Renewable, CO2 emissions , Trade Openness, and Economic growth in Iran

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Abstract: This study examines the potential of Renewable Energy Consumption (REC) in decreasing the impact of carbon emission in Iran and the Greenhouse Gas (GHG) emissions, which leads to global warming. Using the Environmental Kuznets Curve (EKC) hypothesis, this study analyses the impact of electricity generated using RES on the environment and trade openness for the period 1975-2011, using the Autoregressive Distributed Lag (ARDL) approach.
Results of unit root tests show that all variables are non-stationary in their level form and stationary in first difference form. The Cointegration analysis shows that there is evidence of cointegration among the test variables. The validity of the Environmental Kuznets Curve (EKC) hypothesis has been tested for these countries. Granger causality tests represent the existence of a unidirectional causality running from the square of per capita output to per capita CO2 emissions and renewable energy. The renewable energy consumption and economic growth has a positive bidirectional causality and contribution on emissions in the short-term. There are certainly some clarifications that justify the causes of contribution of renewable energies on the emissions.

Key-Words: Renewable Energy, CO2 emissions, Economic growth, Iran, Trade openness, ARDL.

1 Introduction

Energy is the lifeblood of any modern economy. It is a crucial input to nearly all of the goods and services we have today. Stable and reasonably priced energy supplies are vital to maintaining and improving living standards of billions people across the globe. For many decades, the demand of fossil fuel energy attends an exponential growth rate which formed disaster and catastrophic damages on the environment. The emissions of greenhouses gases such carbon dioxide (CO2) are very dangerous aspects that may be considered as the main cause of global warming. However, the consumption of non-renewable energy (oil, coal, natural gas) does not only increase the economic growth but also increases the emissions of CO2. Thus, it is necessary to find a substitutable energy to the fossil one such renewable energy.

Since the negotiation of the Kyoto Protocol, in 1997, there has been a strong emphasis on the need to replace fossil fuels for renewable energy sources (RES). It obliged industrialized countries to limit their greenhouse gas emissions, mainly CO2. Consequently many countries started to shift from dependence on fossil fuels towards the use of more renewable energy sources (RES).Indeed, a sharp increase of CO2 concentration cannot be ignored, mostly due to the combustion of fossil fuels (coal, oil and natural gas) [1] , [2] , [3] arising from the energy sector. Multiple challenges in relation to energy exist, but in particular three topics drive today's energy discussions. First, fossil fuels are a limited resource. Although there are still large supplies of coal, oil and natural gas, given the increasing demand and limited supply it is inevitable that one day supplies will run out. Thus, it is important to search for alternative energy sources. Second, the energy security problem facing energy-importing countries. Large reserves of energy supplies located in particular parts of the world involves risks for many countries in terms of reliability of energy supplies [4].

Many countries faced with energy security and environmental challenges are therefore forced to look for energy alternatives to fossil fuels. It is generally assumed that renewable and nuclear energy are practically carbon free energy sources and are seen as major solutions to the problems associated with global warming and energy security. Therefore many countries are making investments in these energy sources in order to reduce GHG and increase the supply of secure energy.

This paper tries to capture the impact of economic growth, renewable energy consumption, energy consumption, and international trade on CO2 emissions.

2 Literature survey

The majority of these studies may alter the causal direction between variables. Based on the environmental Kuznets curve (EKC) hypothesis, the direction of causality between these variables has been used within a framework by incorporating the square of real GDP, or a multivariate framework by also incorporating energy or trade.

An increasing RES share enhances economic growth and at the same time reduces CO2 emissions; this will be the best policy choice. On the other hand, if promoting RES negatively effects economic growth, at least initially, governments will need to use complementary policies, such as energy-conservation ones, to achieve environmental goals at the least cost.

Sari and Soytas [3] used a generalized forecast error variance decomposition analysis to examine how much of the variance in national income growth could be explained by the growth of different sources of energy consumption (coal, oil, hydro power, asphaltite, lignite, waste and wood) and of employment in Turkey. They found that waste had the largest initial impact, followed by oil. Yet, within the 3-year horizon, lignite, waste, oil and hydro power explained, respectively, the larger amount of GDP variation among energy sources. In general, total energy consumption was almost as important as employment in explaining GDP forecast error variance.

Wolde - Rufael [5] used the Toda-Yamamoto causality test to examine the causal relationship between various kinds of industrial energy consumption and GDP in Shangai for the period 1952-1999. The study found unidirectional Granger causality from coal, coke, electricity and total energy consumption to real GDP, but no causality in any direction, between oil and real GDP.

Ewing et al [6] used the generalized forecast error variance decomposition analysis to study the effect of disaggregated energy consumption (coal, oil, natural gas, hydro power, wind power, solar power, wood and waste) on industrial output in the USA. These effects have to be considered when fully assessing the comparative costs of RES and fossil fuels.

Chien and Hu [7] studied the effects of renewable energy on GDP for 116 economies in 2003 through the Structural Equation Modelling (SEM) approach. They decomposed GDP by the "expenditure approach" and concluded that RES had a positive indirect effect on GDP through the increasing in capital formation. However, they found that RES did not improve the trade balance having no import substitution effect.

Sari et al [3] used the autoregressive distributed lag (ARDL) approach to examine the relationship between disaggregated energy consumption (coal, fossil fuels, natural gas, hydro, solar and wind power, wood and waste), industrial output and employment for the USA. They found that, in the long-run, industrial production and employment were the key elements of fossil fuel, hydro, solar, waste and wind energy consumption, but did not have a significant impact on natural gas and wood energy consumption.

Chang et al [8] used a panel threshold regression (PTR) model to investigate the influence of energy prices on RES development under different economic growth rates for the OECD countries over the period 1997-2006. They claimed there was no direct and simple relationship between GDP and the contribution of RES to energy supply. Changes in economic growth were related with past levels of renewable energy use and not with present ones.

Narayan et al. [9] used a bivariate SVAR to study the impact of electricity consumption on real GDP for the G7 countries. They found a statistically significant positive relationship for every country except the USA, the only country common to our analysis.

Sadorsky [10] examined the relationship between renewable energy consumption (wind, solar and geothermal power, wood and wastes) and income estimating two empirical models for a panel of 18 emerging economies for the period 1994-2003. The study used panel cointegration techniques and a vector error correction model. Sadorsky found that increases in real GDP had a positive and statistically significant effect on renewable energy consumption per capita. However, there was not a bidirectional feedback between the two variables.

Payne [11] compared the causal relationship between renewable and non-renewable energy consumption and real GDP for the USA using annual data from 1949 to 2006. The author used Toda-Yamamoto causality tests in a multivariate framework (including employment and capital formation) and found no Granger causality between renewable and nonrenewable energy consumption and real GDP.

Bowden and Payne [12] use Toda-Yamamoto long-run causality test for US from 1949 to 2006 to examine the causality between sectorial non-renewable/renewable energy consumption and real GDP. The investigation results suggest neutrality hypothesis for commercial and industrial renewable energy consumption and real GDP nexus, while they suggest feedback hypothesis for commercial and residential non- renewable energy consumption and real GDP nexus. Also, there is a unidirectional causality running from residential renewable energy consumption to GDP.

Menyah and Wolde-Rufael [13] explore the causal relationship among renewable and nuclear energy consumption and economic growth for the US over the period of1960–2007. The result suggests no causality between renewable energy and CO2 emissions, but unidirectional causality from nuclear energy consumptiontoCO2 emissions.

Apergis and Payne [14] studied the relationship between renewable energy consumption and economic growth for 20 OECD countries over the period 1985-2005 within a multivariate framework. They comprised capital formation and labor in their analysis. The authors found a long-run equilibrium relationship between real GDP and renewable energy. The Granger causality test indicated bidirectional causality between the two variables both in the short and long-run.

Payne [15] examines the causal relationship between biomass energy consumption and real GDP by using the Toda–Yamamoto causality tests for Granger causality within a multivariate frame- work for the US for the period of 1949–2007. The empirical tests show unidirectional causality running from biomass energy consumption to real GDP.

Tugcu et al. [16] Using a classical augmented production functions, make a comparison between renewable and non-renewable energy sources in order to decide which type of energy is more important for economic growth in the G7 countries. The authors conclude that bidirectional feedback hypothesis between renewable and non-renewable energy and economic growth has been supported. According to these results, we can agree on the vital role of renewable energy in the progresses of the GDP.

Al-mulali et al. [17] use fully modified OLS tests to investigate the bidirectional relationship in the long-run between the renewable energy consumption of high-income, upper-middle-income, lower- middle-income, and high-income countries and GDP growth over the for79% of the countries, neutrality hypothesis for19% of the countries, and conservation and growth hypotheses for 2% of the countries.

Pao and Fu [18] employed vector error correction model to test the relationship of renewable and non-renewable energy consumption and economic growth; empirical results suggest feedback hypothesis for the relationship between GDP and renewable energy consumption and conservation hypothesis for the relationship between GDP and energy consumption. This study explores the relationship between renewable energy consumption and economic growth for Turkey by using Toda and Yamamoto causality tests.

3 Data, Specification Models and Methodology

3.1. Data

This study uses annual time series data for Iran from 1975 to 2011. The period was chosen based on the availability for all the data series. Real GDP per capita (GDP) in constant 2005 US$, CO2 Emissions (CO2) in metric tons per capita, renewable energy consumption (REC) is proxies by the combustible

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renewables and waste (in metric tons of oil equivalent). Trade openness Ratio (TR) is the total value of real import and real export as a percentage of real GDP are employed and population density (people per sq. km of land area) (POPSQ) in this study.

All data are from the World Development Indicators (WDI) online database. All the variables transformed to natural logarithms for the purpose of the analysis. We have used Microfit 4 and Eviews 7.1 to conduct the analysis. Data on per capita CO2 emissions, real GDP per capita, merchandise exports and merchandise imports are obtained from the World Bank Development Indicators online database [19]. All variables are transformed to the natural logarithms form.

3.2 Model

Following the recent empirical works it is possible to test the long-run relationship between CO2 emissions, economic growth, renewable energy consumption, trade openness and population density in a linear logarithmic quadratic form with a view of testing the validity of the EKC hypothesis using the following equation:

$$CO2_t = f(, GDP_t, GDP_t^2, REC_t, TR_t, POPSQ_t) \quad (1)$$

In order to find the long-run relationship between CO2 emissions, economic growth, renewable energy consumption, trade openness and population density, the following linear logarithmic form is proposed:

$$LnCO2_t = \alpha_0 + \alpha_1 LnGDP_t + \alpha_2 LnGDP_t^2 + \alpha_3 LnREC_t + \alpha_4 LnTR_t + \alpha_5 Ln\ OPSQ_t \quad (2)$$

Based on the environmental Kuznets curve hypothesis, the multivariate framework is established to investigate the long run relationship between per capita carbon dioxide (CO2), per capita real GDP (GDP), squared of per capita real GDP (GDP^2), energy renewable consumption (REC), trade openness (TR) and population density is people per square kilometre of land area (POPSQ). As regards the EKC hypothesis, we advance three separate panels to examine the estimated causality of the short and long-run links where emission of CO2 is the dependent variable. Based on EKC hypothesis, the sign and value of a1 and a_2 indicate different functional forms. When $a_1 = a_2 = 0$, this indicates a level relationship, when $a_1 < 0$ and $a_2 = 0$, this indicates a monotonically decreasing linear relationship, when $a_1 > 0$ and $a_2 = 0$, this indicates a monotonically increasing linear relationship, when $a_1 < 0$ and $a_2 > 0$, this represents U-shaped relationship and when $a_1 > 0$ and $a_2 < 0$, this indicates an inverted U-shaped relationship, hence the EKC.

Since renewable energy could be a factor leading to decrease of CO2 emissions, a_3 is expected to be negative. We expect that with renewable energy, the sign is negative if the level of energy used is high enough and the industrial sectors use the clean technology for production; but it could be positive if the level of renewable energy is rather low and the technology used for production is polluting.

The expected sign of trade openness coefficient is mixed. Most of the studies exploring the relationship between CO2 emissions, economic growth, energy use, and international trade reveal that the sign of trade openness slope parameter is positive if the dirty industries of developing economies are producing with heavy share of CO2 emissions. If the productions of pollutant intensive goods are limited due to the environmental regulation, a4 is expected to be negative. According, Jorgenson and Clark Jorgenson [20] concluded that there is a large and stable positive association between population density and CO2 emissions, thus $a_5 > 0$.

4 Econometric Techniques

4.1. ARDL Bounds Testing of Cointegration

The Autoregressive Distributed Lag (ARDL) approach suggested by Pesaran et al. [21] is applicable for variables that are I (0) or I (1) or fractionally integrated. The analysis begins by investigating the unit root test of variables using the augmented Dickey and Fuller [22] ADF and Philips and Perron [23] PP tests. In both tests the null hypothesis of the series has a unit root is experienced against the alternative of stationarity. The ARDL framework of Equation 3 of the model is as follows:

$$\Delta LnCO2_t = a_0 + \sum_{i=1}^{n} a_{1i}\Delta LnCO2_{t-i} + \sum_{i=1}^{n} a_{2i}\Delta LnGDP_{t-i} + \sum_{i=1}^{n} a_{3i}\Delta LnGDP^2_{t-i} + \sum_{i=1}^{n} a_{4i}\Delta LnREC_{t-i} + \sum_{i=1}^{n} a_{5i}\Delta LnTR_{t-i} + \sum_{i=1}^{n} a_{6i}\Delta LnPOPSQ_{t-i} + \lambda\, ECM_{t-1} + u_t \quad (3)$$

a_0 and e_t is the drift component and white noise, respectively. a_1, a_2, a_3, a_4 and a_5 denote the error correction dynamics while a_1, a_2, a_3, a_4, a_5 and a_6 correspond to the long-run relationship in baseline Equation 2.Where ECM $_{t-1}$ is the error correction term which is gained from the following estimated cointegration equation:

$$ECM_t = LnCO2_t - a_0 + \sum_{i=1}^{n} a_{1i}\Delta LnCO2_{t-i} + \sum_{i=1}^{n} a_{2i}\Delta LnGDP_{t-i} + \sum_{i=1}^{n} a_{3i}\Delta LnGDP^2_{t-i} + \sum_{i=1}^{n} a_{4i}\Delta LnREC_{t-i} + \sum_{i=1}^{n} a_{5i}\Delta LnTR_{t-i} + \sum_{i=1}^{n} a_{6i}\Delta LnPOPSQ_{t-i} \quad (4)$$

In the ARDL bounds testing approach the first step is to estimate Equation 3 by Ordinary Least Square (OLS).The critical values of the F-statistics in this test are presented in Pesaran and Pesaran [21] and Pesaran et al. [24].

The Error Correction Term (ECM_{t-1}) indicates the speed of the adjustment and shows how quickly the variables return to the long-run equilibrium and it should have a statistically significant coefficient with a negative sign. To ensure the suitability of the model, the diagnostic and stability tests are also conducted. These include, testing for serial correlation, functional form, normality and heteroscedasticity associated with selected models. Pesaran et al. suggested approximately the stability of long and short-run estimate through Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ). Thus the stability tests such as CUSUM and CUSUMSQ are conducted in order to check the stability of the coefficient in estimated model.

4.2 Granger Causality Analysis

The cointegration approaches are employed to test the existence or absence of long-run relationship between variables. To test the direction of causality between carbon emissions, economic growth, renewable energy consumption and trade openness the Granger [25] approach based on the Vector Error Correction Model (VECM) is employed.

The test answers the question of whether x causes y or y causes x. x is said to be Granger caused by y if y helps in the prediction of the present value of x or equivalently if the coefficients on the lagged y's are statistically significant. In the presence of long-run relationship between variables in the model, the lagged Error Correction Term (ECM_{t-1}) was obtained from the long-run cointegration relationship and was included in the equation as an additional independent variable. The following model was employed to test the causal relationship between the variables Equation 3:

$$\begin{bmatrix} \Delta \mathrm{Ln}\, CO2_t \\ \Delta LnPGDP_t \\ \Delta LnPGDP_t^2 \\ \Delta LnREC_t \\ \Delta LnTR_t \\ \Delta LnPOPSQ_t \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \\ c_6 \\ c_7 \end{bmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \beta_{11i} & \beta_{12i} & \beta_{13i} & \beta_{14i} & \beta_{15i} & \beta_{16i} \\ \beta_{21i} & \beta_{22i} & \beta_{23i} & \hat{a}_{24i} & \beta_{25i} & \beta_{26i} \\ \beta_{31i} & \beta_{32i} & \beta_{33i} & \beta_{34i} & \beta_{35i} & \beta_{36i} \\ \beta_{41i} & \beta_{42i} & \beta_{43i} & \beta_{44i} & \beta_{45i} & \beta_{46i} \\ \beta_{51i} & \beta_{52i} & \beta_{53i} & \beta_{54i} & \beta_{55i} & \beta_{56i} \\ \beta_{61i} & \beta_{62i} & \beta_{63i} & \beta_{64i} & \beta_{65i} & \beta_{66i} \\ \beta_{71i} & \beta_{72i} & \beta_{73i} & \beta_{74i} & \beta_{75i} & \beta_{76i} \end{bmatrix} \begin{bmatrix} \Delta \mathrm{Ln}\, CO2_t \\ \Delta LnPGDP_t \\ \Delta LnPGDP_t^2 \\ \Delta LnREC_t \\ \Delta LnTR_t \\ \Delta lnPOPSQ_t \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \\ \lambda_7 \end{bmatrix} ECM_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \\ \varepsilon_{7t} \end{bmatrix} \quad (5)$$

ECT_{t-1} is the lagged error-correction term. Residual terms are uncorrelated random disturbance term with zero mean and j's are parameters to be estimated. The direction of causality can be detected through the VECM of long-run cointegration. The VECM captures both the short-run and the long-run relationships. The long-run causal relationship can be established through the significance of the lagged ECTs in equations based on test and the short-run Granger causality is detected through the test of significance of F-statistics of Wald test of the relevant j coefficients on the first difference series.

5. Results and Descriptive Statistics

Annual data for CO2 emissions (CO2) (metric tons per capita), per capita real GDP (GDP) which is used as the proxy of economic growth, electricity consumption from renewable resources (REC), trade openness (TR) which is used as the proxy of foreign trade) and population density (UR).The sample period runs from 1975 to 2011 based on the annual times series data availability. All variables are employed with their natural logarithms form.

Table 1 presents some descriptive statistics of the selected variables over the period 1975-2011. The summary common statistics contain the means, median standard deviation (Std. Dev.), maximum and minimum of each series after transformation in logarithms form.

Table1 Descriptive statistics for different variables

Variables	Mean	Std. Dev.	Maximum (Year)	Minimum (Year)
CO_2	4.899168	89.17899	7.852563	2.793954
GDP	2371.391	8841095.	3316.305	1579.396
REC	0.286239	0.140287	0.619966	0.061802
TR	0.651573	0.206497	1.333924	0.439442
POPSQ	34.75358	8.085632	46.31377	20.18831

Source: Author's calculation using Eviews 7.1

In this empirical study we used five different unit root tests to check for the integration order of each variable. We apply unit root tests to ensure that no variable is integrated at I (1) or beyond. We have used the ADF unit root test to check for stationarity. The results in Table 2 indicate that all variables are non-stationary at their level form and stationary at their first differences.

Table 2 Augmented Dickey-Fuller Stationary Test Results

Variable	Constant No Trend	Critical Value	Variable	Constant No Trend	Critical Value
Ln CO2	-0.159886	-2.945842	Δ Ln CO2	-4.723295*	-2.948404
Ln GDP	-0.663392	-2.954021	Δ Ln GDP	-8.703770*	-2.948404
Ln GDP^2	-0.639064	-2.954021	Δ Ln GDP^2	-3.720542*	-2.954021
Ln ELP	-1.332847	-2.945842	Δ Ln ELP	-5.851819*	-2.948404
Ln REC	-6.214266	-2.948404	Δ Ln REC	-9.657918*	-2.951125
Ln TR	-3.212743	-2.948404	Δ Ln TR	-4.517785*	-2.948404
Ln POPES	-2.654373	-2.957110	Δ Ln POPES	-1.753984**	-1.610579

The number inside brackets denotes the appropriate lag lengths which are chosen using Schwarz Criterion.
* Denotes for 5% significance level
**Denotes for 10% significance level

Source: Author's Estimation using Eviews 7.1

The optimum lags are selected relying on minimizing the Akaike Information Criterion (AIC). The maximum lag order two was set. With that maximum lag lengths setting, the ARDL (2 , 2, 0,0, 0,1) model is selected using AIC. ARDL (2, 2, 0, 0, 0, 1) represents the ARDL model in which the CO2 emissions, income and population density take the lag length 2, 2, 1respectively.

When testing for cointegration, the VAR model with two lags, as suggested by AIC and HQIC is considered. As can be seen from Table 3, 4 the Null Hypothesis of no cointegrating relationship against alternative of at most one cointegrating relationship cannot be rejected in any of the models at a 5% level of significance, suggesting that there is cointegrating relationship among variables.

Table 3 Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.876038	204.2528	103.8473	0.0000
At most 1*	0.833090	131.1805	76.97277	0.0000
At most 2 *	0.651974	68.51995	54.07904	0.0015
At most 3	0.380307	31.57823	35.19275	0.1166
At most 4	0.235704	14.82965	20.26184	0.2363
At most 5	0.143503	5.421650	9.164546	0.2403

Trace test indicates 5 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Author's calculation using Eviews 7.1

Table 4 Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.876038	73.07227	40.95680	0.0000
At most 1*	0.833090	62.66059	34.80587	0.0000
At most 2 *	0.651974	36.94172	28.58808	0.0034
At most 3 *	0.380307	16.74857	22.29962	0.2483
At most 4 *	0.235704	9.408004	15.89210	0.3913
At most 5	0.143503	5.421650	9.164546	0.2403

Trace test indicates 5 cointegrating eqn (s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Author's calculation using Eviews 7.1

The null hypotheses of no cointegration are rejected, implying long-run cointegration relationships amongst the variables. Carbon dioxide emissions (CO2), economic growth (GDP), renewable energy consumption (REC), trade openness (TR) and population density (POPSQ) are stationary over the period 1975- 2011. These variables share a common trend and move together over the long run.

The long run estimates are described in Table 5. A result is that the estimates of energy consumption in the long run pollution equation are significant with a coefficient of -0.06. This suggests that a 1% increase in per capita consumption of energy will lead to about 0.06% decrease in per capita CO2 emissions in the long run.

Table 5 Long-run Estimation Results

Dependent Variable: Ln CO2				
Variable	Coefficient	Std. Error	T-Statistic	Prob
Ln GDP	-1.07 **	0.16440	-6.5310	[0.000]
Ln GDP^2	0.13**	0.012968	10.0531	[0.000]
Ln REC	-.085**	.035159	-2.4070	[0.024]
Ln TR	0.12	0.10553	1.1136	[0.276]
Ln POPSQ	0.59 **	0.16686	3.5004	[0.002]
C				

Note** significant at 5 % level

Source: Author's calculation using Microfit 4

All estimated coefficients can be interpreted as long-run elasticities, given that variables are expressed in natural logarithms. The long-run coefficients estimated from these techniques are very similar and have the same magnitude at the 5% significance levels. The EKC that assumes an inverted U-shaped relationship between emissions, economic growth and renewable energy is empirically supported for all estimated models.

For the model indicates that a 1% increase in real GDP decrease emissions by approximately 1.07% and a 1% increase in the square of real GDP increase emissions by 0.13%. In other words, the long-run elasticities of emissions with respect to per capita real GDP is equal to- 1.07. It means that an inverted U-shaped relationship between environmental degradation and real GDP per capita is validated.

The coefficient on trade openness (TR) shows a positive impact on CO2 emissions in Iran. The elasticity of CO2 emissions with respect to openness ratio the long run 0.12, suggesting the contribution of foreign trade CO2 emissions is not only maximal but insignificant during the estimation period. This result is similar to the findings in Halicioglu [1] for the case of Turkey because he shows that the elasticity of emissions with respect to trade openness is positive in the long-run. Also, our long-run elasticities of emissions with respect to trade are not the same as Jalil and Mahmud's result [26]. These authors suggest that trade has a positive and statistically significant impact on emissions.

The long-run estimated coefficient related to renewable energy show that, a 1% increase in renewable energy consumption decrease emissions by 0.85%. On the other hand, the positive sign of POPSQ (0.85) and is statistically significant. This implies that a 1% increase population density will lead to about 0.59% increases in the per capita CO2 emissions. Thus, renewable energy and population density can play an important role in reducing emissions.

Table6. Error correction model (ECM) for short-run elasticity
ARDL (2, 2 , 0 , 0,0,1) selected based on Akaike Information Criterion

Dependent Variable: D(Ln CO2)			
Variable	Coefficient	T-Statistic	Probability
D Ln CO2(-1)	0.47**	2.5623	[0.016]
D Ln GDP	-0.97**	-2.0965	[0.046]
D Ln GDP(-1)	-0.67*	-2.6162	[0.014]
D Ln GDP^2	0.12**	4.1411	[0.000]
D Ln REC	-0.08**	-2.0946	[0.046]
D Ln TR	0.11	1.1790	[0.249]
D Ln POPSQ	-3.27	-1.1294	[0.269]
ECM{−1}	-0.90**	-4.3659	[0.000]
The Short-Run Diagnostic Test Results			
R-Squared	0.68071		
Akaike info Criterion -	45.5008		
Schwarz Criterion	55.5008		
F-Statistic	7.6142	[0.000]	
Durbin-Watson	2.0888		
Serial Correlation LM	.92044	[0.631]	
JB Test for Normality of Errors	1.1826	[0.554]	

Note: **shows a percent level of 5%, *shows a percent level of 10%.

Source: Author's calculation using Microfit 4

The results of cointegration in Table 6 show that the F-statistic is not greater than its upper bound critical value. However, we can conclude that cointegration is supported by the significantly negative coefficient obtained for ECM_{t-1}. The error correction mechanism (ECM) is used to check the short-run relationship among the variables. The coefficient of ECM_{t-1} is statistically significant at 5% level of significance which indicates that speed of adjustment for short-run to research in the long-run equilibrium is significant. The error correction term is statistically significant and its magnitude is quite higher indicates a faster return to equilibrium in the case of disequilibrium.

This term shows the speed of adjustment process to restore the equilibrium. The relatively high coefficients imply a faster adjustment process. The values of the coefficients of ECM_{t-1} (-0.90) indicating that the variables will adjust to the long-run equilibrium in about 1.1 period following a short-run shocks.

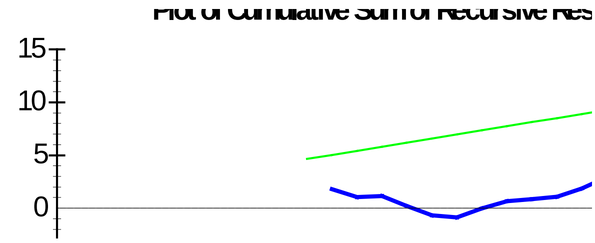
The significant negative and positive coefficients of GDP and $(GDP)^2$ respectively, suggest an inverted U-shaped relationship between per capita CO2 emissions and per capita real GDP supporting the EKC hypothesis. This confirms that CO2 emissions increase with economic growth then reach a turning point and then starts to decline with higher level of economic growth. The turning point of per capita real income turned out to be around 4.14 which are lower than the highest value of real GDP (-0.97) in our sample. In the case of developing countries the EKC's turning points may not be within the observed sample period [27].

The short-run elasticity of CO2 emissions with respect to renewable energy consumption is negative and statistically significant. The coefficient value of- 0.08 suggests that a 1% renewable energy consumption leads to around 0.08% decrease in per capita CO2 emissions. This negative and significant coefficient for per capita electricity production from renewable sources on CO2 emissions is in line with findings of Iwata et al. [27] who found negative coefficient for renewable power generation with respect to CO2 emissions. This implies that renewable energy consumption plays a significant role in decreasing CO2 emissions in short run Iran.

The coefficient of TR in short-run is positive but insignificant. The elasticity of CO2 emissions with respect to trade openness is 0.11 which suggests that 1% increase in foreign trade will lead to around 0.11% increase in per capita CO2 emissions in the short-run in Iran.

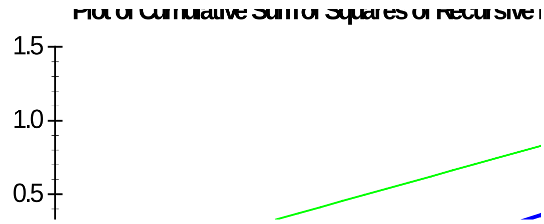
The analytical test statistics do not suggest the presence of any serial correlation and heteroskedasticity. The estimated model also passes the diagnostic tests of normality and functional form. The model was also tested for stability of the short and long-run coefficients by testing the CUSUM and CUSUMSQ tests. Figure 1 and 2 illustrate that the stability of coefficients are supported because the plots of both CUSUM and CUSUMSQ fall within the critical bounds of 5% significance.

Fig.1 Plot of Cumulative Sum of Recursive Residuals



The straight line represents critical bounds around 5% significance level

Fig. 2 Plot of Cumulative Sum Squares of Recursive Residuals



The straight line represents critical bounds around 5% significance level

The diagnostic test statistics do not suggest the presence of any serial correlation and heteroskedasticity. The estimated model also passes the diagnostic tests of normality and functional form. We tested the stability of the short and long-run coefficients by testing the CUSUM and CUSUMSQ tests. The stability of the variables in the estimated models suggests that all the estimated models are stable over the study period. In the next step, we perform the estimation of VECM to draw inferences regarding the direction of causality. The existence of a cointegration relationship among the variables, as shown by the cointegration statistics in Table 3, 4, indicates that there is Granger causality in these variables in at least one direction, but it does not show the direction of this causality. Table 7 shows the results of error correction based Granger causality, including weak short-term Granger causality and long-term Granger causality.

Table7. VECM Granger Causality results

Variable	*Short-run*						*Long -run*
	DLn CO2	DLn GDP	DLn GDP^2	DLn REC	DLn TR	DLn POPSQ	ECM(-1)
DLn CO2	-	0.41514 [0.519]	17.1490*** [0.000]	4.3873*** [0.036]	1.3900 [0.238]	1.2754 [0.259]	19.0614*** [0.000]
DLn GDP	1.6915 [0.193]	-	129.0201*** [0.000]	2.5689* [0.109]	3.5346* [0.060]	4.6034** [0.032]	0.030837 [0.861]
DLnGDP^2	1.5256 [0.217]	39349.1*** [0.000]	-	2.5536 [0.110]	0.090634 [0.763]	4.4958** [0.034]	.40571 [0.524]
DLn REC	3.9534** [0.047]	8.2013*** [0.004]	5.2665** [0.022]	-	2.3193 [0.128]	4.0406** [0.044]	16.5235*** [.000]
DLnTR	.040620 [0.840]	1.2581 [0.262]	1.1086 [0.292]	2.5760* [0.108]	-	11.5111*** [0.001]	7.5521*** [0.006]
DLn POPSQ	.016298 [0.898]	5.6006** [0.018]	.90416 [0.342]	12.0985*** [0.001]	17.1788*** [0.000]	-	46.1868*** [0.000]

x → y means x Granger causes y.
Note: ***, ** and * denote the statistical significance at the 1%, 5% and 10% levels, respectively
Source: Author's calculation using Microfit 4

The Granger causality test results funding the existence of bidirectional short-run causal relationship from renewable energy consumption to CO2 emissions. Furthermore, the long-run causality shows a bidirectional causality running from renewable resources consumption to CO2 emissions. These findings are exactly similar to those of Apergis et al. [4] for a panel of 19 developed and developing countries.

There is no causal relationship between economic growth and emissions .It is obvious that emissions will not be affected by economic growth and any increase in real GDP will grow up the level of emissions in the short-run.

Also, these findings show that renewable energy consumption and economic growth has a positive bidirectional causality and statistically significant contribution on emissions in the short-term. There are certainly some clarifications that justify the causes of contribution of renewable energies on the emissions. The first reason is, in comparison to the energy consumption, renewable energy level is not sufficiently high and has not sufficiently increased which slows its influence on emissions and economic growth. The second reason is connected to a higher increase in the consumption of oil and natural gas which make renewable energy less attractive. Another reason is relatively related to the selected sample and the analysis time period.

4 Conclusion

In this paper, we investigate the long and short-run causal nexus between carbon dioxide emissions, economic growth, renewable energy consumption, trade openness and population density by using model. We aim to test the validity of the EKC hypothesis is over the period 1975-2011 using cointegration techniques. The Autoregressive Distributed Lag (ARDL) approach was chosen to examine the long and short-run relationship between the variables.

The long-run estimates support the inverted U-shaped curve of EKC hypothesis between per capita GDP and emissions. The interesting result deduced from the long-run estimates suggests that, the coefficient of renewable energy consumption is negative and statistically significant. It explains that an increase in the consumption of renewable energy will decrease CO2 emissions.

Additionally, the impacts of trade variables are positive and statistically insignificant. Thus, more trade openness leads to more CO2 emissions. The elasticity of CO2 emissions with respect to trade openness is 0.12 which suggests that 1% increase in foreign trade will lead to around 0.12% decrease in per capita CO2 emissions in the long-run in Iran. However the coefficient of trade openness with respect to CO2 emissions is positive and insignificant in the short-run and this concurs with the findings of Jalil and Mahmud (2009) in the case of China, Nasir and Rehman [28] and Shahbaz et al. [29] for Pakistan.

The Granger causality test based on VECM was employed to test the casual relationship between the same variables. The empirical analysis reveals that there is a cointegration relationship between the selected variables. The significant positive and negative coefficients of GDP and (GDP^2) respectively, suggest an inverted U-shaped relationship between per capita CO2 emissions and per capita real GDP supporting the EKC hypothesis in both short and long-run. This checks that CO2 emissions increase with economic growth then reach a turning point and then starts to decline with higher level of economic growth.

The results imply the importance of renewable energy in controlling CO2 emissions in both short and long run in Iran. Renewable energy can ensure sustainability of electricity supply and at the same time can reduce CO2 emissions. Besides all the positive impacts of renewable energy sources on economic and environment and the Iranian government efforts and investment in development of renewable sources consumption, the progress in consumption of renewable energy in the country has been slow. Hence there is a serious need of policies to promote the consumption of renewable sources and also to bring public awareness to the importance of renewable sources in sustainability of energy in country.

As a policy implication, Iran country should increase trade openness and uses of renewable energy to combat with global warming and reducing CO2 emissions. By growing the usage of renewable energy it will help to reduce energy dependency and promote energy security of energy importing countries too.

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