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Environmental Kuznets curve: an empirical analysis for carbon dioxide emissions in Egypt

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Abstract: The aim of the study is to address the relationship between environmental degradation and economic growth in Egypt. In this regard, the study examines the relationship between carbon dioxide emissions (CO_2), economic growth (real GDP per capita), energy consumption, trade openness and population density employing Johansen cointegration analysis over time series data of 1980–2010. Specifically, the study investigates the existence of Environmental Kuznets Curve (EKC) hypothesis, the relationship between CO_2 emissions and real GDP per capita. The results of the study confirm the existence of long-run relationship between the variables. In addition, the study does not support the existence of EKC either in the short or the long run. Also, it is concluded that energy consumption is correlated positively with CO_2 emissions, while trade openness and population are correlated negatively with it. Granger causality test indicates bilateral causality between economic growth and CO_2 emissions and unilateral causality running from economic growth to energy consumption and from trade openness to economic growth. Important policy implications will be recommended based on these results.

Keywords: environmental Kuznets curve; carbon dioxide emissions; economic growth; trade openness; energy consumption; population; cointegration; Egypt.

1 Introduction

The major threat of increasing greenhouse gases and global warming problem directed world economies, either developed or developing, to work on reducing carbon dioxide emissions as these emissions are regarded as the primary cause of greenhouse effect and have captured increasingly environmental concern in the recent years.

Nowadays, greater concern is directed towards effective environmental regulation policies and multilateral agreements in an attempt to reduce or maintain carbon dioxide emissions and to achieve energy security through shifting to renewable energy resources and adopting energy conservation policies.

It is clear that rapid economic growth and industrialisation expansion in developed countries in general, and developing countries in particular, depend heavily on energy consumption, which adversely affects the environment. In Egypt, all energy forms show a continuous increase as a response to economic expansion and industrialisation and therefore, Egypt faces challenges for shortages of crude oil. Since 2006, Egypt became net importer of crude oil as its consumption from it was 685.44 thousand barrels per day and exceeded its production which was 535 thousand barrels per day. Moreover, in 2009 natural gas's exports began to decline, so authorities think about using coal as an alternative energy resource to meet the continuous increasing demand for energy (EIA, 2015).

Nowadays, Egypt as one of the developing countries faces a big challenge in struggling to achieve high growth rates without deteriorating the environment and this raises the issue of environment–growth nexus that is manifested mainly in examining Environmental Kuznets Curve (EKC) hypothesis. The relationship between economic growth and environmental quality has been explored by investigating EKC hypothesis, which derives its name from the early work of Kuznets and Simon (1955). According to EKC hypothesis at the early stages of economic development environmental degradation increases as per capita income increases, but after a critical turning point environmental quality improves as income per capita rises. This is summarised by an inverted U-shaped curve (M'Henni et al., 2010). In the first stage of industrialisation where people give the priorities to growth and jobs at the expense of environmental quality, pollution increases but after increasing per capita income, people begin to give their concern towards improving environmental conditions and increase their demands towards qualitative growth where countries achieve economic growth per capita beside environmental conservation (Dinda, 2004).

Although numerous studies examined the existence of EKC hypothesis, there is a lack of investigating it in Egypt, so the study aims to add to strand of literature in investigating EKC hypothesis in Egypt over a time period of 1980–2010 which is chosen depending on the availability of data.

The study employs Johansen cointegration approach to investigate the relationship between carbon dioxide emissions per capita, real economic growth per capita, energy consumption per capita, trade openness and population density.

Moreover, the study applies Granger causality test to examine the relationship between carbon dioxide emissions per capita on the one hand and real economic growth per capita and trade openness on the other hand, and also the relationship between real economic growth per capita on the one hand and energy consumption per capita and trade openness on the other hand.

The rest of the paper is organised as follows. Section 2 provides a brief review of the literature. Section 3 explains the model specification, data and methodology. Section 4 discusses the empirical results. Section 5 is a discussion and Section 6 concludes the paper and discusses policy implications.

2 Literature review

There are several studies concerned with examining EKC hypothesis over the years, and these studies have used different techniques between time series and panel data through single-country analysis or multi-country analysis.

Beginning with Grossman and Krueger (1995) who estimated the turning point to be approximately $8000, different scholars investigated the EKC hypothesis using different indicators for environmental degradation such as sulphur dioxide (SO_2) emissions (Day and Grafton, 2003; Fodha and Zaghdoud, 2010), nitrous oxide (N_2O) emissions (Cho et al., 2014), total suspended particulate matter (Seldon and Song, 1994; Day and Grafton, 2003; Orubu and Omtor, 2011), carbon dioxide (CO_2) emissions (De Bruyn et al., 1998; Jalil and Mahmud, 2009; Jaunky, 2011; Du et al., 2012; Esteve and Tamarit, 2012; Hamit-Haggar, 2012; Tiwari et al., 2013; Omay, 2013).

Also, energy consumption is a very important variable affecting CO_2 emissions as it is one of the most important inputs in achieving sustainable development and numerous studies examined energy consumption–economic growth nexus beginning with Kraft and Kraft (1978), followed by Yu and Choi (1985), Abosedra and Baghestani (1989), Masih and Masih (1996), Hwang and Yoo (2014), Lin (2014), Aslan et al. (2014) and Azam et al. (2015). In addition, other studies investigated renewable energy consumption–economic growth nexus (Sari et al., 2008; Sadorsky, 2009; Apergis and Payne, 2011; Yildirim et al., 2012; Ocal and Aslan, 2013; Lin and Moubarak, 2014; Ibrahiem, 2015).

Therefore, several studies included energy consumption in their models when investigating EKC hypothesis and examined energy consumption–economic growth and economic growth–environment nexus in one single model (Wang et al., 2001; Ang, 2007; Acaravci and Ozturk, 2010; Pao et al., 2011; Pao and Tsai, 2011a; Pao and Tsai, 2011b; Zilio and Rcalde, 2011; Shahbaz et al., 2013b; Chandran and Tang, 2013).

Moreover, other studies added trade openness as important variable affecting carbon dioxide emissions, as the relationship between international trade and environment has been investigated and the results were mixed. Some researchers found international trade correlated positively with environmental degradation and confirmed the existence of pollution haven hypothesis where countries with weak environmental regulations will have a comparative advantage in pollution intensive industries and they refer that these are mainly developing countries and this will encourage multinational firms to relocate their production in less strict environmental regulations countries instead of producing in more strict environmental regulation countries (Al-Mulali et al., 2015).

Other scholars were against a significant correlation between environmental regulation and international trade, and this may be attributed to factor endowment hypothesis which confirms the fact the international trade between countries is determined by relatively abundance of production factors as labour and capital, and therefore developed countries have comparative advantage in capital intensive industries which are generally pollution intensive industries and thus environmental regulation has little or no effect on international trade (Abdulai and Ramcke, 2009).

Moreover, various researchers concluded that international trade affects environmental quality positively through technique effect, in which environmentally friendly new technologies are transferred through international trade and the application of these environmentally friendly technologies will improve environmental quality (Harris, 2004).

So this relationship depends on various things as environmental regulations adopted within the country and technological progress; therefore, scholars examining EKC hypothesis have included trade openness as one of the important variables affecting environmental degradation (Jalil and Mahmud, 2009; Halicioglu, 2009; Nasir and Rehman, 2011; Shahbaz et al., 2012; Jayanthakumaran et al., 2012; Tiwari et al., 2013; Farhani et al., 2014).

In addition, there are other variables that other studies took into consideration while investigating EKC hypothesis besides energy consumption and trade openness as population growth (Ahmed and Long, 2013; Onafowora and Owoye, 2014), financial development (Jalil and Feridun, 2011), labour and capital (Al-Mulali et al., 2015), urbanisation (Iwata et al., 2010), globalisation (Shahbaz et al., 2013a) and employment (Ozturk and Acaravci, 2010).

And although several studies employed panel data for group of countries to examine EKC hypothesis (Seldon and Song, 1994; Narayan and Narayan, 2010; Ozcan, 2013; Chow and Li, 2014; Cho et al., 2014), this study examines EKC hypothesis using time-series analysis for Egypt in an attempt to examine this hypothesis in a better framework as time-series analysis gives better results as countries differ in many ways, e.g. size, environmental regulations and other economic conditions (Ahmed and Long, 2013).

3 Econometric specification and methodology

3.1 Model specification and data

In order to test the validity of EKC hypothesis, a log-linear quadratic equation is specified to examine the long-run relationship between CO_2 emissions, economic growth, energy consumption, trade openness and population density as follows:

$$CO_{2_t} = \beta_{0+} \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 EC_t + \beta_4 TO_t + \beta_5 POP_t + \varepsilon_t \quad (1)$$

where CO_{2t} is carbon dioxide emissions per capita, Y_t is real GDP per capita, Y_t^2 is square of real GDP per capita, EC_t is energy consumption per capita, TO_t is trade openness ratio, POP_t is population density (people/km^2) and ε_t is the random error term. All the variables are in their natural logarithms form. It is expected according to EKC hypothesis that the sign of $B_1 > 0$ and $B_2 < 0$. The expected sign of B_3 is positive as combustion of fossil fuel results from energy consumption is considered the main cause of carbon dioxide emissions and the expected sign of B_4 is mixed according to the level of development of the country and environmental regulations adopted and technological progress in the country.

Whereas it is expected to be negative if free trade improves environmental quality, it is expected to be positive if free trade causes environmental degradation, and that is related to pollution haven hypothesis where production of polluting industries is transferred from countries with strict environmental regulation to countries with less stringent environmental regulations, also sign of B_5 may be mixed according to the level of education and development in the country.

Data from 1980 to 2010 for carbon dioxide emissions per capita, real GDP per capita, energy consumption per capita and population density are obtained from the World Development Indicators database (World Bank, 2015), while those for trade openness are obtained from Penn World Table (Heston et al., 2012).

3.2 Econometric methodology

The study will investigate the validity of EKC by examining the relationship between carbon dioxide emissions per capita, real economic growth per capita, energy consumption, trade openness and population density by applying the Johansen and Juselius (1990) maximum likelihood estimation procedure to test for the presence of multiple cointegrating vectors. But first testing for stationary will be conducted, as in time series analysis, most variables tend to have trends, which means they are non-stationary variables, and to avoid this problem, a time series can be transformed into a stationary series after differentiating it at least once, and time series will be integrated of order (*d*) if it is transformed into a stationary series after differencing it (*d*) times (Engle and Granger, 1987).

So the augmented Dickey–Fuller (ADF) test is one of the most efficient tests for univariate analysis to test for the stationary of the variables and considered as a prerequisite test for multivariate analysis. The long-run relationship between variables cannot be estimated unless all variables considered are integrated of the same order. However, as stated by Charemza and Deadman (1992), cointegration can still exist between variables integrated of different orders but under two conditions. First, the dependent variable integrated is of the order not higher than the integration order of any of the independent variables; second, all independent variables have to be cointegrated at the same order or at least two independent variables should be integrated at the same order but higher than the order of integration of the dependent variable (Charemza and Deadman, 1992).

After testing for stationary of all variables in the model, the results of existing of some or all variables in non-stationary state lead to testing a cointegration relationship between variables. When there exists a linear combination between set of integrated variables, they are cointegrated. For example, components in vector X_t are said to be cointegrated of order *d* and *b*, where $0 \leq b \leq d$ if (1) all components of X_t are integrated of order (*d*); (2) there exists a vector *B* (not equal zero) such that $Z_t = B'X_t$ is integrated of order ($d - b$), where *B* is cointegrating vector, (*d*) is the integration order of the two variables and (*b*) is the reduction in the integration order necessary to have a stationary linear combination of the two variables (Engle and Granger, 1987).

Johansen and Juselius (1990) maximum likelihood estimation procedure will be applied to test for the presence of multiple cointegrating vectors. The Johansen's multivariate approach estimates the rank of the matrix α in the following equation:

$$\Delta X_t = \gamma + \sum_{i=1}^{p-1} \delta_i \Delta X_{t-1} + \alpha X_{t-1} + \varepsilon_t \qquad (2)$$

where X_t is a column vector of variables that are integrated of order one and δ_i and α are coefficient matrices, Δ is a difference operator, γ is a constant and *p* is the lag length. If the coefficient matrix α has rank equal to zero, stationary combination cannot be identified, then variables X_t are not cointegrated. Therefore, if the rank of α differs from zero, it is an indicator for the existence of *r* possible stationary linear combinations and also variables are cointegrated (Bento, 2011).

There are two different likelihood ratio tests which are maximum eigenvalue test and the trace test. The maximum eigenvalue test examines the null hypothesis of the r cointegrating vectors against the alternative hypothesis of r +1 cointegrating vectors, while the trace test investigates the null hypothesis that the cointegration rank is equal to r against the alternative that the cointegration rank is k (Bento, 2011).

Moreover, an error correction model will be estimated to test the short-run relationship of the model, which mainly measures the adjustment speed to reach equilibrium path as it determines the short-run error correction responses of the variables to deviations from long-run equilibrium values (Azhar et al., 2007; Johansen and Juselius, 1990).

4 Empirical results and analysis

This study is concerned with testing the validity of EKC during the period 1980–2010, and this will be carried through several steps. First, order of integration for each variable will be tested by using augmented ADF test. Second, Johansen's maximum likelihood multiple cointegration test will be used to test the existence of long-run relationship among the variables. Third, if there exists long-run relationship between variables, an error correction model will be estimated to test the short-run relationship of the model and show the error correction mechanism, and error correction term will indicate the speed of adjustment to reach equilibrium after a short-term shock. Diagnostic and stability tests will be conducted which include heteroscedasticity, serial correlation and normality tests, and also stability tests known as Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Square of Recursive Residuals (CUSUMQ) tests will be employed. Granger causality test will be conducted as well.

So, first ADF test for stationarity is applied to all variables under analysis, where the null hypothesis that is tested is that the series is non-stationary and so has unit root against the alternative hypothesis that the series does not have, and it is carried out on the time series in levels and first differences, and the optimal lag is determined automatically depending on Schwarz information criterion. The results are presented in Table 1.

Table 1 Unit roots test result

Variables	*Test value (level form)*	*Test value (first differenced form)*
CO_2	–0.50522	–8.22204***
Y	0.36668	–3.94148 ***
Y^2	0.78027	–3.843768 ***
EC	–1.91555	–4.73885***
TO	–2.91299*	–3.344700 **
POP	–2.45037	–4.68204***

Notes: ** and *** indicate the rejection of the null hypothesis of ADF test at 5% and 1% levels of significance, respectively.

The previous results show that carbon dioxide emissions per capita, real economic growth per capita, real economic growth per capita square, energy consumption per capita, trade openness and population density are non-stationary at levels and that they are integrated of the order of 1.

The second step is the application of Johansen maximum likelihood cointegration test to investigate the presence of the long-run relationship among the variables, but there is a prerequisite which is specifying the appropriate lag length by conducting a Vector Autoregression (VAR) model including all the variables in the model. Then VAR has to be estimated for number of lags to select the model on the basis of Schwarz criterion and Akaike information criterion, and it is found that the appropriate lag length is one based on Akaike criterion.

Then, the relationship between dependent variable (carbon dioxide emissions per capita) and the explanatory variables (real economic growth per capita, real economic growth per capita square, energy consumption per capita, trade openness and population density) is examined using the multivariate cointegration approach proposed by Johansen and Juselius (1990) and the results are shown in Table 2.

Table 2 Johansen cointegration test results

Hypothesised no. of CE(s)	*Eigenvalue*	*Trace statistic*	*0.05 critical value*	*Prob***
None**	0.956328	215.3838	95.75366	0.0000
At most 1**	0.924170	124.5856	69.81889	0.0000
At most 2**	0.565696	49.78700	47.85613	0.0325
At most 3	0.387627	25.60067	29.79707	0.1411
At most 4	0.261580	11.37868	15.49471	0.1893
At most 5	0.085269	2.584633	3.841466	0.1079

Note: ** indicates the rejection of null hypothesis of no cointegration at the 5% significant level.

Table 2 indicates that the cointegration trace statistic rejects the null hypothesis of no cointegration. Starting with the null hypothesis of no cointegration between the variables, it is found that trace statistic of 215.3 exceeds the 95% critical value 95.75, so the null hypothesis of no cointegration is rejected.

Consequently, the null hypothesis of existence of two cointegration equations at most is rejected at the 5% level of confidence, which confirms the presence of three cointegrating equations at the 5% significance level and this means that there exists a long-run relationship among the variables. In addition, the results of the normalised cointegrating equations are reported in Table 3.

Table 3 The estimated cointegrating equation using Johansen cointegration test

Variables	*Coefficients (t-statistics)*
Y	–37.038*** (–5.35695)
Y^2	2.65752*** (5.54174)
EC	2.597*** (6.45026)
TO	–1.414154*** (–6.80555)
POP	–3.07274*** (–6.82896)

Note: *** indicates (1%) level of significance.

It is concluded from Table 3 that in the long-run all variables are significant and that trade openness and population and economic growth negatively affect carbon dioxide emissions per capita, while energy consumption per capita affects it positively.

So, it can be concluded that energy consumption per capita is the only variable that is correlated positively with pollution and that pollution haven hypothesis does not exist in Egypt, as trade openness is correlated negatively with pollution.

Also, it can be found that there is no evidence for the existence of inverted U-shaped EKC hypothesis in the long run as real economic growth per capita is correlated negatively with carbon dioxide emissions per capita, and square of real economic growth per capita is correlated positively with carbon dioxide emissions per capita.

As long-run relationship is established between the variables, error correction model is conducted in the third step, and the short-run relationship estimated by error correction model is summarised in Table 4.

Table 4 Error correction model estimates

Dependent variable: ΔCO_2		
Regressors	*Coefficients*	*Standard errors*
Intercept	0.0389	0.04043
$\Delta CO_2(-1)$	–0.15023	0.26203
$\Delta Y(-1)$	–1.2671	13.3185
$\Delta Y^2(-1)$	0.121007	0.9736
$\Delta EC(-1)$	0.40031	0.309
$\Delta TO(-1)$	0.0223	0.1703
$\Delta POP(-1)$	–1.4962	1.770
Error correction term	–0.6567	0.346*
Diagnostic tests	Test-statistics	p-value
Serial correlation LM	1.352114	0.258596
ARCH	0.168638	0.684690
White heteroskedasticity	0.709995	0.734973
Normality test JB	1.026	0.598544

Note: * indicates 10% level of significance.

The coefficient of the error correction term is statistically significant at the 10% significance level, and has a negative sign. So, this is an indication for the tendency in the model for carbon dioxide emissions per capita to return to its long-run equilibrium path whenever it shifts away. More specifically, around 65% of the disequilibrium between actual rate of carbon dioxide emissions per capita at previous year and the long-run rate of carbon dioxide emissions per capita would adjust back in the current year. However, EKC hypothesis does not exist in the short run and the rest of the specified variables are found to be insignificant, so this means that there is no effect for these specified variables on carbon dioxide emissions per capita in the short run. This may be quite reasonable as the effects on environmental quality in the form of increasing or decreasing pollution are expected to take some time. The model passes through diagnostic test statistics and the results of the diagnostics tests heteroscedasticity, serial correlation and normality test are shown in the lower part of Table 4, and it can be seen that there is no presence of serial correlation and heteroskedasticity. Also, it passes the diagnostic tests of normality.

Finally, stability of the model is examined by conducting CUSUM and CUSUMQ tests, and from Figures 1 and 2, it can be seen that the plots are within the critical bounds, meaning estimated coefficients of the model are stable.

Figure 1 Plot of cumulative sum of recursive residuals

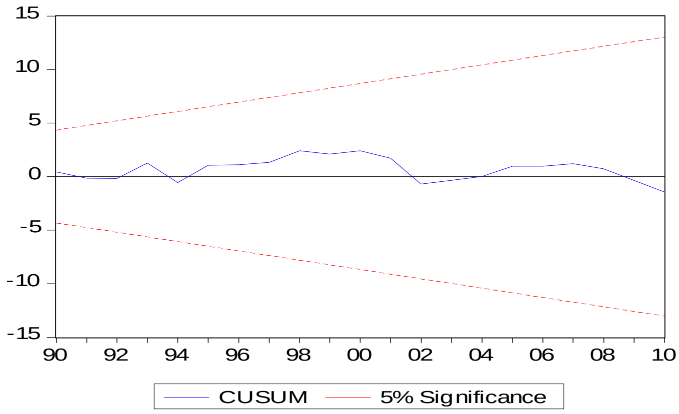
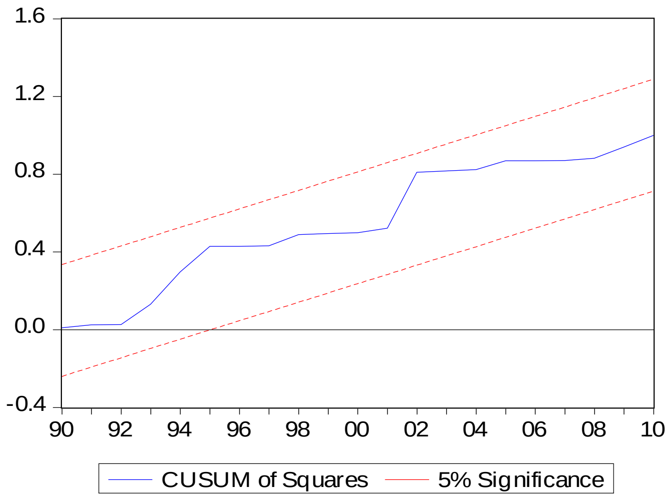


Figure 2 Plot of cumulative sum of squares of recursive residuals



Also, it is of importance to examine the causality relationship between carbon dioxide emissions per capita on the one hand and real economic growth per capita and trade openness on the other hand, and also the relationship between real economic growth per capita on the one hand and energy consumption per capita and trade openness on the other hand. So Granger causality test is employed under the null hypothesis of no causality and the result is shown in Table 5.

From Table 5, it is concluded that there is a bidirectional causality between economic growth and carbon dioxide emissions per capita, and unidirectional causality between economic growth and energy consumption per capita running from economic growth to energy consumption and also unidirectional causality running from trade openness to economic growth and there is no causality between trade openness and carbon dioxide emissions per capita.

Table 5 Pair-wise Granger causality test

Null hypothesis	*F-statistic*	*Prob.*
Y does not Granger cause CO_2	9.05368	0.00562
CO_2 does not Granger cause *Y*	7.34237	0.01155
TO does not Granger cause CO_2	0.02479	0.87606
CO_2 does not Granger cause *TO*	1.80354	0.19047
Y does not Granger cause *EC*	4.27780	0.04831
EC does not Granger cause *Y*	0.61281	0.44055
TO does not Granger cause *Y*	3.88427	0.05907
Y does not Granger cause *TO*	1.21883	0.27933

5 Discussion

The results obtained from employing Johansen cointegration approach indicate that trade openness has negative significant effect on carbon dioxide emissions per capita in the long run and has insignificant effect in the short run. This relationship indicates non-existence of pollution haven hypothesis, and this may be explained by the fact that international trade raises real income per capita in developing countries in general and Egypt in specific, and the result is that people will increase their demand for clean environment and that trade openness does not deteriorate environment in Egypt.

Also, energy consumption per capita positively affects carbon dioxide emissions, which is expected as Egypt mainly depends on fossil fuel, which is considered the major source of carbon dioxide emissions during its combustion and it is considered the "largest oil and natural gas consumer in Africa accounting for more than 20% of total oil consumption and more than 40% of total dry natural gas consumption in Africa in 2013" (EIA, 2015). Additionally, it is found that EKC hypothesis does not exist in Egypt as the relationship between carbon dioxide emissions and economic growth is negative in the long run. Moreover, the results indicate that population density has a negative effect on carbon dioxide emissions per capita, so population is not a contributor to environmental degradation, which means that energy consumption in the model is the only variable that is correlated positively with pollution.

Finally, Granger causality tests indicate unilateral causality running from economic growth to energy consumption, which means that energy conservation policies adopted by authorities will not affect economic growth in the future.

6 Conclusions and policy implications

Economic growth and industrial sector expansion in Egypt put great pressure on the environment, and Egypt is struggling to enhance economic growth which mainly depends on non-renewable energy resources that negatively affect the environment.

Therefore, this study aims at investigating relationship between CO_2 emissions and economic growth (real GDP per capita), energy consumption, population density and trade openness employing Johansen cointegration analysis over time series data of 1980–2010. Moreover, the Granger causality test is conducted to investigate the causality relationship between carbon dioxide emissions per capita on the one hand and real economic growth per capita and trade openness on the other hand, and also the relationship between real economic growth per capita on the one hand and energy consumption per capita and trade openness on the other.

The study confirms the cointegration between carbon dioxide emissions per capita, real economic growth per capita, energy consumption per capita, trade openness and population density, and that energy consumption positively affects carbon dioxide emissions, while population density, trade openness and real economic growth negatively affect it.

In addition, it is shown that EKC hypothesis does not exist either in the short run or the long run. The results revealed that the error correction term is statistically significant and has negative sign and CUSUM and CUSUMQ techniques conducted imply the stability of the model.

Moreover, the results of Granger causality test indicate bilateral causality between economic growth and carbon dioxide emissions, which means that there is interdependence between them and that more emissions are released as a result of economic growth. In addition, any policy concerning the reduction of carbon dioxide emissions will negatively affect economic growth. But the unilateral causality from economic growth to energy consumption indicates that any conservation policies regarding energy consumption will not harm economic growth as energy consumption does not Granger cause economic growth. Moreover, there is unidirectional causality running from trade openness to economic growth, confirming the importance of trade in enhancing economic growth.

So from these results, there are several policy implications for Egypt that must be taken into consideration. First, the government has to implement more energy conservation policies as this will not harm economic growth. Second, Egypt has to adopt more strict environmental regulations to control pollutants emitted from burning of non-renewable sources of energy and environment quality will be improved without negatively affecting economic growth. Third, Egypt has to alternate gradually to more environment-friendly sources of energy, i.e. renewable energy resources, instead of depending on fossil fuels.

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