Energy Consumption and Economic growth in Iran: Cointegration and Causality Analysis

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Abstract: This study seeks to determine the direction of causality between energy consumption and economic growth (EG), using annual data from 1967 to 2008. In our empirical analysis, we implement a bounds-testing approach to co-integration and an augmented form of the Granger causality test to identify the direction of the relationship between these variables both in the short and long run. Stationarity tests reveal that both series are non-stationary, or I (1). Moreover, we found a cointegration relationship between energy consumption and GDP. The short-run dynamics of the variables show that the flow of causality runs from energy use to GDP, and there is a long-run bi-directional causal relationship (or feedback effect) between the two series. In addition, we find that energy consumption keeps on growing as long as the economy grows in Iran.

Key-Words: Energy consumption, Economic growth, Error Correction, Iran.

1 Introduction

Energy is also an essential factor of production [1]. All production involves the transformation or movement of matter in some way and all such transformations require energy. Some aspects of organized matter that is information might also be considered to be non-reproducible inputs. Energy as a factor of production must be incorporated into machines, workers, and materials in order to be made useful. This provides a biophysical justification for treating capital; labor etc. as factors of production [2].

Energy plays a crucial role in the economic development of a country. It enhances the productivity of factors of production and increases living standards. It is extensively recognized that economic development and energy consumption are interdependent [3]. The energy crisis of the 1970s and persistently high energy prices, particularly oil prices, have had a significant impact on the economic activity of developing economies. The causal relation between energy consumption and economic growth has been a well-studied topic. Energy is one of essential factors for any country’s economic development and therefore plays an important role in economy activities. Energy demand, supply and pricing impact on the socioeconomic development, the living standards and the overall quality of life of the people [4]. On the other hand, higher level of economic development could induce more energy consumption.

Over the past three decades, a lot of studies using the concepts of cointegration and Granger causality focused on several countries and time periods. The key question in energy economics, however, is whether economic growth (EG) leads to energy consumption (EC) or whether EC leads to EG. The results differ even on the direction of causality and the short-term versus long-term effects on energy
policies. Depending upon what kind of causal relationship exists, its policy implications may be significant. The outline of this paper is as follows. Section 2 provides a survey of the economic literature on the nexus between energy consumption and GDP. Section 3 contains an overview of the applied empirical methodology and a brief discussion of the data used. Section 4 discusses our empirical results. Section 5 presents some concluding remarks.

2 Literature Review
The causal relationship between energy consumption and income is a well-studied topic in the energy economics literature. The series between EC and EG has been the focus of extensive research for much of the past three decades. A large number of studies show the causal relationship between both variables; conducted for developing and developed economies. Kraft and Kraft [5] tested for causality between energy consumption and GNP for this country for the 1947-74 periods by utilizing Sims methodology. They concluded unidirectional causality running from GNP to energy consumption.

Other studies found mixed results due to utilization of different time frames, data sets or methodologies. Yu and Choi [6] concluded that there exists a causal relationship between GNP and energy consumption for South Korea and Philippines. Erol and Yu [7] examined the relationship between EC and GDP for England, France, Italy, Germany, Canada and Japan with the data spanning 1952 to 1982 and found bidirectional causality relationship for Japan, unidirectional from EC to GDP for Canada and unidirectional from GDP to EC for Germany and Italy.

Stern [8] declared that causality relationship in bivariate models is not healthy since the substitution effect of energy with other variables is ignored; he inquired the relationship between USA’s EC and GDP with a multivariate cointegration model and could not found any relationship.

Wolde-Rufael [9] also discovers conflicting results with little support for the hypothesis that energy causes economic growth. Similarly, using a multivariate causality test. The possibility of implementing energy conservation policies in countries in the similar stages of development prompted the study by Lee [10] which investigates the possible relationship between energy consumption and national income in 11 major industrialized countries. The results generally do not find evidence to support that the energy consumption and economic growth have neutral relationship. In all, the results indicate bidirectional causality in the United States, unidirectional causality from growth to energy consumption for Japan, Italy and France, and unidirectional running from energy consumption to economic growth in Switzerland, the Netherlands, Belgium and Canada.

Mehrara [11] found unidirectional causality from EG to EC for 11 oil exporting countries. Akinlo [12] found also contradictory evidence for eleven African countries. Linear and nonlinear Granger causality carried out for eight newly industrialized Asian and USA. Mallick [13] investigates the link between energy use and economic growth using the Granger causality test on India’s annual data for the period of 1970 to 2005. The tests suggest that economic growth fuels increased demand for both crude oil and electricity consumption while the growth in coal consumption drives economic growth. The variance decomposition analysis of Vector Auto regression (VAR) however suggests the possibility of a bidirectional influence between electricity consumption and economic growth.

The directions of the causality relationship between energy consumption and aggregate income could be categorized into four types, each of which has important implications for energy policy. Ozturk [14], we can have:

- Neutrality hypothesis: no causality exists between GDP and energy consumption.
- Conservation hypothesis: the unidirectional causality running from GDP to energy consumption.
- Growth hypothesis: the unidirectional causality running from energy consumption to GDP.
- Feedback hypothesis: the bi-directional causality flows between GDP and energy consumption.

3 Econometric Methodology and Data
In this research we use time-series econometric analysis. So, the VAR (Vector Auto Regressive) and VEC (Vector Error Correction) models were used. Most of time series have unit root as many studies indicated, among others, that most of the
time series are non-stationary. The presence of a unit root in any time series means that the mean and variance are not independent of time.

### 3.1 Unit Root Test

First, the Augmented Dickey Fuller (ADF) tests are used to check whether each data series is integrated and has a unit root ([15, 16]). The ADF test is based on the value of t-statistics for the coefficient of the lagged dependent variable compared with special calculated critical values. If the calculated value is greater than the critical value, then we reject the null hypothesis of a unit root; the unit root does not exist, and our variable is stationary [17]. The ADF test is based on the following regressions.

\[
\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{i=1}^{n} \alpha_i \Delta Y_{t-i} + \epsilon_t
\]

Where \(Y\) is a time series, \(t\) is a linear time trend, \(\Delta\) is the first difference operator, \(\alpha_0\) is a constant, \(n\) is the optimum number of logs on the dependent variable and \(\epsilon\) is the random error term.

### 3.2 Cointegration Analysis

Engle and Granger [18] provided a totally new method for analyzing time series. It is well known that a time series model can only be built once the included series in the model are stationary. Engle and Granger show that if independent series are integrated of the same order \(d\), denoted by \(I(d)\), and if the residuals of the linear regression among these series are integrated of the order \(d - b\), \(I(d - b)\), then the series are said to be co-integrated of the order \(d, b\), denoted as \(CI(d, b)\). There is a great advantage in finding (long-term) co-integration relationships, as the series need no longer be transformed and, hence, the forecasting power increases substantially.

The existence of long-run equilibrium (stationary) relationships among economic variables is referred to in the literature as cointegration. Engel and Granger pointed out that a linear combination of two or more non-stationary variables may be stationary. If such a stationary combination exists, then the non-stationary time series are said to be co-integrated. The VAR based cointegration test using the methodology developed in Johansen is described below:

Consider a VAR of order \(p\)

\[
y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B x_t + \epsilon_t
\]

Where \(y_t\) is a \(k\)-vector of non-stationary \(I(1)\) variable, \(x_t\) is a \(d\)-vector of deterministic variables and \(\epsilon_t\) is a vector of innovations. If the economic variables are cointegrated, we can proceed to utilize the Vector Auto-regression (VAR) representation. This VAR can be rewritten as follows:

\[
\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p} \Gamma \Delta y_{t-i} + \beta x_t + \epsilon_t
\]

where, \(\Pi = \sum_{i=1}^{p} A_t - I\) and \(\Gamma = - \sum_{i=1}^{p} A_t\)

Granger representation theorem asserts that if the coefficient matrix \(\Pi\) has reduced rank \(r < k\), then there exists \(k \times r\) matrices \(\alpha\) and \(\beta\) each with rank \(r\) such that \(\Pi = \alpha \beta\) and \(\beta y_t\) is \(I(0)\). Johansen’s method is to estimate the \(\Pi\) matrix from an unrestricted VAR and to test the null hypothesis that the restriction implied by the reduced rank of \(\Pi\) can be rejected against the alternative hypothesis that the matrix \(\Pi\) has full rank. Johansen procedure provides two statistics, one is LR test based on the stochastic matrix.

### 3.3 Var and Granger Causality

The use of a simple traditional Granger causality has been identified by several studies (such as [18], [19]) as not sufficient if variables are \(I(1)\) and cointegrated. If time series included in the analysis are \(I(1)\) and cointegrated, the traditional Granger causality test should not be used, and proper statistical inference can be obtained by analysing the causality relationship on the basis of the error correction model (ECM). Many economic time-series are \(I(1)\), and when they are cointegrated, the simple F-test statistic does not have a standard distribution. If the variables are \(I(1)\) and cointegrated, Granger causality should be done in the ECM.

Let’s denote \(PCEC_t\) and \(PCGDP_t\) for the natural logarithms of the corresponding per capita energy consumption and real GDP per capita respectively; and suppose that \(PCEC_t\) and \(PCGDP_t\) are both integrated of order 1, the VAR model developed by Granger can be defined as:

\[
\Delta PCEC_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta PCEC_{t-i} + \sum_{i=1}^{r} \gamma_i \Delta PCGDP_{t-i} + U_{1t}
\]

\[
\Delta PCGDP_t = \varphi + \sum_{i=1}^{k} \delta_i \Delta PCEC_{t-i} + \sum_{i=1}^{r} \theta_i \Delta PCGDP_{t-i} + U_{2t}
\]
This study uses the Akaike’s information criterion (AIC) to determine the optimal lag length of $\Delta PCEC_t$ and $\Delta PCGD_t$. The equations (4) and (5) are first estimated by OLS method, and then we apply the normal F Wald test for the joint significance of the coefficients on the lagged terms in the unrestricted models. Specifically, the following null hypotheses are necessarily tested:

(A) $H_0: \sum_{i=1}^{p} \beta_i \Delta PCEC_{t-i} + \sum_{i=1}^{q} \gamma_i \Delta PCGD_{t-i} = \pi_1 ECT_{1,t-1} + U_{1t}$

(B) $H_0: \sum_{i=1}^{p} \sigma_i \Delta PCEC_{t-i} + \sum_{i=1}^{q} \theta_i \Delta PCGD_{t-i} = \pi_2 ECT_{2,t-1} + U_{2t}$

It is possible to have that (a) energy consumption causes economic growth (reject B, but do not reject A), (b) economic growth causes energy consumption (reject A, but do not reject B), (c) there is a bi-directional feedback between energy consumption and economic growth (reject A and B), and (c) energy consumption and economic growth are independent (do not reject A and B).

According to Mehrara [11], the most popular method for Granger causality tests, is based on the VECM if variables are cointegrated. The VECM can avoid shortcomings of the VAR based models in distinguishing between a long- and a short-run relationship among the variables. Theoretically, cointegration implies the existence of causality between variables, but it does not indicate the direction of the causal relationship. The VECM is estimated by using the following VAR model:

\[ \Delta PCEC_t = \pi_1 + \sum_{i=1}^{p} \beta_i \Delta PCEC_{t-i} + \sum_{i=1}^{q} \gamma_i \Delta PCGD_{t-i} + \pi_1 ECT_{1,t-1} + U_{1t} \]  

\[ \Delta PCGD_t = \pi_2 + \sum_{i=1}^{p} \sigma_i \Delta PCEC_{t-i} + \sum_{i=1}^{q} \theta_i \Delta PCGD_{t-i} + \pi_2 ECT_{2,t-1} + U_{2t} \]

Where $ECT_{1,t-1}$ and $ECT_{2,t-1}$ are the error correction terms, $\Delta$ is the first difference and we are serially uncorrelated random error terms with mean zero, ($p$ and $q$) are the optimal lag lengths. $ECT_{1,t-1}$ is the lagged value of the residuals from the cointegration regression of PCEC on PCGD, and $ECT_{2,t-1}$ is the lagged value of the residuals from the cointegration regression of PCGD on PCEC. Equation 6 will be used to test the causality running from income to energy consumption and Equation 7 will be used to test the causation from energy consumption to income.

Where the error correction term ($ECT_{1,t-1}$) is derived from the long-run cointegration relationship and measures the magnitude of the past disequilibrium. The coefficients, $\pi_1$ of the $ECT_{1,t-1}$ represent the deviation of the dependent variables from the long-run equilibrium. Within this VECM model, we can examine whether the relationship between energy consumption and economic growth is weak Granger causality, long-run Granger causality, or strong Granger causality. The weak Granger causality exists if we can find the short-run relationship between energy consumption and economic growth. The long-run causality can be tested by looking at the significance of the speed of adjustment, which is the coefficient of the error correction term. This is easily based on the t statistic. Specifically, we must test the following null hypotheses:

(C) $H_0: \pi_1 = 0$ or Granger non-causality in the long run.

(D) $H_0: \pi_2 = 0$ or Granger non-causality in the long run.

According to Belloumi [20], the significance of $\pi$ indicates that the long-run equilibrium relationship is directly driving the dependent variable. If $\pi$, say, in equation (7) is zero, then it can be implied that the change in energy consumption does not respond to deviation in the long-run equilibrium for the $t-1$ period.

The short-run causality is based on a standard F-test statistics to test jointly the significance of the coefficients of the explanatory variable in their first differences. The long-run causality is based on a standard t-test. Negative and statistically significant values of the coefficients of the error correction terms indicate the existence of long-run causality.

### 3.1 Data

For the purpose of this paper, all the variables analysed have been expressed in a logarithmic scale. Our empirical study uses the time-series data of real per capita GDP and per capita energy consumption for the 1967-2008 periods in Iran. The data comprise Gross Domestic Product (GDP) will be in real terms and collected from the International Financial Statistics published by Central Bank Iran [21]. Energy data are collected from the energy balance sheet's Iranian Ministry of Energy [22]. In this paper, per capita energy consumption is expressed in terms of kg oil equivalent.

### 4 Empirical Analysis

Figure 1 shows the historical trends of real per capita GDP and per capita energy consumption for Iran in a log scale.
As a preliminary analysis, some descriptive statistics are presented in the following Table 1.

**Table 1 Explanatory data analysis**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCGDP</td>
<td>1.788302</td>
<td>1.817841</td>
<td>0.450169</td>
<td>-0.512442</td>
<td>2.506685</td>
</tr>
<tr>
<td>PCEC</td>
<td>8.497606</td>
<td>8.446234</td>
<td>0.203439</td>
<td>0.168236</td>
<td>2.191645</td>
</tr>
</tbody>
</table>

Source: Author’s Estimation using Eviews 7.1

We applied time-series techniques on stationarity and unit root processes, in order to check some stationarity properties. Table 2 contains results of common unit root tests, for two variables. The Result from table 2 provides strong evidence of non stationarity in levels. This can be seen by comparing the observed values (in absolute terms) of the ADF test statistics with the critical values (also in absolute terms) of the test statistics at the 1% and 5% 10 level of significance. Therefore, the null hypothesis is accepted and it is sufficient to conclude that there is a presence of unit root in the variables at levels and all the variables were differenced one. This indicates that the PCGDP and PCEC variables of Iran are individually I (1). Given that integration of the two series is of the same order, we continue to test whether the two series are cointegrated over the sample period.

**Table 2 Augmented dickey-fuller stationary test results**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Constant</th>
<th>Critical Value</th>
<th>Constant</th>
<th>Critical Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Trend</td>
<td>1%</td>
<td>5%</td>
<td>Trend</td>
</tr>
<tr>
<td>PCGDP</td>
<td>-2.109965</td>
<td>-3.605593</td>
<td>-2.556042</td>
<td>-4.203044</td>
</tr>
<tr>
<td>PCEC</td>
<td>-2.264448</td>
<td>-3.615588</td>
<td>-2.941145</td>
<td>-4.211848</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

Since the series examined have the same order of integration, this paper is able to perform the johansen and juselius cointegration procedure. Cointegration tests have been subsequently applied, in order to find the long-run relationship between real per capita GDP (PCGDP) and energy consumption (PCEC). Therefore, to carry out the test, we need to make an assumption regarding the trend underlying our data. We assume here that the level data have no deterministic trends and the cointegrating equations have intercepts.

**Table 3 Unrestricted Cointegration Rank Test (Trace)**

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>Critical Value</th>
<th>Prob. **</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.443458</td>
<td>25.95245</td>
<td>18.39771</td>
<td>0.0036</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.060888</td>
<td>2.511959</td>
<td>3.841466</td>
<td>0.1130</td>
</tr>
</tbody>
</table>

Trace test indicates no cointegration eq(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values

**Table 4 Unrestricted Cointegration Rank Test (Maximum Eigenvalue)**

<table>
<thead>
<tr>
<th>Hypothesized No. of CE(s)</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>Critical Value</th>
<th>Prob. **</th>
</tr>
</thead>
<tbody>
<tr>
<td>None*</td>
<td>0.443458</td>
<td>23.44049</td>
<td>17.14769</td>
<td>0.0053</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.060888</td>
<td>20511959</td>
<td>30841466</td>
<td>0.1130</td>
</tr>
</tbody>
</table>

Max-Eigenvalue test indicates no cointegration eq(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 Estimation using Eviews 7.1

Starting with the null hypothesis of no cointegration among the variables, H0: r0=0, the trace test as shown in Table 3 and 4, the null hypothesis of no cointegration is rejected at the 5% level of significance. Hence, results of both tests imply that we reject the hypothesis of no cointegrating equation at the 5% significance level. Turning to the maximal eigenvalue statistic is *, which is above the 5% critical value of *. Hence, the null hypothesis of r0=0 is rejected at the 5% level of significance. Since the two series are cointegrated, a VECM is set up for investigating short- and long-run causality. The lag-order selection has been chosen according to the Akaike’s information criterion (AIC): one lag intervals in first differences, for both series.
The estimation results of the error correction models in Table 5 indicate that the lagged error correction terms have the negative signs as expected. While the coefficient of the lagged error correction term in the PCEC equation is zero and insignificant, and significant in the PCEC equation. This significance implies that the change in logarithm of per capita energy consumption (growth rate) does rapidly respond to any deviation in the long-run equilibrium (or short-run disequilibrium) for the t-1 period. In other words, the effect of an instantaneous shock to per capita energy consumption will be completely adjusted in the long-run.

### Table 5 The estimation results of the Error Correction Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intercept</th>
<th>ECT1,t-1</th>
<th>ΔLPCECt-1</th>
<th>ΔPCGDP t-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coef.</td>
<td>-0.027476</td>
<td>-0.219601</td>
<td>0.415384</td>
<td></td>
</tr>
<tr>
<td>t-Stat.</td>
<td>(-1.98776)</td>
<td>(-1.00027)</td>
<td>2.98950</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.329</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intercept</th>
<th>ECT2,t-1</th>
<th>ΔPCGDPt-1</th>
<th>ΔPCECt-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coef.</td>
<td>-0.014295</td>
<td>0.643092</td>
<td>-0.191721</td>
<td></td>
</tr>
<tr>
<td>t-Stat.</td>
<td>(0.73869)</td>
<td>(3.05884)</td>
<td>(-6.6275)</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.308</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s Estimation using Eviews 7.1

Table 6 shows the results of the causality test based on the VECM. Granger causality tests suggest a bi-directional flow, at 1% significance level, for real per capita GDP and energy consumption in the Iranian case, in the short-run; and a unidirectional directional flow, at 1% significance level, for real per capita energy use and per capita GDP. The short-run dynamics of the variables show that the flow of causality runs from energy use to GDP, and there is a long-run bi-directional causal relationship (or feedback effect) between the two series. So, energy consumption and economic growth complement each other such that radical energy conservation measures may significantly hinder economic growth [20], [23]. This has important policy consequences, as it suggests that energy restrictions do not seem to harm economic growth in Iran. Also, the growth in GDP per capita leads to a similar growth in energy consumption per capita. We find evidence that energy consumption and economic growth move together In Iran.

### Table 6 Granger causality tests

<table>
<thead>
<tr>
<th>Test statistic</th>
<th>Causality type</th>
<th>ΔPCECt</th>
<th>ΔPCGDPt</th>
</tr>
</thead>
<tbody>
<tr>
<td>F- Stat.</td>
<td>Weak</td>
<td>6.77357</td>
<td>6.474191</td>
</tr>
<tr>
<td></td>
<td>Strong</td>
<td>4.74009</td>
<td>5.79546</td>
</tr>
<tr>
<td>g²- Stat.</td>
<td>Weak</td>
<td>0.01630</td>
<td>0.000990</td>
</tr>
<tr>
<td></td>
<td>Strong</td>
<td>0.04861</td>
<td>0.000599</td>
</tr>
</tbody>
</table>

5 Conclusions

The purpose of this paper is to contribute to the literature on the nexus between GDP and energy consumption, in recent econometric techniques. So, we studied the relationship between real per capita GDP and per capita energy consumption for Iran, using annual data covering the period 1967-2009. The time-series properties of the data were assessed using several unit root tests (ADF). Empirical findings indicate that both series are clearly non-stationary, as and I (1) process. The analysis shows that energy consumption and GDP are cointegrated. This means that there is (possibly bi-directional) causality relationship between the two. Then, cointegration analysis revealed that there is a long-run relationship between GDP and energy consumption based on a VEC model after testing for multivariate cointegration between per capita energy use and per capita GDP. The short-run dynamics of the variables show that the flow of causality runs from energy use to GDP, and there is a long-run bi-directional causal relationship (or feedback effect) between the two series. So, energy consumption and economic growth complement each other such that radical energy conservation measures may significantly hinder economic growth [20], [23].

References: