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Energy Consumption and Real GDP in Iran

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ABSTRACT: As one of the most important production factors and one of the most urgent final products, energy has a special position in the growth and development of the country. This paper examines the causal relationship between Real GDP and energy consumption in various economic sectors including (household and commercial, industry, transportation and agriculture sectors) for Iran during 1967–2010 using the time series technique known as the Toda-Yamamoto method. Moreover, an error correction model is also estimated so that the results of these two methods are compared. We found a strong unidirectional causality from energy consumption in industry sector to real gross domestic product. Energy consumption in industry sector can observably promote the development of economy.

Keywords: energy consumption; real GDP; causality; Iran.
JEL Classifications: O40; Q41

1. Introduction

Iran is one of the leading members of OPEC (Organization of Petroleum Exporting Countries) and the Organization of Gas Exporting Countries (GECF). Energy resources in Iran consist of the fourth largest oil reserves and the second largest natural gas reserves in the world. In 2010, Iran was the third-largest exporter of crude oil globally after Saudi Arabia and Russia. Energy wastage in Iran amounts to six or seven billion dollars. The energy consumption in the country is extraordinarily higher than international standards. Iran is one of the most energy-intensive countries of the world with per capita energy consumption 15 times that of Japan and 10 times that of European Union. Also due to huge energy subsidies, Iran is one of the most energy inefficient countries of the world, with the energy intensity three times higher than global average and 2.5 times the Middle Eastern average (Wikipedia, 2012).

As one of the most important production factors and one of the most urgent final products, energy has a special position in the growth and development of the country. Given the close relations between energy consumption and real GDP in Iran, the determination of quality and quantity relationship between these two variables can be effective in helping to explain the energy sector policies.

A quick look at the past problems shows that there have always been great competitions over energy takeover at the global level, because national security and stability of the government systems are largely dependent upon access to these resources. Fortunately, by virtue of having diversified energy resources and reserves, Iran is now considered as one of the world's richest countries. These resources in Iran are provided for consumers with prices far lower than those in other countries and are more readily available; nonetheless, the amount of energy consumption and waste is much higher than that of industrialized countries. Any non-efficient use of energy can reduce limited reserves. The per capita primary energy supply during 1999-2006 increased from 13.5 barrels of crude oil equivalent to 20.4 barrels and the per capita final energy consumption during this period has increased from 10.3 barrels of crude oil equivalent to 12.53 barrels. The growth rates of both final energy consumption and GDP have reached by 10 percent and 8.4 percent, respectively. It means that the increase in energy consumption has not been in the direction of improving living conditions and increasing the welfare of society; conversely, it has been spent in an inappropriate and unsystematic manner, leading to the waste of energy in the production processes or other economic sectors (Energy Balances, 2006).

In this study we aimed to test relationship between real GDP and energy consumption in various economic sectors including (household and commercial, industry, transportation and agriculture sectors) for Iran.

The paper is organized as follows. In Section 2, we present a review of the literature. Section 3 presents data and econometric methodology and empirical results. Section 4 represents conclusions.

2. Literature Review

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. 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.

Over the past two decades, the relationship between energy consumption and economic growth has been widely discussed by many researchers around the world (see Ozturk, 2010 for a detailed survey on energy-growth nexus). In the industrial economic life of communities, energy plays a fundamental role; that is, once energy is available adequately and timely, economic development will also be possible. Mehrara (2007) investigated the causal relationship between per capita energy consumption and per capita GDP in oil exporting countries. He found strong unidirectional causality from economic growth to energy consumption. Chu and Chang (2012) studied applies bootstrap panel Granger causality to test whether energy consumption promotes economic growth using data fromG-6 countries. They find that there is one-way causality from economic growth to oil consumption only in the US, and that oil consumption does not Granger cause economic growth in G-6 countries except Germany and Japan. Yang (2000) found that there is unidirectional causality running from economic growth to oil consumption in Taiwan. Shengfeng et al. (2012) found unidirectional causality from electricity consumption to economic growth in China. Zhang-wei and Xun-gang (2012) analyzed the relationship between energy consumption and economic development based on the VAR model using temporal series of China from 1990 to 2009. They found a unidirectional causality from energy consumption to gross domestic product. Glasure and Lee (1997) investigated the causality between energy consumption and GDP for South Korea and Singapore. They found bidirectional causality between income and energy for both countries. Ang (2008) showed that output growth Granger causes energy consumption in Malaysia. Selim et al. (2010) analyzed dynamic causal relationship between electricity consumption and economic growth in the Romanian economy for the period of 2001 – 2010. Their results supported that causality runs from electricity consumption to economic growth in the case of Romania economy. Rashid and Kocaaslan (2013) examined the relation between energy consumption volatility and unpredictable variations in real GDP in the UK. Their results showed that the variability of energy consumption has a significant role to play in determining the behavior of GDP volatilities. Behboudi et al. (2010) examined the co-integration relationship between energy consumption and GDP in a panel of 78 selected developed and developing countries from 1970 to 2006. Based on their results, the existence of a co-integration relationship between GDP and energy consumption is confirmed both for developed and developing countries. Examples of this line of research include Masih and Masih (1996), Cheng and Lai (1997), Asafu-Adjaye (2000), Stern (2000), Hondroyiannis (2002), Paul and Bhattacharya (2004), Liu and Li (2007), Zhixin and Xin (2011), Mahadevan and Asafu-Adjaye (2007), Akinlo (2008), Chiou-Wei et al.(2008), Lee and Chang (2007), Bartleet and Gounder (2010), Ozturk et al. (2010), Odhiambo (2009), Balat (2008), Lau et al. (2011), Li et al. (2011), Abalaba and Abiodun Dada (2013), Soytas and Sari (2003), Ozturk and Acaravci (2010), Wolde-Rufael (2005), and Narayan and Smyth (2008) that mainly focus on the co-integrating relationship between energy consumption and economic growth.

In all the research strands, there are a limited number of examples that examine the above-considered nexuses in Iran. Amadeh et al. (2009) examined causality relation between energy consumption and economic growth in economy of Iran for the period 1971-2003. Their results show that there is a long run and short run unidirectional causality relationship from energy consumption to economic growth. Fallahi and Montazeri (2010) studied the effect of energy use on the growth of Iranian economy for the period 1973-2007. They showed that the energy use had a negative effect on the economic growth. Examples of this line of research in Iran include Arman and Zare (2005), Arman and Zare (2007), Arman et al. (2011), Mousavi et al. (2011) that mainly focus on the co-integrating relationship between economic growth and energy consumption.

3. Data, Econometric Methodology and Empirical Results

3.1. Data

The annual data of real gross domestic product(LGDP), Energy consumption in industry sector(LEIN), Energy consumption in transportation sector(LETR), Energy consumption in agriculture sector(LEAG), and Energy consumption in household sector(LEHO) are used for the period 1967-2010. Real GDP series, measured in billions of constant 1997 prices, are drawn from the national accounts of Iran. Energy consumption in various economic sectors of Iran was obtained from the statistical center of Iran. Figures 1-5 show the series in natural logarithm. All series have increased over time, though there have been some changes in their slope.

Figure 1. Time series plot of real GDP

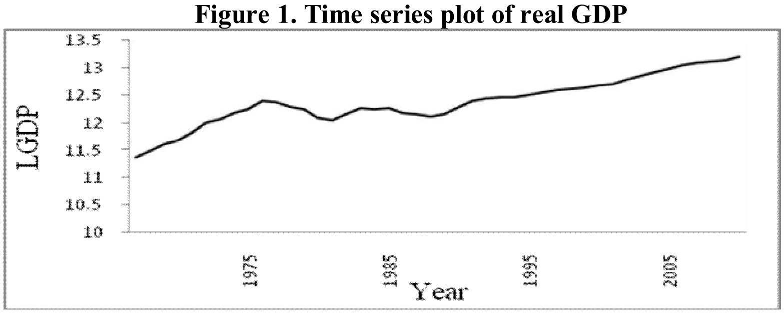


Figure 2. Time series plot of energy consumption in industry sector

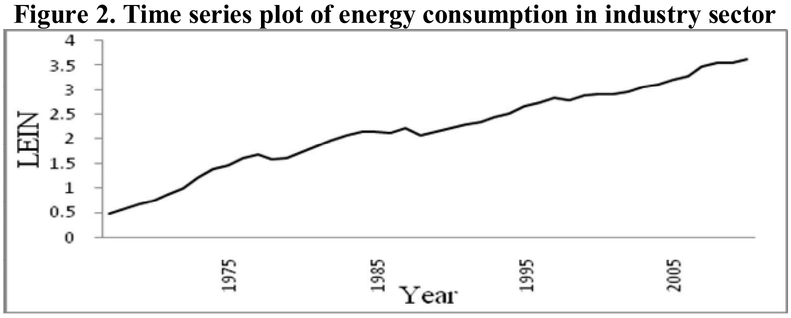


Figure 3. Time series plot of energy consumption in transportation sector

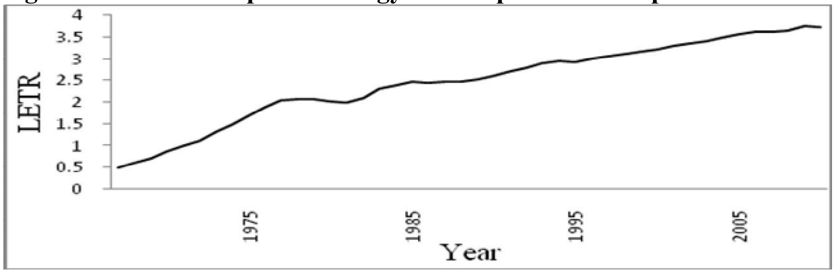


Figure 4. Time series plot of energy consumption in agriculture sector

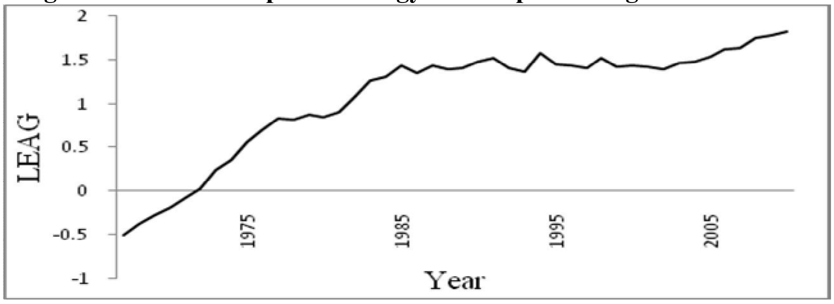
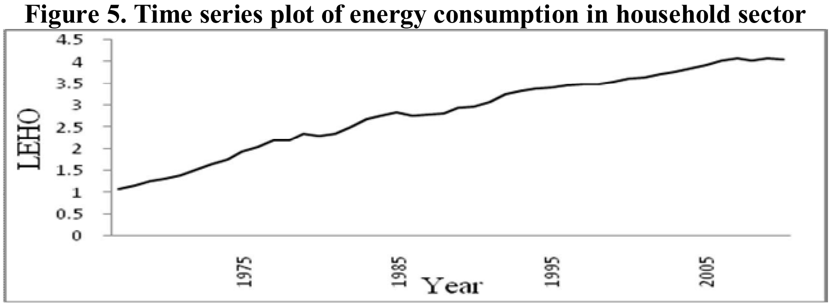


Figure 5. Time series plot of energy consumption in household sector



This study investigates the existence of causality among real GDP and energy consumption in Iran in various economic sectors including (household and commercial, industry, transportation and agriculture sectors) using the Toda and Yamamoto (1995) approach.

3.2. Unit root tests

Before proceeding TY process, unit root tests is required to obtain the maximal integration order of variables. This testing is necessary to avoid the possibility of spurious regression. The results of Augmented Dickey-Fuller (ADF) suggest that the energy consumption in transportation sector is stationary in level in the case of Intercept and trend, and the other variables are found to be integrated of order one (Table 1).

Table 1. Results of the Dickey-Fuller unit root test in levels and first differences*

Variables	Level		First differences	
	Intercept	Intercept and trend	Intercept	Intercept and trend
LGDP	-0.03(1)	-1.93(1)	-3.97(0)*	-4.20(0)*
LEIN	-0.44(0)	-2.52(0)	-5.82(0)*	-5.74(0)*
LETR	-2.01(3)	-4.71(2)*	-3.76(0)*	-4.18(2)*
LEAG	-3.07(0)*	-2.92(0)	-5.85(0)*	-6.18(0)*
LEHO	-2.41(0)	-2.36(0)	-5.30(0)*	-5.79(0)*

Note: The number in parentheses indicates the appropriate order of lag lengths determined via SIC.
*denotes statistically significant at 5% level.

The figures indicate that it is reasonable to assume one exogenous structural break in the year 1980. Therefore, one dummy variable is considered for years of war (1980-1987).

As regards the stationarity tests, it seems appropriate to account for structural breaks in the data series. As shown by Perron (1989), tests that do not account for structural breaks may falsely fail to reject the unit root null hypothesis when the data generating process is trend-stationary with a one-time break. Therefore, Perron's model B is applied in order to capture a change in the slope of LGDP, LEIN, LEHO and LEAG.

$$y_t = \mu^B + \theta^B Du_t + \beta^B t + \gamma^B DT_t + \alpha^B y_{t-1} + \sum_{i=1}^{k} c_i \ \Delta y_{t-i} + e_t \tag{1}$$

where y is the test variable, *DU* is a dummy variable having the value of 0 until the year of the structural break and 1 from the following year onwards, *DT* is a dummy taking the value of t for each year after the break and the value of 0 for all previous years, and t is an (0, σ2) innovation series.

Table 2. Perron unit root test results

Variables				
LEAG	0.95	1.59	-0.40	0.45
LEIN	1.63	0.83	2.14	-1.96
LGDP	3.92*	3.89*	-3.65**	-2.28
LEHO	2.16	0.65	-1.62	1.7

T = 44, λ= 0.3.
* and ** denote rejection of the unit root hypothesis at 5% and 10% levels, respectively.

The results of Perron's unit root test for nonstationary variables indicate that the unit root hypothesis is rejected at the 5% level and 10% only for LGDP (Table 2). Therefore, the results of the augmented Dickey-Fuller and Perron tests on each time series reveals that LEAG, LEIN and LEHO exhibit a unit root, while other variables are stationary.

3.3. Econometric methodology

3.3.1. Toda and Yamamoto methodology

Toda and Yamamoto causality test does not require knowledge of the integration and co-integration properties of the system. This test involves estimation of an augmented VAR($k + d_{\max}$) model where k is the optimal lag length in the original VAR system, and $d_{\max}$ is the maximal order of integration of the variables in the VAR system. The procedure employs a modified Wald (MWald) test for restrictions on the parameters of the VAR (k), where k is the lag length of system. The Wald statistic follows an asymptotic Chi-square distribution with degrees of freedom equal to the number of "zero restrictions". Considering the augmented VAR (2)

$$v_t = \alpha + \beta v_{t-1} + \gamma v_{t-2} + e_{vt} \tag{2}$$

where $v_t = (x_1, x_2)'$, *α* is a (2×1) vector of constants, *β*, γ are (2×2) coefficient matrices, and e_{vt} denotes white noise residuals. We apply the TY procedure to examine the real GDP-energy consumption nexus in Iran.

Given that all series are not integrated of the same order, so the TY procedure to test for Granger causality appears to be the most appropriate method. We have determined the maximum order of integration (d) to be 1. The optimal lag length (k) based on Schwarz information criterion (SC) and adjusted LR test statistic is 1. We then estimate a system of VAR in levels with total lags of 2, employing the seemingly unrelated regression (SURE) framework as follows:

$$\begin{bmatrix} LGDP_t \\ LEIN_t \end{bmatrix} = \beta_0 + \beta_1 + \begin{bmatrix} LGDP_{t-1} \\ LEIN_{t-1} \end{bmatrix} + \beta_2 \begin{bmatrix} LGDP_{t-2} \\ LEIN_{t-2} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{3}$$

$$\begin{bmatrix} LGDP_{t} \\ LETR_{tt} \end{bmatrix} = \beta_0 + \beta_1 + \begin{bmatrix} LGDP_{t-1} \\ LETR_{t-1} \end{bmatrix} + \beta_2 \begin{bmatrix} LGDP_{t-2} \\ LETR_{t-2} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} LGDP_{t} \\ LEAG_{t} \end{bmatrix} = \beta_0 + \beta_1 + \begin{bmatrix} LGDP_{t-1} \\ LEAG_{t-1} \end{bmatrix} + \beta_2 \begin{bmatrix} LGDP_{t-2} \\ LEAG_{t-2} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} LGDP_{t} \\ LEHO_{t} \end{bmatrix} = \beta_0 + \beta_1 + \begin{bmatrix} LGDP_{t-1} \\ LEHO_{t-1} \end{bmatrix} + \beta_2 \begin{bmatrix} LGDP_{t-2} \\ LEHO_{t-2} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (6)$$

The empirical results of Granger Causality test based on Toda and Yamamoto methodology is estimated through MWALD test and reported in Table 3.

Table 3. Granger causality test results

Equation	LGDP	Economic sectors
Model 1: real GDP, energy consumption in industry sector		
	LGDP	LEIN
LGDP	–	2.75(0.09)**
LEIN	1.41(0.23)	–
Model 2: real GDP, energy consumption in transportation sector		
	LGDP	LETR
LGDP	–	0.04(0.83)
LETR	9.08(0.003)*	–
Model 3: real GDP, energy consumption in agriculture sector		
	LGDP	LEAG
LGDP	–	0.004(0.94)
LEAG	3.52 (0.06)**	–
Model 4: real GDP, energy consumption in household sector		
	LGDP	LEHO
LGDP	–	1.48(0.22)
LEHO	2.05(0.15)	–

* and ** represent significance at the 5% and 10%,Significance implies that the column variable Granger causes the row variable.

The test results in Table 3 suggest that the null hypothesis of Granger non-causality from energy consumption in industry sector to real GDP can be rejected at the 10% significance level. On the other hand, the hypothesis that real GDP do not Granger cause energy consumption in industry sector cannot be rejected. Therefore, we find evidence that there is a unidirectional causality from energy consumption in industry sector to real GDP. That is, an increase in energy use in this sector will bring about an increase in real GDP, but not vice versa. This implies that the energy consumption in industry sector can be used as a leading indicator for future real GDP in Iran. Another important result is that real GDP Granger causes the energy consumption in transportation and agricultural sectors in the long run but the inverse is not true in Iran. That is, an increase in real GDP brings about an increase in energy consumption in these sectors. As seen in the Table 3, it is clear that there is no Granger causality between energy consumption in household sector and real GDP.

3.3.2. Error correction method

Before applying the error correction method, the equilibrium relationship between the variables is considered. In this section we estimate a long-run equilibrium relationship between the energy consumption in various sectors of the economy and real GDP using Auto Regressive Distributed Lag. Thus, equations 7 and 8 are estimated.

$$\Delta LGDP_t = a_1 + \sum_{i=1}^{k} b_{i1}\Delta LGDP_{t-i} + \sum_{i=1}^{k} c_{i1}\Delta LX_{t-i} + \sigma_1 LGDP_{t-1} + \sigma_2 X_{t-1} + \varepsilon_{1t} \quad (7)$$

$$\Delta LX_t = a_2 + \sum_{i=1}^{k} b_{i2}\Delta LGDP_{t-i} + \sum_{i=1}^{k} c_{i2}\Delta LX_{t-i} + \omega_1 LGDP_{t-1} + \omega_2 X_{t-1} + \varepsilon_{2t} \quad (8)$$

where LGDP is real gross domestic product and LX is the energy consumption in various economic sectors including (household, industry, transportation and agriculture sectors). The F-test is used for testing the existence of long-run relationship. When long-run relationship exists, F-test indicates which variable should be normalized. The null hypothesis for no co-integration among variables against the alternative hypothesis is below:

$$\begin{cases} H_0 : \sigma_1 = \sigma_2 = 0 \\ H_1 : \sigma_1 \neq \sigma_2 \neq 0 \end{cases}, \quad \begin{cases} H_0 : \omega_1 = \omega_2 = 0 \\ H_1 : \omega_1 \neq \omega_2 \neq 0 \end{cases} \quad (9)$$

The co-integration test under the bonds framework involves the comparison of the F-statistics against the critical values, which are generated for specific sample sizes. The calculated F-statistics are reported in Table 4.

Table 4. Bound Testing Results

Normalized Model	Calculated F-Statistics	
F_{LGDP} (LGDP| LEIN)	5.19**	
F_{LEIN} (LEIN| LGDP)	1.30	
F_{LGDP} (LGDP| LETR)	2.44	
F_{LETR} (LETR| LGDP)	4.89**	
F_{LGDP} (LGDP| LEAG)	1.78	
F_{LEAG} (LEAG| LGDP)	8.01*	
F_{LGDP} (LGDP| LEHO)	2.81	
F_{LEHO} (LEHO| LGDP)	2.981	
Critical value bounds for the wald F-statistic		
Level of significance	Lower bound value I(0)	Upper bound value I(1)
1%	7.05	7.81
5%	4.93	5.76
10%	4.04	4.78

* and ** represent significance at the 5% and 10% levels .
Note:Critical values are extracted from Pesaran et al. (2001)

Asafu-Adjaye(2000) interpreted the weak Granger causality as 'short run' causality in the sense that the dependent variable responds only to short-term shocks to the stochastic environment.

The existence of a long-run relationship among real GDP and energy consumption in industry, transportation and agricultural sectors suggests that there must be Granger causality at least in one direction, but it does not indicate the direction of temporal causality between the variables. We examine both short-run and long-run Granger causality in this section within ECM framework. Table 5 reveals results of the short and long run Granger causality.

The short-run causal effect is obtained by the F-test of the lagged LEIN, LETR, and LEAG variables, while the t-statistics on the coefficient of the lagged error-correction term in equations (10), (11), and (12) indicates the significance of the long-run causal effect, respectively .

$$DLGDP = \alpha + \sum_{i=1}^{k} \beta_i DLGDP_{t-i} + \sum_{i=1}^{l} \gamma_i DLEIN_{t-i} + \theta ECT_{t-1} + \varepsilon_t \tag{10}$$

$$DLETR = \alpha + \sum_{i=1}^{k} \beta_i DLGDP_{t-i} + \sum_{i=1}^{l} \gamma_i DLETR_{t-i} + \theta ECT_{t-1} + \varepsilon_t \tag{11}$$

$$DLEAG = \alpha + \sum_{i=1}^{k} \beta_i DLGDP_{t-i} + \sum_{i=1}^{l} \gamma_i DLEAG_{t-i} + \theta ECT_{t-1} + \varepsilon_t \tag{12}$$

where D is a difference operator; ECT represents error-correction term derived from the long-run co-integrating relationship; and the ε_t is error-correction terms assumed to be uncorrelated and random with mean zero. The coefficient of the ECT, θ, represents the deviation of the dependent variable from the long-run equilibrium. We can test the long-run and short-run causality between energy consumption and real GDP Using the VECM.

The results from the short-run and long-run dynamics based on the Engle-Granger (1987) error correction model are presented in Table 5.

Table 5. Granger causality test results based on the ECM

Dependent variable	Short-run causality F-statistics	long-run causality t-statistics ECT(-1)	Joint causality F-statistics
Model 1: real GDP, energy consumption in industry sector			
	DLEIN		
DLGDP	7.87(0.005)*	-3.5602(0.001)*	17.55(0.000)*
Model 2: real GDP, energy consumption in transportation sector			
	DLGDP		
DLTR	27.68(0.000)*	-2.61(0.013)**	38.66(0.000)*
Model 3: real GDP, energy consumption in agriculture sector			
	DLGDP		
DLEAG	8.36(0.004)*	-3.77(0.001)*	23.44(0.000)*

*and ** respectively show the significance in 1% and 5% levels.
Notes: The number inside the parenthesis represents t ratios.

In the short-run, energy consumption in industry sector is significant at 1%. This implies that energy consumption in industry sector Granger causes real GDP in the short-run. To determine whether energy consumption in industry sector causes real GDP or visa vice in the long-run, we look at the coefficient on the ECT in equation 10. The ECM analysis results showed unidirectional causality from energy consumption in industry sector to real GDP. The significance of this coefficient implies the presence of long-run causality among energy consumption and real GDP. In the long-run, the coefficient on the lagged error correction term (- 0.23) is significant with the correct sign at 1%, which confirms the results from the bounds test for co-integration. Thus, energy consumption in industry sector causes real GDP both in the long-run and in the short-run.

The coefficient of DLGDP (-1) is significant for both equations 11 and 12. Therefore, there is short-run causality from real GDP to energy consumption in agriculture and transportation sectors. The coefficients of the ECT are significant in the equations 11 and 12 which indicate that long-run causality runs from real GDP to energy consumption in agriculture and transportation sectors.

It is also desirable to check whether the two sources of causation are jointly significant, in order to test Granger causality. This is referred to as a strong Granger causality test. The joint test indicates which variable(s) bear the burden of short run adjustment to re-establish long run equilibrium, following a shock to the system. A test of these restrictions can be done using F-tests (Asafu-Adjaye, 2000).

4. Conclusion

As the driving force of most manufacturing and services activities, energy has a special place in economic development. In this study we aimed to test relationship between real GDP and energy consumption in various economic sectors including (household and commercial, industry, transportation and agriculture sectors) for Iran during 1967–2010. We examined whether there is casual relationship between energy consumption and real GDP. This paper applied Toda and Yamamoto and error-correction models to test causal relation between real GDP and energy consumption in Iran. Our results suggest that energy consumption in industry sector Granger causes real GDP in the long run and short run, but not vice versa. Moreover, the results showed that there is a unidirectional long run and short-run causal effect running from real GDP to energy consumption in transportation and agricultural sectors. According to test results, there is no Granger causality between energy consumption in household sector and real GDP.

Therefore, the increase in energy consumption in industry sector is driving economic growth. Due to the lack of Granger causality between energy consumption in household sector and real GDP, can be concluded that energy consumption in this sector has not driven economic growth and the policy of economizing in energy consumption in this section can be used without slowing economic growth.

The results suggest that energy consumption in industry sector is an important element determining economic growth in Iran. Therefore, increasing energy consumption, especially in the industry sector, seems to be an active way to increase real GDP and the government of Iran can pursue conservative energy policy in the long run without impeding economic growth.

Finally, the correct attitude of domestic industries toward the issue of optimizing energy consumption not only ensures the profitability of these industries, but also provides new financial resources; these, in turn, can be a source of new investments by adopting scientific methods of management and at the same time prevent the waste of national resources at national level.

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