Bivariate Cointegration Analysis of Energy-Economy Interactions in Iran

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Abstract: Fixing the prices of energy products below their opportunity cost for welfare and redistribution purposes is common with governments of many oil producing developing countries. This has often resulted in huge energy consumption in developing countries and the question that emerge is whether this increased energy consumption results in higher economic activities. Available statistics show that Iran's economy growth shrunk for the first time in two decades from 2011 amidst the introduction of pricing reform in 2010 and 2014 suggesting a relationship between energy use and economic growth. Accordingly, the study examined the causality and the likelihood of a long term relationship between energy and economic growth in Iran. Unlike previous studies which have focused on the effects and effectiveness of the reform, the paper investigates the rationale for the reform. The study applied a bivariate cointegration time series econometric approach. The results reveals a one-way causality running from economic growth to energy with no feedback with evidence of long run connection. The implication of this is that energy conservation policy is not inimical to economic growth. This evidence lend further support for the ongoing subsidy reforms in Iran as a measure to check excessive and inefficient use of energy.

Keywords: energy consumption; economic growth; granger causality; VAR; Iran

JEL Classification: C22; O40; Q43; Q48

1. Introduction

The energy sector is until recently, often considered a minor fragment in nearly all countries but the impact energy on the overall performance of an economy is very vital. This is particularly so in many oil rich developing economies where the production and export earnings from the development of energy products has remain the main source of financing major economic and social development. Two important but interconnected factors will among others fairly describe the present economic feat of any MENA[2] countries like Iran in the present day. These are oil price fluctuations and foreign sanctions which regrettably, are determined outside

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[2] MENA is common acronyms for the countries in the Middle East and North African known to be a region with large oil reserves.

the system. Therefore, as oil trades and revenue remained the mainstay of government's economic activities, huge and sporadic shocks arising from the international energy markets will remain a dominant exogenous factor in Iran's fiscal operation in particular and the growth of the economy at large. This highlights the point that oil trade and pricing has greatly shaped the path of economic growth of Iran's in the last forty years – a development that may not end shortly.

The various shocks in the international oil market and the attendant crisis from the 1970s has continued to draw nation's attention to the prominence of energy as an essential factor of production. Subsequently, there has been several empirical evidence attesting to the significance of energy as production input sidewise capital and labour (e.g. IEA, 2004). Economic theory suggests that the rate at which a country uses energy resources mainly depends on both the economic structure and the share of each sector in the production activities along the stages of development country's economy. Accordingly, while the highly mechanised industrial economies are likely to consume more energy, mostly agricultural and service based economies will use less energy inputs in relative terms. (Soile, 2012).

The academics have shown great and keen interest in both the dictates of economic theory and the empirical link between economic growth and energy use. However, the more the energy-economy causality studies, the varied the conclusions depending to a large extent on the method used. Yet, the inferences drawn on the outcomes of these studies has great consequences for policy formulation. To this end, the paper seeks to explore two connected but separate objectives which are to establish the direction of causality (if it exists) between energy usage and economic activities in Iran and examine their long run connection in a co-integration analysis

Iran is an ideal preference for this type of investigation for a few peculiarities. First, Iran's energy prices are highly subsidised until the end of 2010 when the government commenced the initial phase of a major subsidy reform by raising energy prices to promote efficient use. According to the Iran Oil and Gas Monthly Report of April 30, 2014, the second phase of the subsidy reform intended to further manage domestic consumption was implemented in April 2014. Unfortunately, Iran's economy growth which averaged 8% in the 2001-2010 decade shrunk for the first time in two decades from 2011 and grew only marginally in 2014. This suggests a relationship between energy use and economic growth that deserve to be investigated.

Second, Iran has experienced numerous domestic political conflicts as well as a disconnected foreign relations for many years with consequent adversities on the country's energy consumption pattern in specific and the nation's socio-political and economic progress in general. A prominent member of the Organisation of Petroleum Exporting Countries (OPEC), Iran's proven natural gas reserves positions her among the top two in the world. Yet, the natural gas sector barely satisfy only domestic consumption which is about 54% of the country's total energy consumption. Even as the second largest producer of crude oil in OPEC with a daily production of about 3.7mbbl[1], Iran still imports a considerably proportion of its gasoline consumption due to limited refinery capacity (EIA, 2012). Iran's demand for primary energy and per capita output in real terms grew at an average rate of 5.5% and 1.3% respectively between 1980 and 2013 (see table 1 below). There is no doubt that these trend deserve an assessment to unravel the possible link between this growth in energy demand and the growth of Iran's economy.

Third, carefully investigated and corroborated results on the nature of causality and the long run association between energy consumption and economic performance can serve the dual purpose of practical policy guidance and overall macroeconomic management. For instance, policy makers in Iran like other typical net oil exporting nations engage in setting end use prices for both domestic and industrial energy consumers below their opportunity costs – an action that often results into higher domestic consumption and gross inefficiency in the use of energy. This is a policy that is only rational if and only if a causality that runs from energy consumption to economic growth without feedback is established.

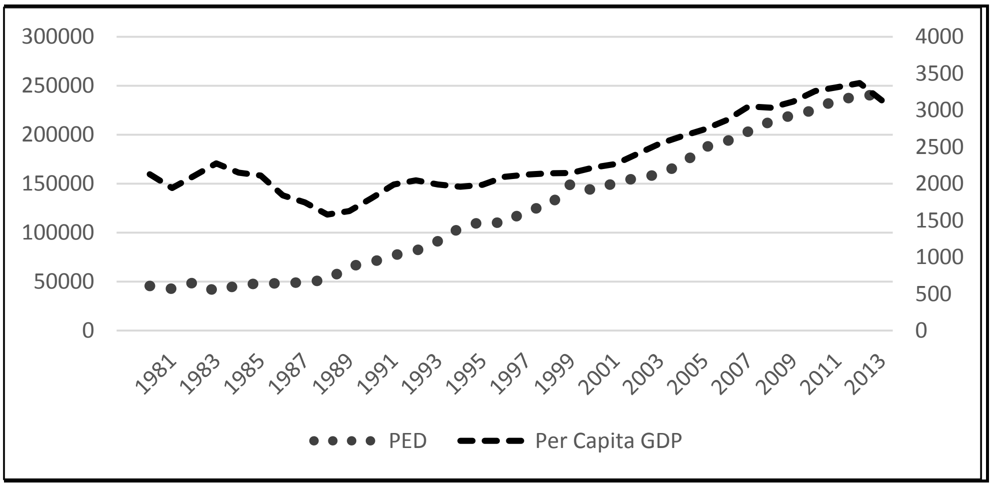

Figure 1. Primary Energy and Real per capita GDP of Iran (1980-2013)

Source: Computed by the author from IEA energy balance data, 2015

[1] See Energy Information Administration (EIA, 2012) Country Analysis Brief.

2. Literature Review[1]

The literature on energy-economy link is very rich with two general classification. The first categories are studies that investigate individual countries (country specific) and the other class which study set of countries with defined peculiarities (group specifics). While country specific studies can give broad information about a country energy-economy link, the group specific studies can tell if economies with similar features behave similarly. For instance, Soytas and Sari (2003) study the energy-economy interactions in two economically distinct groups – the best 10 emerging and the G7 nations. The outcome shows that while energy conservation may be use to arrest excessive demand in Italy and Korea, such a policy will be inimical to growth in France, Turkey, Japan, and Germany. Their results show that growth and energy granger cause each other only in Argentina. Interestingly, a similar group study by Lee in (2006) comprising 11 industrial economies reported an opposite results on the energy-economy relationship for Japan and France.

This is one of the very many evidences in the literature to corroborate our earlier assertion that different studies can obtain different results for the same country depending on methods, data and time. Perhaps, evidence of bi-directional causality between energy consumption and growth was found by Paul and Bhattacharya (2004) with the application of the Johansen multivariate cointegration technique alongside the standard granger causality test using Indian time series data between 1950 and 1996. Using a different data sets and decomposing energy into coal, oil and electricity, Mallick (2009) finds that while the quest for higher growth is stimulating higher consumption of both oil and electricity, coal usage is the only energy that fuels growth in India. Still on India, Wolde-Rufael (2010) explores further decomposition of the energy to include nuclear consumption and reassesses the energy-economy interaction with a bound-test cointegration method. Though, labour and capital are accounted for in the model, the results confirm that nuclear energy also stimulates economic growth in India.

Considerable efforts have also been made to examine the short and the long term energy-economy interactions in developing countries. Using enhanced test of series stationarity, error-correction and cointegration techniques, Lee, (2005) finds evidence supporting a one-way causality running from energy to growth with no feedback for a panel of 18 countries. The results appear plausible given that more energy may be consumed as these economies develops suggesting that efficiency in use will be a better policy for demand management as against conservation policy. A similar investigation conducted on a panel of 11 net oil exporting countries by Mehrara, (2007) suggests that these countries could implement pricing reforms in their energy sector to enhance conservation without impairing economic growth. Wolde-Rufael, (2009) studies energy-economy interaction in a panel of 17 African

[1] This section benefits extensively from an earlier work by the author.

countries with labour and capital included as variables in a multivariate system. While the causality results rejects the proposition of neutral energy-economy relationship in 15 countries, the outcome of the variance decomposition are generally too weak for any cogent conclusions.

Similarly, the implicit assumption of panels' homogeneity by existing energy-growth nexus was challenged by Akkemik and Goksal, (2012) by investigating the causal relationship between energy consumption and GDP for a large panel of 79 countries with data for the period of 1980 to 2007. After due account for panel heterogeneity, the results of the heterogeneous causality and non-causality as well as the homogeneous causality and non-causality revealed that only about 10% of the countries studied exhibit a one-way granger causality while about 20% and 70% exhibit no Granger causality and bi-directional granger causality respectively.

Kahsai et al. (2010) tested the empirical causal relationship between energy consumption and economic growth in a panel of low and middle income Sub-Saharan African countries using a panel unit root test and co-integration method. The results support the neutrality hypothesis in the short-run for low income countries and a strong bi-directional causality between energy consumption and growth in the long-run. The study attributed the dissimilar results for low and middle income countries to the role of income level in energy–growth causality and concluded that Sub-Saharan African countries should formulate sustainable development policies to enhance efficient allocation of resources in order to increase energy access in the region. The results of the empirical study by Menegaki, (2011) which used a random effect model within a multivariate panel framework to investigate the renewable energy and growth causality in 27 European countries. The results reported no evidence of causality between GDP and renewable energy consumption. Though the panel causality tests revealed that renewable energy, greenhouse gas emissions and employment are related in the short term, the co-integration estimates indicated at best, the neutrality hypothesis on the relationship between economic growth and renewable energy consumption in Europe.

Mahmoodi and Mahmoodi. (2011) employed the ARDL bound test and the Toda-Yamamoto modified Granger causality test to examine the causal and the long-run relationship between renewable energy consumption and economic growth for seven developing countries in Asia. The findings provide evidence of one-way causality running from economic growth to renewable energy consumption in Iran, Pakistan, India and Syria; a bi-directional causality between renewable energy consumption and economic growth in Jordan and Bangladesh; and no causality for Sri Lanka. Shahbaz et al. (2012) examined the relationship between both the renewable and non-renewable energy consumption and economic growth in case of Pakistan. The results of the ARDL bounds tests and the structural break co-integration and unit root tests indicated that both types of energy consumption, growth, labour, and capital are co-integrated in the country while the VECM Granger causality tests reveal a feedback hypothesis for each of renewable energy, non-renewable energy consumption and capital with economic growth

3. Methodology

Generally, a single model cannot practically serve the diverse purpose of modelling energy consumption and economy growth interactions as there are quite numerous considerations arising because of the pervasive role of energy in practically all economic activities. This according to Soile (2012) suggests that "a perfect model" if such exist, would among other things provide for a disaggregation of production sectors; allow for endogenous factor substitutions; comprise various consumers and factor endowments; and account for agents' consumption behaviour. Therefore, the model adopted in previous literature depends on the researcher's specific interest in relation to the kind of desired interaction about energy and the economy.

Given the aim of this paper which is to ascertain the causal relationship between variables and investigate the stability properties of the data as a requirement for cointegration and error correct analyses, the models described below are purposely targeted at reaching empirical conclusions regarding this objective. In all the following equations, lower case Latin or Greek letters represents fixed parameters; upper case letters represent endogenous and exogenous variables while the subscripts t and i merely stand for time period.

3.1. The Granger Test

The study employed the test suggested by Granger (1969) which presumed that the facts relevant to the prediction of any variable in the model are contained solely in the time series properties of these variables. The test is conducted by estimating the regression equations 1 and 2 below:

$$EG_t = \sum_{i-1}^{n} \alpha_i \, EC_{t-i} + \sum_{j-1}^{n} \beta_j \, EG_{t-j} + u_{1t} \quad \dots\dots\dots\dots\dots.1$$

$$EC_t = \sum_{i-1}^{n} \lambda_i \, EC_{t-i} + \sum_{j-1}^{n} \delta_j \, EG_{t-j} + u_{2t} \quad \dots\dots\dots\dots\dots..2$$

By assumption, the disturbances U_{1t} and U_{2t} are uncorrelated. The first equation above postulates that the current real gross domestic product EG relates to past values of EG itself as well as energy consumption EC_t while the second equation postulates the same for EC

- If in equation 1, the estimated coefficients on the lagged EC_t are statistically significant as a group (i.e. $\sum\alpha_i \neq 0$) and the set of estimated coefficients on the lagged EG_t in equation 2 are statistically insignificant (i.e. $\sum\delta_i = 0$), this indicates *Unidirectional* causality running from EC to EG without feedback.
- There is *Unidirectional* causality running from EG to EC without feedback if the set of the lagged EC_t coefficients in equation 1 are not statistically significant as a group (i.e. $\sum\alpha_i = 0$) and the test of the lagged EG_t coefficients in equation 2 are statistically significant (i.e. $\sum\delta_i \neq 0$).
- where the sets of EG_t and EC_t coefficients in both equations are statistically significant, we have a case of *Bilateral* causality implying that both variables granger cause each other
- Finally, the two variables are Independent of each other when the sets of EG_t and EC_t coefficients in both equation are statistically insignificant.

3.2 The Vector Autoregressive (VAR) Model

The Vector Autoregressive (VAR) is a theoretic, non-structural model that makes minimal theoretical demands on the structure of the model. The model is *auto – regressive* because the lagged value of the dependent variable usually appears on the right-hand side of the equations while the term 'vector' stems from the fact that it deals with a vector of two (or more) variables. The model is expressed in equations 3 and 4 as follows:

$$EG_t = \alpha + \sum_{j-1}^{k} \beta_j \, EC_{t-j} + \sum_{j-1}^{n} \gamma_j \, EG_{t-j} + u_{1t} \; \ldots\ldots\ldots\ldots.3$$

$$EC_t = \alpha' + \sum_{j-1}^{k} \theta_j \, EC_{t-j} + \sum_{j-1}^{n} \delta_j \, EG_{t-j} + u_{2t} \; \ldots\ldots\ldots\ldots.4$$

Where k and n are the highest number of lags required to capture most of the effect that the variables have on each other. In this study, the Akaike Information Criterion (AIC) is used to choose the optimal lag length. Therefore, each equation of the model will have the same number of lags usually refers to as the optimal lag for the two equations. With this, each equation is imposed a linear constraint and therefore can be estimated using the Least Square (OLS) method.

3.3 Tests for Stationarity

Since most time series always indicate the presence of a stochastic trend, we apply the Augmented Dickey-Fuller tests to check if the variables in equation 3 and4 above may be integrated, the study uses (Dickey and Fuller, 1979; 1981) to test the null hypothesis that the series is stationary or not. The relevant equations for the augmented Dickey Fuller tests are as follows (note that *u* is white noise)

$$\Delta EG_t = \alpha + \delta t + \emptyset^* EG_{t-1} + \sum_{i=1}^{p-1} \emptyset_i \, \Delta EG_{t-i} + u \; \dots\dots\dots\dots.5$$

$$\Delta EC_t = \alpha + \delta t + \emptyset^* EC_{t-1} + \sum_{i=1}^{p-1} \emptyset_i \, \Delta EC_{t-i} + u \; \dots\dots\dots\dots.6$$

3.4. Co-integration Analysis

In order to establish the number of co-integrating equations within the equations of the VAR above, the study agree to the unrestricted co-integrating rank test. Also while it is possible to correct random walk in variables by mere differencing of these variables, the study opted to estimate the VAR equation by applying some co-integrating restrictions because in some cases, a linear combination of two variables that follow random walk can be stationary. By this we avoid loss of essential long run information that normally characterised the former approach.

3.5. The Error Correction Mechanism (ECM)

The error correct mechanism captures the entire dynamics of variables in the ECM equation below in the short run and it is applicable where the variables are co-integrated but the co-integrating regressions have stationary residuals. By definition, δ_{t-1} is the proxy for the disequilibria which tells the path to equilibrium in the long run.

$$\Delta RG_t = \alpha + \sum_{i=1}^{k} \gamma_i \, EG_{t-i} + \sum_{j=0}^{m} \lambda_j \, \Delta EC_{t-j} + \delta ECM_{t-1} + u \; \dots\dots\dots\dots.7$$

So if the error correction term (δ) is significant, it shows the fraction of the disequilibria in economic growth (RG) in period (t) corrected in the period (t+1). Therefore, the study specifies an over-parameterised ECM model within the context of general to specific in order not to confine the dynamics of our model.

4. Results and Analysis

4.1. The Data sets

The study uses time series data on two variables namely, economic growth in real terms proxies by (gross domestic product in constant 2000 US$) and the total final consumption in (thousand tons of oil equivalents). These data were sourced from IEA, (2015) covering the period of 1971 to 2013. The choice of real gross domestic product (EG) is partly due to the clearest picture of economic activities in an economy and partly because it is adjusted for inflation which better approximates the true variation(s) in national output across the relevant period. The study uses final energy consumed as against primary energy employed by other studies advantage its vital plus. Unlike primary energy which may overstate actual consumption, final consumption captures what is truly accessible to the various sectors of the economy to consume excluding all associated transformation losses.

4.2. The Granger Causality Results

The results of the Granger-Causality test (with equations 1 and 2) are provided in table 1 below. From the results, the Null hypothesis that EC does not Granger-cause EG cannot be rejected since the F-statistic (0.7133) is not significant even at 10% level. However, the statistical significance of the F-statistic value of (10.5264) is at both 1% and the conventional 5% level, we reject the Null hypothesis that EG (the natural log of real GDP) does not Granger caused energy use (LNEC). The implication of this is that there is a *unidirectional* causality running from economic growth to energy consumption without feedback in Iran.

Table 1. Granger Causality Results for Iran

Null Hypothesis:	Obs	F-Statistic	Prob.
LNGDP does not Granger Cause LNEC	41	10.5264	0.0003
LNEC does not Granger Cause LNGDP		0.71334	0.4968

Source: Author's computation from E-views 9

4.3. The Vector Autoregressive (VAR) Model Results

Table 2 below contains the results of the VAR models of equations 3 and 4. The optimal lag length determined by the Akaike Information Criterion for each dependent and the other independent variable in each equation is -2 (i.e. first and second lags). Equation 3 postulates that current economic growth (EG) depends on itself at lags 1 and 2, and the immediate past values of energy consumption (EC). From the results, economic growth (EG) exhibits positive and statistically significant relationship with its immediate past values and negatively related to second lag values but not statistically significant with both first and second lag values of EC. The corresponding equation 4 hypothesis that energy consumption (EC) depends on its lag 1 and 2 values and past values of EG. The results show that a unit increase in EC at lag 1 will result in 0.462 unit increase in current energy consumption and 0.695 units in lagged EG values. These outcomes generally corroborates that of the causality results that economic growth stimulates energy use and not the other way.

Table 2. The Results of the Vector Auto Regressive (VAR) Model

Sample (adjusted): 1973 2013

Included observations: 41 after adjustments

Standard errors in ( ) & t-statistics in [ ]

Variable	EC			EG		
EC(-1)	0.461621	(0.19250)	[2.39797]	-0.096342	(0.24283)	[-0.39676]
EC(-2)	0.468550	(0.18358)	[2.55229]	0.114766	(0.23157)	[0.49560]
EG(-1)	0.686515	(0.15435)	[4.44765]	1.504795	(0.19470)	[7.72868]
EG(-2)	-0.694757	(0.15142)	[-4.58822]	-0.58957	(0.19100)	[-3.08670]
C	0.603563	(0.28317)	[2.13145]	0.504506	(0.35719)	[1.41243]
R-squared		0.9895			0.9286	
Adj. R-squared		0.9884			0.9206	
F-statistic		850.1947			116.9585	

Author's computation from E-views 9

4.4. Results of the Unit Root Tests

Both the Augmented Dickey-Fuller (ADF) and the Philip Perron (PP) tests criteria were used in this study to conduct unit root test on the economic growth (EG) and energy consumption (EC) variables. The lag lengths were chosen automatically based on Schwarz Information Criterion (SIC). The results presented in table 3 below show that while both variables are stationary at first difference, they are not at levels. Therefore, both series EG and EC are of the order I(1) with the computed ADF and PP t-Statistics of (EC, -4.16; RG, -4.52) and (EC, -3.84; RG, -4.66) respectively. These estimates are statistically significant at 5% levels.

Table 3. Augmented Dickey Fuller (ADF) and Philip-Perron (PP) Unit Root Test Results

Null Hypotheses: δ(RG) has a unit root; δ(EC) has a unit root

Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

Variables	ADF Test Critical Value	ADF test Stat	Prob. value	Order of Integration	PP Test Critical Value	PP test Adj. t-Stat	Prob. value
EC	-3.5298	-2.2243	0.1006	I(0)	-3.5298	-0.9194	0.3695
δ(EC)	-3.5331	-4.1601	0.0114	I(1)	-3.5331	-3.8421	0.0162
EG	-3.5331	-1.2056	0.8984	I(0)	-3.5298	-0.7181	0.7954
δ(EG)	-3.5331	-4.5072	0.0059	I(1)	-3.5331	-4.6623	0.0035

Source: Author's computation from E-views 9

4.5. Co-integration Tests and Analysis

Since both the economic growth and energy consumption series contain unit root, the study conducts a cointegration test put forward by Johansen to ascertain whether the variables have a common stochastic trend. The results of the Johansen cointegration tests (appendices 1) show that the variables are co-integrated with both the trace and Eigenvalue tests statistics indicating at least two (2) co-integrating equations. All the applicable statistics of the cointegration results indicates that the variables are cointegrated and that both EG and EC have a linear combination (see table 4**)**. However, the Durbin-Watson test confirms that the residual is stationary. Altogether, this result implies that both economic growth and energy consumption do not follow "random walks" in the end and the implication therefrom is that there exist a long run equilibrium relationship between EG and EC in Iran.

Table 4. Cointegration Test Results

		t-Statistic		Prob.*
ADF test statistic		-5.2801		0.0021
Test critical values:	1%	5%	10%	
	-4.2529	-3.5485	-3.2071	
	Coefficient	Std. Error	t-Statistic	Prob.

ECM(-1)	-1.2013	0.0119	-4.2801	0.0000
C	-5.9224	428.6315	-0.3154	0.7412
@TREND(1970)	7.1546	62.5742	0.1778	0.5605
R-squared	*0.6945*			
22Adjusted R-squared	*0.6464*			
Durbin-Watson stat	*1.9688*			
Log likelihood	*141.972*			
F-statistic	*21.782*			
Prob(F-statistic)	*0.0000*			

Source: Author's computation from E-views 9. Note: Null Hypothesis: ECM has a unit root

4.6. Estimation Results for Error-Correction Mechanism (ECM)

The result of the short term dynamic specification as regard the error correct mechanism (ECM) is presented in table 5 below. In the regression, D(EC) captures the short run disturbances while the ECM(-1) shows the adjustment toward the long run equilibrium. The results show that short run changes in energy consumption (EC) exerts significant positive effects on economic growth (EG) while the error-correct term is not statistically significant. The ECM only correct about 0.001 of the discrepancy between the actual and the equilibrium or long run value of economic growth (EG) in a year.

Table 5. Error-Correction Mechanism Results

Included observations: 41 after adjustments				
	Coefficient	Std. Error	t-Statistic	Prob.
D(EC)	0.0039	0.0007	5.3493	0.0000
ECM(-1)	0.0012	0.0009	1.3323	0.1924
C	-4.5632	3.6881	-1.3146	0.2016
R-squared	0.4903	F-statistic	15.0540	
Adjusted R-squared	0.4574	Prob(F-statistic)	0.0002	
Durbin-Watson stat	1.8139	Akaike info criterion	6.8132	

Source: Author's computation from E-views 9

5. Conclusions

The quest for effective demand management strategy in the Iranian energy industry began in 2009 with the adoption of fuel rationing policy. As a follow up on this conservative strategy, the country further commenced a major pricing reforms in late 2010. All these are meant to correct the prevailing inefficiencies in the pricing of energy products. This trend has become customary in many oil rich developing economies of the world. When governments set the domestic oil and energy prices below the free market costs, there is that tendency for both over consumption and inefficiency in the use of energy. However, rationing and other energy conservation policy can disrupt the pace of domestic productivity and slow down the trend of economic progress particularly where the causal relationship between the country’s growth and energy runs from the latter without feedback.

This study is therefore motivated by the need to explore the causal relation and the long run energy-economy relationship in Iran. The results show that both energy and growth have long run relationship but the former does not granger cause the latter. By implication, subsidy removal, rationing and other conservative demand management policies currently been pursued by the government of Iran to reform the energy sector are good steps in good direction. The observation from available evidence is that energy-economy link varies across countries, we therefore suggest that other countries proposing reform in their energy sector explore similar investigation.

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