The Dynamic Links between Economic Growth, Energy Intensity and CO2 Emissions in Iran

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Abstract: This article examines the determinants of CO2 emissions using the ARDL and data from 1975 to 2011 for Iran approach. The empirical results show that the energy intensity and urbanization increases CO2 emissions in the long run. The results confirm the existence of an environmental Kuznets curve between real GDP and CO2 emissions, which means that higher levels of economic growth, environmental impact decreases over time. Therefore, all the evidence suggests that policy makers should focus on urban planning and the development of clean to make a substantial contribution to both reduce non-renewable energy consumption and energy mitigation of climate change.

Keywords: CO2 emissions, Economic growth, Energy Intensity, Urbanization, Iran, ARDL.

1 Introduction
Climate change and global warming are the greatest and most controversial environmental issues of our time. The carbon dioxide emitted by burning accumulated fossil fuels, as well as contributions from other gas emissions greenhouse of human origin, are warming the atmosphere and oceans of the earth [1].

Human activities involving the burning of fossil fuels and biomass combustion produces greenhouse gases that affect the composition of the atmosphere and climate of the planet. These activities are increasing with the rapid pace of urbanization in recent decades, which eventually cause serious damage to the environment through energy consumption. In addition, the expansion of service industries, which is the result of economic development, can increase demand for energy and therefore leads to emissions. Therefore, the purpose of this article is to identify the determinants of pollutant.

Understanding the spatial and temporal distribution of carbon dioxide (CO2) emissions can aid policy by helping to develop proper regulatory frameworks to mitigate harmful anthropogenic greenhouse gas (GHG) emissions, which are the cause of global climate change.

This article examines the relationship between CO2 emissions by urbanization and focusing on the environmental Kuznets curve hypothesis (EKC).

The rest of the paper is organized as follows: section 2 presents a review of the existing literature. Section 3 presents the research methodology, including the specification of the model and the estimation strategy. The empirical results are presented in Section 4. Finally, Section 5 concludes the article.

2 Literature survey
The causal relationship between CO2 emissions and economic growth is well studied in the literature of the energy issue. Many studies show a causal relationship between the two variables; conducted to develop and mature. Kraft and Kraft [2] tested for
causality between energy consumption and GDP of that country for the periods from 1947 to 1974 using the methodology Sims. They found unidirectional causality from GDP energy consumption.

Energy plays a vital role in economic development. It performs a key for sustainable development. The findings of the previous studies suggested that the results are inconclusive depending on the methods and time period employed.

Energy plays a vital role in economic development. It performs a key to sustainable development. Results from previous studies have suggested that the results are inconclusive according to methods and time periods used.

Alam et al. [3] studied the causal relationship between energy consumption, CO2 emissions and income in India. Evidence supported the bidirectional causality between energy consumption and CO2 emissions in the long term. However, there was no causality between energy consumption and income and between CO2 emissions and income. Thus, the authors concluded that energy saving policies can be used without affecting economic growth. In addition, the CO2 reduction is less easy in India, due to lack of causality in any direction.

York et al. [4] considered that there is no evidence of the EKC for total CO2 emissions and urbanization in 142 countries in the year 1996.


Managi [6] considered that economic growth and the reduction of environmental degradation are compatible, according to the environmental Kuznets curve hypothesis (CEC). It was proposed that a relationship inverted between economic growth and environmental pollution is empirically associated with smaller levels of pollution after a moment's old income threshold U. Based on a simple regression analysis.

Li et al. [7] used panel unit root, heterogeneous panel cointegration and dynamic OLS methods to examine the relationship between energy consumption and economic growth for 30 provinces in China. Their results presented that there was a positive long-run relationship between energy consumption, CO2 emissions and economic growth. They found that a 1% increase in GDP per capita increased the energy consumption and CO2 emissions by 0.5% and 0.43% respectively.

Mallick [8] studied the link between energy consumption and economic growth using Granger causality test on annual data from India for the period 1970-2005 tests suggest that fuels economic growth demand for crude oil and electricity consumption while growth increased coal consumption engine of economic growth. However, analysis of variance of the regression vector auto decomposition (VAR) suggests the possibility of a two-way influence between electricity consumption and growth.

Sadorsky [9] used vector Auto regression techniques to study the relationship among renewable energy consumption, income, oil prices and CO2 emissions in the Group of 7 (G7) countries over the period of 1980e2005. The results show that in the long-run, an increase in real GDP per capita and carbon dioxide emissions per capita are found to contribute in increase in G7 renewable energy consumption per capita.

Menyah and Wolde-Rufael [10] investigated vector auto regression technique to study the relationship among CO2, renewable energy, and nuclear energy and real output for the US over the period of 1960e2007. They find unidirectional causality running from nuclear energy consumption to CO2 emissions but no causality is found between renewable energy consumption and CO2 emissions.

Iwata et al., [11] took into account nuclear energy and find poor evidence in support of the EKC hypothesis in the cases of 11 OECD countries.

Poumanyvong and Kaneko [12] considers different stages of development and provides evidence of the positive effects of population, wealth and urbanization on CO2 emissions for all income groups, low, medium and high for 17 developed countries covering the period 1960-2005.

Boopen et al. [13] analyzed the relationship between GDP and Carbon dioxide emission for Mauritius over the time period 1975-2007. The results reveal that GDP is linked with carbon dioxide emission and have a significant negative relationship between them.

Liddle [14] studied positive associations between GDP per capita and CO2 emissions from transport and between the total population and CO2 from transport, using a panel of 29 provinces in China from 1995 to 2010.

Shahbaz et al. [15] showed the relationship between income and energy consumption in Romania using annual data for the time period 1980e2008. The results suggest a positive association between real output and energy consumption in Romania. They also identified a strong positive correlation between non-renewable energy consumption and emissions of carbon dioxide.

Martínez-Zarzoso and Maruotti [16] for developing countries during the period from 1975 to 2003 confirm the existence of an inverted U-shaped
relationship between CO2 emissions and urbanization, indicating that urbanization at higher levels contributes to reductions in environmental damage. Using a semi-parametric model, Martínez-Zarzoso Maruotti and [16] to developing countries during the period 1975-2003 confirm the existence of an inverted-U relationship between CO2 emissions and urbanization, indicating that urbanization at higher levels contribute to the reduction of environmental damage, using a semi-parametric model.

Li et al. [17] tested the relationship between CO2 emissions, energy consumption and economic development using a panel data of 28 provinces in China. The result confirmed the cointegration relationship among the three variables. Moreover, the study found evidence of bi-directional causality between CO2 emissions and energy consumption as well as between energy consumption and economic growth. In addition, energy consumption and economic growth caused CO2 emissions in the long run while CO2 emissions and economic growth were the long-run causes of energy consumption. The organization of the remainder of this paper is as follows.

Zhang and Lin [18] showed that population, affluence, industrialization and energy intensity increase CO2 emissions for the whole sample, whereas the results are different across the different regions.


### 3 Research methods

#### 3.1 Model specification

The objective of this model is to examine the relationship between CO2 emissions, urbanization and income and energy intensity using the EKC hypothesis. After the energy intensity is used as an indicator of technology is added to the base model STIRPAT. The model is as follows:

\[ \text{CO}_2 = f(\text{GDP}, \text{URB}, \text{EI}) \]  

To find the long-run relationship between the variables, the log-linear form following is proposed:

\[ \text{LnCO}_2 = \alpha_0 + \alpha_1 \text{LnGDP} + \alpha_2 \text{LnGDP}^2 + \alpha_3 \text{LnURB} + \alpha_5 \text{LnEI} \]  

In the above equation, GDP is GDP per capita GDP$^2$ means the squared term of GDP per capita, URB is urbanization, and EI is energy intensity. After the recent empirical work, it is possible to test the long-term relationship between the variables.

#### ARDL Bounds Test

The Autoregressive Distributed Lag (ARDL) approach suggested by Pesaran et al. [20] is applicable for variables that are I (0) or I (1) or fractionally integrated. The ARDL framework of Equation 3 of the model is as follows:

\[ \Delta \text{LnCO}_2 = a_0 + \sum_{i=1}^{n} a_{i1} \Delta \text{LnGDPCO}_2 + \sum_{i=1}^{n} a_{i2} \Delta \text{LnGDP}^2 + \sum_{i=1}^{n} a_{i3} \Delta \text{LnURB} + \sum_{i=1}^{n} a_{i4} \Delta \text{LnEI} + \lambda \Delta \text{ECM}_{t-1} + \epsilon_t \]  

(3)

\[ a_1, a_2, a_3 \text{ and } a_4 \] correspond to the long-run relationship in Equation. Where \( \text{ECM}_{t-1} \) is the error correction term which is gained from the following estimated cointegration equation:

\[ \text{ECM}_2 = \text{LnGDP} - a_0 + \sum_{i=1}^{n} a_{i1} \Delta \text{LnCO}_2 + \sum_{i=1}^{n} a_{i2} \Delta \text{LnGDP} + \sum_{i=1}^{n} a_{i3} \Delta \text{LnURB} + \sum_{i=1}^{n} a_{i4} \Delta \text{LnEI} \]  

(4)

#### Granger Causality Analyses

Cointegration tests are only able to indicate whether the variables are cointegrated and whether a long-run relationship exists between them, testing the direction of causality between CO2 emission, economic growth, renewable energy consumption, non-renewable and population. The Granger [21] approach based on the Vector Error Correction Model (VECM) is employed, considering each variable in turn as a dependent variable for model. Next, the ARDL method is employed to examine the long-run and short-run Granger causalities between variables. The residuals, obtained using the long-run estimates in Model are used as dynamic error correction terms. The following model was used to test the causal relationship between the variables:

**The Granger causality analysis**
Cointegration tests are not able to indicate if the variables are cointegrated, if a long-term relationship between them tests the direction of causality between CO2 emissions, economic growth, urbanization and energy intensity. Granger [21] based on the vector error correction model (VECM) approach is used, considering in turn each variable as a model for the dependent variable. Then the method of ARDL is used to examine the long-term and short-term Granger causality between variables. The residue obtained using the long-term estimates in the model are used as dynamic error correction terms.

The following model was used to test the causal relationship between the variables:

$$
\begin{align*}
\Delta \ln CO_2_t & = \Delta \ln GDP_t + \Delta \ln GDP^2_t + \Delta \ln URB_t + \Delta \ln EI_t + \sum_{i=1}^{4} \lambda_i \Delta \ln CO_2_{t-i} + \sum_{i=1}^{4} \lambda_i \Delta \ln URB_{t-i} + \sum_{i=1}^{4} \lambda_i \Delta \ln EI_{t-i} \\
\Delta \ln GDP_t & = \beta_1 \Delta \ln CO_2_t + \beta_2 \Delta \ln GDP_t + \beta_3 \Delta \ln GDP^2_t + \beta_4 \Delta \ln URB_t + \beta_5 \Delta \ln EI_t + \sum_{i=1}^{4} \hat{\lambda_i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{4} \hat{\lambda_i} \Delta \ln GDP^2_{t-i} + \sum_{i=1}^{4} \hat{\lambda_i} \Delta \ln URB_{t-i} + \sum_{i=1}^{4} \hat{\lambda_i} \Delta \ln EI_{t-i} \\
\Delta \ln GDP^2_t & = \beta_{12} \Delta \ln CO_2_t + \beta_{13} \Delta \ln GDP_t + \beta_{14} \Delta \ln GDP^2_t + \beta_{15} \Delta \ln URB_t + \beta_{16} \Delta \ln EI_t + \sum_{i=1}^{4} \hat{\lambda_{12}} \Delta \ln GDP_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{13}} \Delta \ln GDP^2_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{14}} \Delta \ln URB_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{15}} \Delta \ln EI_{t-i} \\
\Delta \ln URB_t & = \beta_{21} \Delta \ln CO_2_t + \beta_{22} \Delta \ln GDP_t + \beta_{23} \Delta \ln GDP^2_t + \beta_{24} \Delta \ln URB_t + \beta_{25} \Delta \ln EI_t + \sum_{i=1}^{4} \hat{\lambda_{21}} \Delta \ln CO_2_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{22}} \Delta \ln GDP_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{23}} \Delta \ln GDP^2_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{24}} \Delta \ln URB_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{25}} \Delta \ln EI_{t-i} \\
\Delta \ln EI_t & = \beta_{31} \Delta \ln CO_2_t + \beta_{32} \Delta \ln GDP_t + \beta_{33} \Delta \ln GDP^2_t + \beta_{34} \Delta \ln URB_t + \beta_{35} \Delta \ln EI_t + \sum_{i=1}^{4} \hat{\lambda_{31}} \Delta \ln CO_2_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{32}} \Delta \ln GDP_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{33}} \Delta \ln GDP^2_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{34}} \Delta \ln URB_{t-i} + \sum_{i=1}^{4} \hat{\lambda_{35}} \Delta \ln EI_{t-i} \\
\Delta \ln CO_2_{t-1} & = \hat{\lambda_1} \Delta \ln GDP_{t-1} + \hat{\lambda_2} \Delta \ln GDP^2_{t-1} + \hat{\lambda_3} \Delta \ln URB_{t-1} + \hat{\lambda_4} \Delta \ln EI_{t-1} + \hat{\lambda_5} \Delta \ln CO_2_{t-1} 
\end{align*}
$$

ECM_{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.

Data Description
The time series data for Iran covering the period from 1975 to 2011 are collected for CO2 emissions, GDP per capita, urbanisation, total population size and energy intensity. CO2 refers to total carbon dioxide emissions that come from the consumption of energy in millions of metric tons. Energy intensity is measured as the total primary energy consumption in quadrillion Btu divided by GDP (year 2005 U.S. Dollars, Purchasing Power Parities). The data for CO2 emissions and energy intensity from the Iran Energy Information Administration [22].

The total population is taken to be the midyear population size, and Urbanisation is generally measured as the percentage of the population living in urban areas. Therefore, the urban population (% of the total) is applied as a reliable proxy for urbanisation. GDP and population data are from the World Development Indicators (WDI) online database [23].

All natural logs transformed for the analysis variables. We used Eviews 7.1 and Microfit 4 to analyse.

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

Table 1 Descriptive statistics for variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Std. Dev.</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2</td>
<td>4.899168</td>
<td>7.852563</td>
<td>2.793954</td>
<td>1.573910</td>
<td>0.586476</td>
<td>2.070219</td>
</tr>
<tr>
<td>GDP</td>
<td>2371.391</td>
<td>3316.305</td>
<td>1579.396</td>
<td>495.5663</td>
<td>0.414305</td>
<td>1.924741</td>
</tr>
<tr>
<td>URB</td>
<td>59.28753</td>
<td>69.33464</td>
<td>45.83033</td>
<td>7.756424</td>
<td>-0.256606</td>
<td>1.672542</td>
</tr>
<tr>
<td>EI</td>
<td>1.547568</td>
<td>2.060000</td>
<td>0.580000</td>
<td>0.454828</td>
<td>-0.858743</td>
<td>2.421806</td>
</tr>
</tbody>
</table>

Source: Author's calculation using Eviews 7.1

In this empirical study we used Augmented Dickey-Fuller Stationary 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 (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

<table>
<thead>
<tr>
<th>Variables</th>
<th>Constant No Trend</th>
<th>Critical Value</th>
<th>Variable</th>
<th>Constant No Trend</th>
<th>Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln CO2</td>
<td>-0.159886</td>
<td>-2.945842</td>
<td>Δ Ln CO2</td>
<td>-4.723295</td>
<td>-2.948404</td>
</tr>
<tr>
<td>Ln GDP</td>
<td>-0.663392</td>
<td>-2.954021</td>
<td>Δ Ln GDP</td>
<td>-3.720542</td>
<td>-2.954021</td>
</tr>
<tr>
<td>Ln GDP^2</td>
<td>-0.639064</td>
<td>-2.954021</td>
<td>Δ Ln GDP^2</td>
<td>-3.782666</td>
<td>-2.954021</td>
</tr>
<tr>
<td>Ln URB</td>
<td>-4.267206</td>
<td>-2.945842</td>
<td>Δ Ln URB</td>
<td>-3.175612</td>
<td>-2.948404</td>
</tr>
<tr>
<td>Ln EI</td>
<td>-4.879982</td>
<td>-2.945842</td>
<td>Δ Ln EI</td>
<td>-2.495561</td>
<td>-2.948404</td>
</tr>
</tbody>
</table>

The number inside brackets denotes the appropriate lag lengths which are chosen using Schwarz Criterion.

* Denotes for 5% significance level

Source: Author's Estimation using Eviews 7.1

The null hypotheses of no cointegration are rejected, implying long-run cointegration relationships amongst the variables. These variables share a common trend and move together over the long run. The VECM is set up for investigating short and long-run causality.
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, 1, 1, 0, 2) model is selected using AIC ARDL (2, 1, 1, 0, 2) represents the ARDL model in which CO2, GDP, GDP^2 and EI take the lag length 2, 1 and 2 respectively.

All estimated coefficients can be interpreted as long-run elasticities, given that variables are expressed in natural logarithms in table 2. The long-run coefficients of CO2, GDP, GDP^2, URB and EI estimated from these techniques have the same magnitude at the 5% significance levels.

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>T-Statistic</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln CO2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln GDP</td>
<td>-4.13**</td>
<td>0.26931</td>
<td>-15.3544</td>
<td>[0.000]</td>
</tr>
<tr>
<td>Ln GDP^2</td>
<td>0.30**</td>
<td>0.013868</td>
<td>21.6729</td>
<td>[0.000]</td>
</tr>
<tr>
<td>Ln URB</td>
<td>3.86 **</td>
<td>0.32205</td>
<td>11.9891</td>
<td>[0.000]</td>
</tr>
<tr>
<td>Ln EI</td>
<td>-0.71**</td>
<td>0.11931</td>
<td>-5.9735</td>
<td>[0.000]</td>
</tr>
</tbody>
</table>

Note: ** significant at 5% level.
Source: Author's calculation using Microfit 4

The estimated long-run coefficients for GDP per capita and its square does not satisfy the EKC hypothesis because the coefficients for both GDP per capita and its quadratic term are, negative and positive respectively and significant in table 4. For the model indicates that a 1% increase in real GDP decrease CO2 emission by approximately 4.13%.

With respect to the relationship between urbanisation and CO2 emissions, it is found that a 1% increase in urbanisation increases CO2 emissions by 3.86% in Iran. This result is consistent with the results of Liddle and Lung [24]. They find a positive association between urbanisation and CO2 emissions from transport in OECD countries. The greater urbanisation leads to more public transport use and thus to lower emissions. In other words, when a certain level of urbanisation is achieved, emissions tend to increase in developed countries.

The energy intensity has a positive and significant effect on CO2 emissions at the 1% level. The related coefficient demonstrates that an increase in energy intensity decreases CO2 emissions by 0.71% in the long run.

The cointegration test is supported by the significantly negative coefficient obtained for ECMt-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.

Table 4 Error correction model (ECM) for short-run elasticity ARDL (2, 1, 1, 0, 2)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>T-Statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>D Ln GDP</td>
<td>20.66**</td>
<td>2.7987</td>
<td>[0.009]</td>
</tr>
<tr>
<td>D Ln GDP^2</td>
<td>-1.33**</td>
<td>-2.7344</td>
<td>[0.011]</td>
</tr>
<tr>
<td>D Ln URB</td>
<td>5.18 **</td>
<td>6.7950</td>
<td>[0.000]</td>
</tr>
<tr>
<td>D Ln EI</td>
<td>-0.05</td>
<td>-.24317</td>
<td>[0.810]</td>
</tr>
<tr>
<td>ECM (-1)</td>
<td>-1.34**</td>
<td>-7.6630</td>
<td>[0.000]</td>
</tr>
</tbody>
</table>

The Short-Run Diagnostic Test Results

R-Squared 0.82806
Akaike info Criterion 56.3324
Schwarz Criterion 48.5557
F-Statistic 20.0666 [0.000]
Durbin-Watson 2.0135

Note: ** shows a percent level of 5%.
Source: Author's calculation using Microfit 4

Table 4 shows the rate adjustment process to restore the balance. The relatively high coefficients imply a faster adjustment process. The values of the coefficients ECM t-1 (1.34) indicating that the variable will adjust to the long-term equilibrium in about 0.75 period following a short-term shock. The coefficient of urbanization is 5.18, implies that a 1% increase in the volume of urbanization will lead to 5.18% increase in CO2 emissions.

Table 6 VECM Granger Causality results
The results of the causality test are based on the VECM. The causality test for the variables used in Model is reported in Tables 6. The findings are interpreted for the relationships between CO2 emissions and the other variables. GDP per capita, urbanization and energy intensity have positive and significant effects on CO2 emissions, implying these three variables do Granger-cause CO2 emissions in the short run. The empirical results presented indicate, bidirectional causality from GDP per capita to CO2 emissions is obtained in the short run for Iran. This result is also consistency to the findings of Apergis et al. [25] and Salim and Rafiq [26] who find bidirectional causality between income and emissions for a mix of developed and developing countries.

Interesting results are obtained as regards the effect of CO2 on the intensity of energy. The impact of CO2 emissions on energy intensity is suggesting that the increase in CO2 emissions can stimulate the use of sources of energy intensity.

5 Conclusion
This article attempts to explore the relationship between CO2 emissions, the size of the population economic growth, urbanization and energy consumption in Iran by using the ARDL approach for an extended period of time, from 1975 to in 2011.

The properties of time series data were evaluated using several unit root tests (ADF). The empirical results indicate that the two series are clearly non-stationary, as I (1) process. The results of Granger causality show that there is a unidirectional causal link urbanization and energy intensity of CO2 emissions and bidirectional causality between GDP per capita and CO2 emissions per capita.

Empirical evidence indicates that consumption of urbanization plays an important role in increasing CO2 emissions. Therefore, the government should develop and implement effective support policies to promote investment in new renewable energy technologies.

References:


