IS THERE A COINTEGRATION RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND GDP IN IRAN?

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Abstract

This paper tries to unfold the linkage between energy consumption and GDP by undertaking a co-integration analysis for Iran with annual data over the period 1980-2010. The analysis shows that energy consumption and GDP are co-integrated. This means that there is (possibly bi-directional) causality relationship between the two. We establish that there is a unidirectional causality running from GDP to energy consumption indicating that energy saving would not harm economic growth in Iran. In addition, we find that energy consumption keeps on growing as long as the economy grows in Iran.

Key words: Error correction; Iran; energy consumption; economic growth; Kuznets Curve.

JEL classification: C32, Q43, Q54

1- Introduction

Iran has the third large oil reserves and the second largest natural gas reserves in the world. Iran is in a constant competition to use its energy resources more effectively in the face of subsidization and the need for technological advances in energy exploration and production. The energy consumption in this country is extraordinarily higher than international standards. With an economy which is expected to maintain a rate of growth about 1 to 4 percent for decades, Iran’s role in the world energy market becomes increasingly influential. This makes it important to predict Iran’s future demand and supply for energy. The objective of this paper is to apply the Bayesian vector autoregressive methodology to forecast Iran’s energy consumption and to discuss potential implications. The slower growth reflects an expected slower economic growth and the decline in energy consumption due to structural changes in the Iran economy.

The heavy reliance on oil and gas in Iran is due to abundant domestic stocks of oil and gas. Today, following two decades of low economic growth and rising demand for energy products, optimization of production and consumption and also the care about future generations absorbed citizens and authorities attention into itself. As a result, Iran policy makers have begun acknowledging the need of clean sources of energy, particularly natural gas and electricity. For moving in this direction, we should consider that the share of oil in Iran's total energy consumption has declined further, while the share of gas and electricity has increased substantially.

There is a multi-dimensional need for studying the energy situation in Iran. First, Iran has a strategic position as a gas and oil export and second, the Iran economy has had a boom-bust structure in the recent past and it is interesting to study her development performance.

We can show that due to unsustainable process where extra money has to be borrowed for paying the national debt service, important indicators of the Iran economy have weakened. In addition, unemployment is still high (12.3% in 2011 according to WB data) and there has been no growth in wages. Understanding long-term Energy transitions and development trajectories is a great challenge in the move towards sustainable development in a globalizing world. Energy transitions are defined as investments in possibly cleaner technologies to replace and expand the depreciating capital stock to meet growing energy demand. When considered over a longer time horizon, but also across countries, significant changes in energy technologies and consumption can be observed. Thereupon, we study the following question in this paper, using a co-integration analysis: Is there a (Granger) causal link between energy consumption (EC) and GDP? What is the direction of this causality? Is there a decoupling of energy consumption from economic growth? The application of a full-fledged cointegration analysis to Iran has not been undertaken before. So the renewing part is to do a more comprehensive analysis with more recent data. Also the analysis on its own is more comprehensive than is generally the case in the literature, where the focus is mainly on establishing the causality between GDP en EC, rather than building an ECM model as well. Furthermore, the application to Environmental Kuznets Curve (EKC) is also refreshing, as the cointegration analysis, which is hardly used, is the only correct way to test the EKC hypothesis. Having a better view on link between energy consumption and GDP can help untangle the question to which extent economic growth can be sustained under various energy availability scenarios (LİSE and VAN MONTFORT, 2005).

The relevancy of this article is also related to a more general question, namely how to meet the energy consumption challenges without interrupting economic growth within a country. This paper is also timely, as demonstrated by the current historic high oil/energy prices. The remainder of this paper is organized as follows. Section 2 presents the method used in this paper. Section 3 presents the data and discusses the results of the co-integration analysis. The final section concludes.

2. Cointegration analysis

2.1 Method

The cointegration test is based in the methodology developed by Johansen (1989), and Johansen and Juselius (1993). Johansen's method is to test the restrictions imposed by cointegration on the unrestricted variance autoregressive, VAR, involving the series. The mathematical form of a VAR is

$$y_t = \theta_1 y_{t-1} + \cdots + \theta_p y_{t-p} + \vartheta X_t + \varepsilon_t \qquad (1)$$

where y_t is an *n*-vector of non-stationary *I(1)* variables, x_t is a d-vector of deterministic variables, $\theta_1, .., \theta_p$ and ϑ are matrices of coefficients to be estimated, and ε_t is a vector of innovations that may be contemporaneously correlated with each other but are uncorrelated with their own lagged values and other right-hand side variables.

Engle and Granger (1987) 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.

Several steps can be distinguished in undertaking a co-integration analysis on time series. For ease of exposition, but without loss of generality, we consider two time series only, namely x_t andy_t.

First, the order of integration of x_t and y_t has to be established. Non-stationary series are particularly problematic when they have a unit root, which is equal to being integrated of the order one, I (1). This series is a random walk (possibly with drift), where the future value is equal to the past value (possibly with drift) with an error. The difficulty in using a random walk series is that it is typically heteroscedastic and cannot be used for forecasts. It is possible to test for a unit root using the Augmented Dickey-Fuller (ADF) test (Said and Dickey 1984) or the Phillips-Perron (PP) test (Phillips and Perron 1988). For instance, the ADF produces a statistic, which needs to cross a critical value above which the series can be confirmed to be stationary. This test needs to be run for different orders of integration, with trend and/or intercept and a number of lags. In this manner the order of integration can be determined (LİSE and VAN MONTFORT, 2005).

Second, let us assume that x_t and $y_t$are integrated of the order one: I(1). By running a simple OLS, it can be verified whether these series are co-integrated. This is the case once the residuals are stationary. This can be verified by undertaking either the Johansen maximum likelihood cointegration test or by determining the order of integration of the residuals by using the same ADF as before again.

$$y_t = \emptyset x_t + \varepsilon_t \qquad (2)$$

Once the residuals ε_t of Equation (2) are white noise, then there is one co-integrating factor (as established by the OLS), which is a good predictor of the long-term relationship among the variables (Harvey 1990). In general, when more variables are considered, it is possible to find multiple cointegrating vectors. Third, a so-called vector error-correction modeling approach is needed to test for the exogeneity of the variables. The short-term variation can be predicted by using an error correction model (ECM). For instance, by using the following model:

$$\Delta y_t = \alpha + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \sum_{j=1}^{m} \gamma_i \Delta x_{t-j+1} + \delta ECT_{t-1} + \varepsilon_t \qquad (3)$$

Where the $\alpha, \beta, \gamma, \delta$ are coefficients which need to be derived through a VAR regression, Δ is the difference, and φ is the co-integrating factor, which can be derived through OLS in a first stage. ECT stands for error correction term, which can be established by Equation (2). Fourth, the causality between variables can be established. It is then possible to verify whether, say, energy *Granger*-causes economic growth, the other way around, or both. Moreover, once a co-integration relation is established between x_t and $y_t$then either x_t has to (Granger) causey_t, the other way around, or both. Masih and Masih (1997), for instance, propose the ECM in equation (4):

$$\Delta y_t = \alpha_1 + \sum_{i=1}^{m} \beta_{1i} \Delta x_{t-i+1} + \sum_{i=1}^{m} \gamma_{1i} \Delta y_{t-i} + \delta_1 ECT_{t-1} + \varepsilon_{1t}$$

$$\Delta x_t = \alpha_2 + \sum_{i=1}^{m} \beta_{2i} \Delta x_{t-i} + \sum_{i=1}^{m} \gamma_{2i} \Delta y_{t-i+1} + \delta_2 ECT_{t-1} + \varepsilon_{2t} \qquad (4)$$

$$ECT_t = y_t - \emptyset x_t$$

Where, as before, the $\alpha, \beta, \gamma, \delta$ are coefficients which need to be derived through a VAR regression, Δ is the difference, and φ is the co-integrating factor, which can be derived through OLS in a first stage. ECT stands for error correction term.

3- Result

3.1 Data

For Iran, data have been collected from various sources. These data comprise yearly observations over the years 1980-2010, namely:

• Total population in millions,

• Economic growth, defined as GDP in constant 2000 prices in local currency units, Total primary energy use in kilograms of oil equivalent per capita.

Energy data are obtained from *BP Statistical Review2011and the Titi Tudorancea Bulletin*. The GDP data are obtained from *World Development Indicators (WDI) 2011*, published by the World Bank (2011).

3.2 ADF Unit Root Test

Nelson and Plosser (1982) argue that almost all macroeconomic time series typically have a unit root. Thus, by taking first differences the null hypothesis of nonstationarity is rejected for most of the variables. Unit root tests are important in examining the stationarity of a time series because nonstationary regressors invalidates many standard empirical results and thus requires special treatment. Granger and Newbold (1974) have found by simulation that the F-statistic calculated from the regression involving the nonstationary time-series data does not follow the Standard distribution. This nonstandard distribution has a substantial rightward shift under the null hypothesis of no causality.

Thus the significance of the test is overstated and a spurious result is obtained. The presence of a stochastic trend is determined by testing the presence of unit roots in time series data. Non-stationarity or the presence of a unit root can be tested using the Dickey and Fuller (1981) tests.

The test is the t statistic on φ in the following regression:

$$\Delta Y_t = \beta_0 + \beta_1.trend + \rho Y_{t-1} + \sum_{i=0}^{\infty} \varphi_i \Delta y_{t-i} + \varepsilon_t \quad (5)$$

Where Δ is the first-difference operator, ε_t is a stationary random error (Chang, at all, 2001).

The results of the unit root tests for the series of energy consumption and GDP variables are shown in Table 1. The ADF test provides the formal test for unit roots in this study. The p-values corresponding to the ADF values calculated for the two series are larger than 0.05. This indicates that the series of all the variables are non-stationary at 5% level of significance and thus any causal inferences from the two series in levels are invalid.

Tab.1: Results of ADF Test for Unit Roots

Variables	Trend and Intercept	first difference	Critical values (5%)	
LEC	-2.51	-5.72	-3.63	-3.64
LGDP	-1.97	-4.27	-3.57	-3.58

Note: The optimal lags for the ADF tests were selected based on optimising Akaike's information Criteria AIC, using a range of lags. We use the Eviews software to estimate this value.

Source: BP Statistical Review2011and the Titi Tudorancea Bulletin.

The analysis of the first differenced variables shows that the ADF test statistics for all the variables are less than the critical values at 5% levels (Table 1). The results show that all the variables are stationary after differencing once, suggesting that all the variables are integrated of order I (1).

3.3 Analyses and discussion

GDP = f(EC) or EC = g(GDP)? This is exactly the question we would like to address in this paper. Once we have firmly established a cointegration relationship between EC and GDP, then we know that there is (Granger) causality at least in one direction and possibly both. Continuation of the cointegration analysis can establish the direction of causality. Hence, we leave the decision of causality to the analysis (LİSE and VAN MONTFORT, 2005).

Since OLS-estimates of relationships between non-stationary variables are inefficient and biased, we have first tested whether the variables EC and GDP are stationary, using the augmented Dickey-Fuller (ADF) test. The results show the two variables to be non-stationary, while the first order differences of the variables are stationary (LİSE and VAN MONTFORT, 2005).

As a second preliminary step we have tested whether the two variables are co-integrated. This is important, since if they are co-integrated, a long-run relationship between the variables would exist even if they are individually non-stationary and we could then estimate an error-correction model (Engle and Granger, 1987). Testing for co-integration proceeds as follows. First we estimate the long-term relationship between the GDP variables and the EC variables:

$$EC_t = \emptyset\, GDP_t + \varepsilon_t \;\leftrightarrow\; ECT_t = EC_t - \emptyset\, GDP_t \qquad (6)$$

Next we test whether the error correction term (ECT_t) in the above equation is stationary or not. We do this also by means of the ADF-test. The ADF-test statistics show that GDP and EC are co-integrated (LİSE and VAN MONTFORT, 2005).

Now we can use the error-correction-model and use the estimation results to obtain estimates of the coefficients in the following long run regression equation:

$$EC_t = \alpha + \sum_{i=1}^{m} \beta_i EC_{t-i} + \sum_{j=1}^{m} \gamma_j GDP_{t-j} + \delta ECT_{t-1} + \varepsilon_t \qquad (7)$$

The results presented below are those for the final regression equations obtained by a stepwise regression procedure of variables with a t-value larger than 1, selected from all independent variables$x_{t-m}, \dots, x_t$. Afterwards we have tested for mis-specification. Assuming k=2 and m=2 the final estimated regression relation appears to be well specified and passes several tests on mis-specification:

• Durbin-Watson test and Godfrey test (serial correlation in the residuals);

• Ramsey.s reset test (functional form of the final regression equation);

• Langrange multiplier test (normality of the residuals);

• Breusch-Pagan test (heteroskedasticity in the residuals);

• Chow test for stability of the coefficients;

The error correction model (ECM) yields the following result (standard deviations between brackets):

$$\Delta EC_t = -13.08 + 1.26\, \Delta GDP_t - 0.14\, \Delta GDP_{t-1} - 0.02 \Delta EC_{t-1} - 0.68 (EC_{t-1} - 0.93 GDP_{t-1}) + \varepsilon_t \quad (8)$$

(4.35) (0.21) (0.33) (0.20) (0.19) (0.36)

Where the residual's are I (0) and $R^2 = 0.751$.

Using the estimation results of the above error correction model, we get the following result for the long run relation (standard deviations between brackets):

$$EC_t = -13.08 + 1.26\, GDP_t - 0.14\, GDP_{t-1} + 0.23\, GDP_{t-2} + 0.34 EC_{t-1} + 0.002 EC_{t-2} + \varepsilon_t \quad (9)$$

(4.35) (0.21) (0.33) (0.35) (0.21) (0.19)

From the above equation it follows that the Energy Consumption in a specific year is strongly influenced by the GDP in that year (i.e. positive sign), and the Energy Consumption and the GDP of the previous year (i.e. respectively positive and negative sign). The influence of two years ago is statistically insignificant and thus negligible.

We can also test the Granger causality using the above error correction methodology (see Greene, 2000). Therefore we apply an error correction model for the time series *ECt* and *GDPt–1* with *k*=1 and *m*=1. The results of this error-correction model are used to estimate the coefficients of the following long-run relation with $R^2 = 0.34$ (standard deviations between brackets):

$$EC_t = -10.36 + 0.31\, GDP_{t-1_t} + 0.52\, GDP_{t-2} + 0.45 EC_{t-1} + \varepsilon_t \quad (10)$$

(2.12) (0.38) (0.32) (0.27)

This long run relation gives a significant indication for Granger causality. While the regression coefficient of GDP_{t-1} is not significant, the regression coefficient of GDP_{t-2} differs significantly from zero (with probability level 0.05). Using the log likelihood ratio statistic with probability 0.01 it turns out that the time series GDP_{t-1} and GDP_{t-2} together are correlated significantly with the time series EC_t. So, we may confirm Granger causality from GDP to EC.

The Granger causality from *EC* to *GDP* can also be tested. Once again, we apply an error correction model for the time series GDP_t and EC_{t-1} with k=1 and m=1. The results of this error correction model are used to estimate the coefficients of the following long run relation:

$$GDP_t = 9.14 + 0.040\, EC_{t-1} + 0.10\, EC_{t-2} + 0.58\, GDP_{t-1} + \varepsilon_t \qquad (11)$$

(2.20) (0.15) (0.24) (0.25)

This long run relation gives not a significant indication for Granger causality. Using the log likelihood ratio statistic (probability 0.26) it turns out that the time series $EC_{t\text{-}1}$ and $EC_{t\text{-}2}$ together are not correlated significantly with the time series GDP_t. So, we may not confirm Granger causality from EC to GDP. This has important policy consequences, as it suggests that energy restrictions do not seem to harm economic growth in Iran.

3.4 The Environmental Kuznets Curve

There is a large body of literature related to the so-called Environmental Kuznets Curve (EKC). If the EKC hypothesis is true than environmental problems will be solved ultimately in time as long as the economy keeps on growing. If an EKC relationship could be found, the models used generally are not suitable for forecasting and generalization of the results are not possible. Still then, it would be reaffirming to establish such a relationship for Iran (LİSE and VAN MONTFORT, 2005).

We try to test the EKC hypothesis for Iran by using energy consumption as an indicator of the environment. We are testing an energy Kuznets curve hypothesis to establish a link between energy consumption per capita (ECPC) and GDP per capita (GDPPC).

In order to test the EKC hypothesis several studies estimate the coefficients of the quadratic relationship between the dependent variable ln($ECPC_t$) and the independent variables ln($GDPPC_t$) and $ln(GDPPC_t)^2$. However, in this case this is not allowed because ln($ECPC_t$) (probability 0.44), ln($GDPPC_t$) (probablility 0.65) and $(ln(GDPPC_t)^2$ (probablility 0.82) do have unit roots.

According to the augmented Dickey-Fuller test with two lags, there is no unit root for $\Delta\, ECPC_t$ (probability 0.00), Δ ($GDPPC_t$) (probability 0.00) and $\Delta(GDPPC_t)^2$ (probability 0.00). Therefore, instead of the mentioned quadratic regression relation we estimate the following simple linear regression relation between $\Delta\, ECPC_t$ and $\Delta\, GDPPC_t$ (with the corresponding standard deviations between brackets):

$$\Delta\, ECPC_t = 0.03 + 1.18\, \Delta GDPPC_t + 0.53\, \Delta (GDPPC_t)^2 + \varepsilon_t \qquad (12)$$

(0.02) (0.23) (0.27)

The regression coefficients in equation (12) have probability levels 0.15 and 0.00, and the $R^2 = 0.58$. If the EKC hypothesis is true, the regression coefficient of Δ GDPPCt has to be smaller than 0. Nevertheless, this coefficient turns out to have a significantly positive sign.

4- Conclusion

This paper undertook a quantitative analysis of development trajectories and energy transitions for the energy situation in Iran. A cointegration analysis was undertaken to answer the following question: What is the link between energy consumption and GDP in Iran? The analysis shows that energy consumption and GDP are co-integrated. This means that there is (possibly bi-directional) causality relationship between the two. We establish there is not any causality runs unidirectionally from GDP to energy consumption. This does not mean that energy consumption does not matter for the Iran economy; however, the analysis shows that the role of energy consumption is relatively small. 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 in tandem in Iran. This means that the Iran economy is still on an unrestrained growth path. Areas for future research are to undertake a sectorial cointegration analysis to verify in which sectors the results of this paper takes over. This could lead to a more precise policy recommendation as to where energy conservation policies would not harm the economy.

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