Upper and Lower critical bounds (Pesaran *et al*., 2001). The Lower Critical Bounds (LCB) assumes that the variables are integrated of degree zero; I(0) and the Upper Critical Bounds (UCB) assumes that the variables are integrated of degree one: I(1). If the calculated F-Statistic value is greater than the UCB, then we reject the null hypothesis of no cointegration, meaning that there is a long-run relationship among the variables. If the calculated F-Statistic is below the LCB, then we do not reject the null hypothesis of no cointegration. If the value of the calculated F-statistic falls between the LCB and UCB, then the result is inconclusive.

In the case of cointegration, then the second stage of the ARDL approach is the estimation of the long-run equation in the form:

$$y_t = \theta + \sum_{i=1}^{p}\sigma_i y_{t-i} + \sum_{i=0}^{q}k_i x_{t-i} + \varepsilon_t \quad (2)$$

Here p and q represent the lags in the variables. To obtain the long-run elasticity of the variables, x and y are transformed to logarithmic form and Equation 2 is written as:

$$y_t = \theta + \sigma_1 y_{t-1} + \sigma_2 y_{t-2} + k_0 x_t + k_1 x_{t-1} + \varepsilon_t$$

Then we calculate the long-run elasticity of variable x as:

$$\xi_x = \frac{k_0 + k_1}{1 - \sigma_1 - \sigma_2} \quad (3)$$

The third stage in the ARDL approach is to obtain the short-run relationship among the variables in the model by using the residuals of the long-run from Equation 2 with one lag. Therefore, the short-run error correction takes the following format:

$$\Delta y_t = \mu + \sum_{i=1}^{r}\pi_i \Delta y_{t-i} + \sum_{i=0}^{s}\omega_i \Delta x_{t-i} + \gamma \epsilon_{t-1} + v_t \quad (4)$$

where, γ represents the error correction coefficient, which measures the speed of correction of the disequilibrium in the short-run to reach the equilibrium in the long-run.

After verifying the cointegration, or the existence of a long-run relationship among the variables, we will test for the long-run and short-run causal relationship. This relationship involves the existence of a causal relationship in at least one direction; however it does not determine that direction. Therefore, to determine the direction, we will use the Granger Causality test in the long-run and short-run within the framework of the Vector Error Correction Model (VECM) (Equation 4). In Equation 4, the significance of the first difference, ω_i, is used to test the direction of the short-run causality and the significance of the error correction coefficient, γ, is used to test the direction of the long-run causality. These tests will be implemented on the CO_2 emission model.

The CO_2 Emission Model

We describe the functional relationship between CO_2 emissions and the per-capita real GDP, representing economic growth, in the following format:

$$CO_{2t} = f(GDP_t, GDP_t^2, EN_t) \quad (5)$$

To obtain consistent and efficient coefficients, we transform the variables into the logarithmic format therefore, the model becomes:

$$lnCO_{2t} = \beta_0 + \beta_1 \ln GDP_t + \beta_2 lnGDP_t^2 + \beta_3 \ln EN_t + \varepsilon_t \quad (6)$$

where, CO_{2t} represents the per-capita CO_2 emission at time t, GDP_t is the per-capita real GDP in Jordanian Dinar (JD) and EN_t is energy consumption. According to the EKC hypotheses, the expected sign of the per-capita real GDP is positive and negative for the squared per-capita real GDP. Since the energy consumption is considered a factor that increases CO_2 emission, its expected sign is positive.

The Results

Table 1 shows the results of the unit-root test of the variables used in the model using the ADF approach. The results show that *ln*GDP^2, *ln*GDP and *ln*CO_2 are not stationary at the level but are stationary at the first difference. This means that they are integrated of degree one; I(1), at the 1% significance level. The variable *ln*EN is stationary at level, so it is I(0) at the 1% significance level. The results were confirmed using the PP test.

Since some of the variables were stationary at the level and the others at the first difference, then the ARDL bounds tests will be used to test for the existence of cointegration among the variables of the model (Pesaran *et al*., 2001). The test for cointegration will be performed using the following equations, where CO_2, GDP and EN are the independent variables:

$$\Delta lnCO_{2t} = \beta_{0co2} + \sum_{i=1}^{p}\beta_{ico2}\Delta lnCO_{2t-i} + \sum_{j=0}^{q}\beta_{jco2}\Delta lnGDP_{t-j} + \sum_{k=0}^{r}\beta_{kco2}\Delta \ln GDP_{t-k}^2 + \sum_{l=0}^{s}\beta_{lco2}\Delta lnEN_{t-l} + \beta_{1co2}lnCO_{2t-1} + \beta_{2co2}lnGDP_{t-1} + \beta_{3co2}\ln GDP_{t-1}^2 + \beta_{4co2}lnEN_{t-1} + \varepsilon_{1t} \quad (7)$$

$$\Delta lnGDP_t = \beta_{0GDP} + \sum_{i=0}^{p}\beta_{iGDP}\Delta lnCO_{2t-i} + \sum_{j=1}^{q}\beta_{jGDP}\Delta lnGDP_{t-j} + \sum_{k=0}^{r}\beta_{kGDP}\Delta \ln GDP_{t-k}^2 + \sum_{l=0}^{s}\beta_{lGDP}\Delta lnEN_{t-l} + \beta_{1GDP}lnCO_{2t-1} + \beta_{2GDP}lnGDP_{t-1} + \beta_{3GDP}\ln GDP_{t-1}^2 + \beta_{4GDP}lnEN_{t-1} + \varepsilon_{2t} \quad (8)$$

$$\Delta lnEN_t = \beta_{0EN} + \sum_{i=0}^{p}\beta_{iEN}\Delta lnCO_{2t-i} + \sum_{j=0}^{q}\beta_{jEN}\Delta lnGDP_{t-j} + \sum_{k=0}^{r}\beta_{kEN}\Delta \ln GDP_{t-k}^2 + \sum_{l=1}^{s}\beta_{lEN}\Delta lnEN_{t-l} + \beta_{1EN}lnCO_{2t-1} + \beta_{2EN}lnGDP_{t-1} + \beta_{3EN}\ln GDP_{t-1}^2 + \beta_{4EN}lnEN_{t-1} + \varepsilon_{3t} \quad (9)$$

To perform, the cointegration test, we use the following hypotheses:

- H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$, means no cointegration
- H_1: $\beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq 0$, which refers to the existence of cointegration

Before estimating Equation 7, 8 and 9, the lags of the first differences are determined according to the Schwarz Bayesian Criterion (SBC). The lags for the CO_2 and GDP equations were (0, 0, 0, 0) and for the EN equation was (1, 0, 1, 0) ARDL. After the estimation of Equation 7, 8 and 9 using the ADRL approach, we see the results of the cointegration test in Table 2.

To check for the existence of cointegration for the CO_2 model, the calculated F-statistic at 7.8783 is larger than the UCB at the 1% significance level with three variables, the constant and no time factor. This result indicates the existence of cointegration among the variables of the CO_2 model.

For the GDP model, the calculated F-Statistic was 3.3439; this falls between the upper and lower critical bounds at the 5% significance level, indicating an inconclusive result of cointegration. For the EN model, there was no cointegration because the calculated F-statistic of 0.85814 fell below the LCB.

Due to the presence of cointegration among the variables of the CO_2 model, this cointegration involves the existence of a long-run relationship among the variables that take the formula:

$$lnCO_{2t} = \beta_{0co2} + \sum_{i=1}^{p}\beta_{ico2}lnCO_{2t-i} + \sum_{j=0}^{q}\beta_{jco2}lnGDP_{t-j} + \sum_{k=0}^{r}\beta_{kco2}\ln GDP_{t-k}^2 + \sum_{l=0}^{s}\beta_{lco2}lnEN_{t-l} + \varepsilon_{1t} \quad (10)$$

Before estimating Equation 10, the lags of the variables are determined using the SBC, where the lags were (1, 1, 0, 1) ARDL. After the estimation, we estimated the following relationship:

$$\begin{gathered} lnCO_{2t} = -149.9 + 41.907 lnGDP_t - 2.933 \ln GDP_t^2 + 0.17 lnEN_t \\ (-6.3513)(6.3459)(-6.3363)(5.3882) \\ [0.000][0.000][0.000][0.000] \\ \bar{R}^2 = 0.80 \end{gathered} \quad (11)$$

Table 1. The Results of ADF Test for the Model of CO_2 Emissions

	ADF statistic				
	Level		First differences		
Variables	Order of integration	Intercept and trend	Intercept	Intercept and trend	Intercept
$lnCO_2$	-3.60218	-2.46178	-5.662210*	-5.841389*	I(1)
*ln*GDP	-1.25248	-1.3915	-3.689668*	-3.24745	I(1)
$lnGDP^2$	-1.23138	-0.79107	-3.696185*	-3.22873	I(1)
*ln*EN	-3.020697*	-4.774139*	-	-	I(0)

*: Statistically significant at 1%

Table 2. The results of the cointegration test for the variables: CO_2, GDP and EN

K = 3		F-statistic
$CO_{2t} = f(GDP_t, GDP_t^2, EN_t)$, ARDL (0,0,0,0)		7.8783* [0.000]
$GDP_t = f(CO_{2t}, GDP_t^2, EN_t)$, ARDL (0,0,0,0)		3.3439** [0.029]
$EN_t = f(GDP_t, GDP_t^2, CO_{2t})$, ARDL (1,0,1,0)		0.85814 [0.507]
Critical values bounds***		
Significant level	Lower Critical Bounds (LCB) I(0)	Upper Critical Bounds (UCB) I(1)
1%	4.29	5.61
5%	3.23	4.35
10%	2.72	3.77

(*) and (**) means statistically significant at 1% and undetermined, respectively, Source: Pesaran *at al*. (2001)

Table 3. The results of the diagnostic tests for the CO_2 emissions model

Lagrange multiplier statistics	p-Value
Normality test	[0.459]
Serial correlation LM test	[0.136]
Heteroskedasticity test	[0.603]

We obtained the long-run elasticities for the variables EN, GDP and GDP^2 from Equation 11 taking into account the lags in the variables. From Equation 11, we can see that the signs of the variables GDP and GDP^2 were consistent with the EKC hypotheses, indicating that pollution increases with income increases in the early stages of economic development. After the economy reaches a certain level of economic growth, the level of pollution starts to decrease, meaning that the relationship takes an inverted U shape.

From the results we can see that the CO_2 emission model for the Jordanian economy verifies the existence of the EKC. Based on that, we can obtain the Turning Point (TP) for the long-run relationship between CO_2 emission and the GDP through the following procedure:

$$\frac{\partial lnCO_{2t}}{\partial lnGDP_t} = 41.907 - 5.866 \ln GDP_t = 0$$

$$\Rightarrow \ln GDP_t = 7.143$$

$$\Rightarrow TP = 1265.2$$

The TP is the income turning point at which the CO_2 emissions start to decline as income increases. To verify that the TP is a maxima, we determined that the Second Order Condition (SOC) was negative. From that we can see that the TP equals 7.143 in logarithmic form and 1265.2 in regular form. Thus, the TP happens at a per-capita GDP of 1265.2 J.D, which occurred between 2003 and 2004. Therefore, we can conclude that the willingness to pay to obtain better environmental quality starts at a later period of economic growth in the Jordanian economy.

The other variable that affects the CO_2 emissions; energy consumption (EN), has a positive sign and a significant value. This indicates that EN and CO_2 emissions have a direct relationship. The elasticity of EN was 0.17, meaning that a 1% increase in energy consumption in Jordan leads to 0.17% increase in per-capita CO_2 emission. This relationship is attributed to the intensive use of traditional energy sources that is considered one of the most important factors of production in many economic activities, such as the manufacturing and transportation sectors. The minimal amount of switching to clean energy sources also contributed to that direct significant relationship.

To check for the fitness of the model used in the study, we performed the diagnostic tests according to the Lagrange multiplier statistics shown in Table 3.

The normality test indicates that the error terms are normally distributed and the serial correlation test, based on the *p*-value of the LM-test, indicates the absence of serial correlation. The heteroskedasticity test indicates the consistency of the variation in the error terms.

For the purpose of checking the direction of the causal relationship among the variables, we use the Granger Causality approach in the long and short-run within the framework of VECM. These can be represented by the following formats:

$$\Delta lnCO_{2t} = \gamma_{0co2} + \sum_{i=0}^{p}\gamma_{ico2}\Delta lnCO_{2t-i} + \sum_{j=0}^{q}\gamma_{jco2}\Delta lnGDP_{t-j} + \sum_{k=0}^{r}\gamma_{kco2}\Delta \ln GDP^2_{t-k} + \sum_{l=0}^{s}\gamma_{lco2}\Delta lnEN_{t-l} + \lambda_{co2}ECT_{t-1} + u_{1t} \quad (12)$$

$$\Delta lnGDP_t = \gamma_{0GDP} + \sum_{i=0}^{p}\gamma_{iGDP}\Delta lnGDP_{t-i} + \sum_{j=0}^{q}\gamma_{jGDP}\Delta lnCO_{2t-j} + \sum_{k=0}^{r}\gamma_{kGDP}\Delta \ln GDP^2_{t-k} + \sum_{l=0}^{s}\gamma_{lGDP}\Delta lnEN_{t-l} + \lambda_{GDP}ECT_{t-1} + u_{2t} \quad (13)$$

$$\Delta lnEN_t = \gamma_{0EN} + \sum_{i=0}^{p}\gamma_{iEN}\Delta lnEN_{t-i} + \sum_{j=0}^{q}\gamma_{jEN}\Delta lnGDP_{t-j} + \sum_{k=0}^{r}\gamma_{kEN}\Delta \ln GDP^2_{t-k} + \sum_{l=0}^{s}\gamma_{lEN}\Delta lnCO_{2t-l} + u_{3t} \quad (14)$$

Here, λ_{CO2} represents the error correction factor for the CO_2 model and λ_{GDP} represents the error correction factor for the GDP model, while ECT_{t-1} represents the error correction factor for the previous period that is obtained from the long-run relationship from each model.

The error correction factor is included in the models that contain co-integrated variables. Therefore, the CO_2 and GDP models will contain the error correction factor to determine the direction of the causal relation both in the long and short-run relationship. For the EN model, which does not contain cointegration variables, the short-run relationship will be estimated without the addition of the error correction factor.

As stated before, the direction of the causal relationship for Equation 12, 13 and 14 in the short-run is based on the significance of the difference coefficients of the independent variables γ_j, γ_k and γ_i. However, in the long-run, the direction of the causal relationship is determined based on the significance of the coefficient of the error correction factor, λ, which should have a negative sign. Table 4 shows the results of the direction of the causal relation test.

We can see from the causal relation test that, for the CO_2 emission model, there is a short-run causal relationship from the per-capita GDP, in both the linear and quadratic forms and the energy consumption variables to the per-capita CO_2 emission variable. Also, the coefficient of the error correction factor is significant for the previous period, indicating the existence of a long-run causal relation between the CO_2 emission and the determinant factors. This shows that the variables GDP and GDP^2 have positive and negative effects, respectively, on CO_2 emissions. Those relationships, as well as the negative effect of energy consumption on CO_2 emissions, confirm the EKC in the case of the Jordanian economy.

The value of the error correction factor, $\lambda_{CO2,}$ is -0.71496 and it is significant. This confirms the existence of a long-run relationship among the variables. From that, we can see that about 71.5% of the disequilibrium is corrected in the period following any shock that hits the independent variables that affect the dependent variable. The value of the λ_{CO2} in this case represents a quick adjustment speed, which means that the disequilibrium in the CO_2 emission variable lasts for about 1.4 years.

For the GDP model, we can see from Table 4 that there is a short-run causal relationship that goes from the CO_2 emissions and energy consumption to the GDP. The coefficient of the error correction term, λ_{GDP}, is significant, indicating the existence of a long-run causal relationship going from the CO_2 emissions and energy consumption to the GDP.

For the energy consumption EN model, there exists only a short-run causal relationship that goes from the CO_2 and GDP variables to the energy consumption.

Table 4 shows the reciprocal relationship between the CO_2 emission and the GDP. There is a long-run and short-run causal bi-directional relationship between the CO_2 emissions and the real GDP. Thus, there is a reciprocal relationship between the economic and environmental indicators. There is a causal bi-directional relationship between CO_2 emissions and energy consumption in the short-run. There is a short-run bi-directional relationship between GDP and energy consumption.

Table 4. The results of the short and long run causality for the models: CO_2 emissions, GDP and EN

	Direction of causality				
	Short- run causality				Long-run causality
Dependent variable	$\Sigma\Delta lnCO_2$	$\Sigma\Delta lnGDP$	$\Sigma\Delta lnGDP^2$	$\Sigma\Delta lnEN$	ECT_{t-1}
$\Delta lnCO_2$	-	(5.4423)* [0.000]	(-5.4238)* [0.000]	(3.3713)* [0.002]	-0.71496 (-5.3667)* [0.000]
$\Delta lnGDP$	(3.9686)* [0.001]	-	-	(-2.6891) [0.013]	-0.61454 (-3.9626)* [0.001]
$\Delta lnEN$	(4.0760)* [0.000]	4.8507** [0.0175]	1.3389 [0.194]	-	-

(*) and (**) means the values are statistically significant using t-static and F-static tests, respectively

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From these results, we can see that the relationship between the CO_2 emissions and the economic growth in the Jordanian economy confirms the EKC hypothesis, which is used to determine the income Turning Point (TP). Our results are similar to the results of (Ang, 2007; Pao and Tsai, 2011; Shahbaz *et al*., 2012; Tiwari *et al*., 2013). However, the results are different from what Pao *et al*. (2011) found because of the difference in the environmental status and its relationship with the economic conditions in different countries.

Conclusion

Based on our analysis of the relationship between the environmental and economic indicators, we arrived at several conclusions. The economic and environmental indicators moved together over time. That reflects the correlative relationship between them. The CO_2 emission model conformed with the EKC hypotheses, meaning that the relationship between economic growth and CO_2 emissions takes an inverted U shape. The pollution level increases at the beginning of the economic growth stages, reaches a certain level and then starts declining. This means that the first stages of the growth that give economic benefit are accompanied by sacrifice in the environmental quality. However, after a certain point, the environmental quality improves.

We can infer from the TP obtained from the CO_2 emission model that the improvement in environmental quality happens in later periods of economic growth in the Jordanian economy. This means that the willingness to pay to obtain an environment quality with lower CO_2 emission starts at a late period of economic growth in Jordan.

There is a direct relationship between CO_2 emissions and energy consumption. This can be attributed to the intensive use of the traditional fossil fuel energy resources, which are very important production factors in the manufacturing and transportation sectors. Also contributing to that direct relationship is the insufficient shift to the use of alternative clean energy sources.

There exists a bi-directional causal relationship in the long-run and short-run between the economic variables and energy consumption on one side and the environmental indicator. This indicates that there is a reciprocal effect between economic growth and the environmental indicator in the long-run and short-run of the economic growth stages in the Jordanian economy.

In general, we found that there is a dynamic linkage between the economic and environmental indicators. The economic indicators increase the pressure on the environment in Jordan in the long run.

One of the important results that the study showed is the existence of a bi-directional causal relationship between the GDP and the environmental indicators. This relationship indicates that policy makers should take into account the trade-off between the economic well-being and the conservation of the environment when they make decisions to increase the economic growth or to protect the environment.

Based on the above conclusions, the authors suggest that policy makers should include environmental considerations when making macroeconomic policies. Including this relationship in policy development should help to ease the effect of environmental deterioration while obtaining sustainable growth. Also, we suggest the development and use of a technologically advanced and environmentally friendly production means that maximizes the use of cleaner fuel sources.

Also the authors suggest a change in the pattern of private transportation means, which contributes to large amounts of CO_2 emission, through the use of light trains. This change will have two benefits. The environment will benefit through the reduction of CO_2 emissions and the economy will benefit through the reduction of energy consumption, which was a major portion of the Jordanian budget. However, it would be of interest for future work to do such research on other countries especially Jordan's neighbors.

Finally, any policy decision that deals with economic growth must take into account its effect on the environment. At the same time, any strategy that aims to protect the environment must take into account its effect on the environment.

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Author's Contributions

Mohaned Al-Hamdi: Writing and arrangement of the paper.

Mohammad Alawin: The statistical Analysis.

Kais Alwan: Collection of the data.

Saeed Al-Tarawneh: Supervision of the research.

Ethics

No Ethical issues expected to arise after the publication of the manuscript.

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