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15 April 2017

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Abstract

The relationship between energy consumption and economic growth has undergone extensive investigation and the empirical evidences are mixed ranging from bi- and uni-directional causality to no causality. These conflicts may be due to the fact that countries have different energy consumption patterns and various sources of energy. This paper is the first study on causal relationships between industrial energy consumption and real regional economic growth based on the panel data for 31 provinces in Iran over the period 2004–2014. We employ the GMM-SYS approach for the estimation of the panel vector autoregression (PVAR) model. Afterwards, by doing an in-depth analysis of energy consumption data, the purpose of this paper is to contribute to the debate by examining the causality in various forms of energy consumption (Diesel fuel, Natural Gas, Gasoline, Kerosene, LPG&LNG, Petroleum and Electricity). We discover: (a) totally, there is bidirectional causality between industrial energy consumption and regional growth; (b) regional growth leads to Gasoline consumption; (c) Natural gas consumption leads to regional growth; (d) there exists no causal relationship between regional growth and Diesel fuel, Kerosene, LPG&LNG and Petroleum consumption; (e) there is also bidirectional causality between industrial electricity consumption and regional economic growth. Taken together, the results of this study involve valuable information for policy makers at regional level.

Keywords: Energy consumption, GDP PerCapita, Manufacturing sector, Causality, Panel VAR, Iran.

JEL codes: O13, R11, L60, C33, Q43, N55.

1. Introduction

Since the seminal work of Kraft and Kraft (1978), examining the causal relationship between economic growth and energy consumption has been subject to numerous empirical studies which tried to find the direction of causality between energy consumption and economic growth using different econometric techniques. However, the results of empirical studies are mixed ranging from bi- and uni-directional causality to no causality for both developed and developing countries. These conflicting results may be due to the fact that countries have different energy consumption patterns and various sources of energy. Therefore, different sources of energy may have varying impacts on the output of an economy (Soytas and Sari, 2007). For example, Erol and Yu(1987), Chontanawat et al.(2006), Halicioglu(2007), Yoo(2006), Lee(2006), Ghosh(2002), Cheng and Lai(1997) and Masih and Masih(1996) for the cases of Germany, Canada, Turkey, Thailand, France, India, Taiwan and Indonesia, respectively, find no causality running from energy consumption to economic growth. While Soytas and Sari(2003), Lee(2006), Asafu-Adjaye(2000), Masih and Masih(1998), Soytas and Sari(2003), Masih and Masih(1996), Lee and Chang(2005) and Fatai et al.(2004), for the same countries, find uni-directional causality from energy consumption to GDP growth. Uni-directional causality from energy consumption to economic growth also were found in the cases of U.S.(Stern, 1993; 2000), Philippines(Yu and Choi, 1985), Singapore(Glasure and Lee, 1997), Sri Lanka(Masih and Masih, 1998; Morimoto and Hope, 2004), China(Shiu and Lam, 2004), Belgium, Netherland and Switzerland(Lee, 2006). On the other hand, a reverse uni-directional causality running from economic growth to energy consumption was found for the cases of South Korea (Yu and Choi, 1985; Oh and Lee, 2004; Soytas and Sari, 2003), Italy (Erol and Yu, 1987; Lee, 2006), Pakistan(Aqeel and Butt, 2001), Malawi(Jumbe, 2004), Bangladesh(Mozumdar and Marathe, 2007; Ashgar, 2008), Sudan and Zimbabwe (Akinlo, 2008). In some countries, such as U.S.(Yu and Choi, 1985; Lee,2006), Canada(Ghali and El-Sakka,2004), Poland and U.K(Yu and Choi, 1985), Sweden(Lee,2006), China(He et al.,2007), India(Paul and Bhattacharya, 2004), South Korea(Oh and Lee, 2004), Malaysia and Singapore(Yoo, 2006), Argentina(Soytas and Sari,2003), Philippines(Asafu-Adjaye, 2000; Fatai et al.,2006), Pakistan(Masih and Masih,1996), Taiwan(Hwang and Gum, 1992), Nepal(Dhungel, 2008) and some African countries(Ebonon, 1996; Akinlo, 2008), bi-directional causality between economic growth and energy consumption were found, and finally, no causality were found in the cases of U.S.(Akarca and Long, 1980; Yu and Hwang, 1984; Yu and Jin, 1992), U.K(Erol and Yu, 1987; Lee, 2006), Canada and France(Erol and Yu, 1987), Germany(Lee, 2006), Turkey(Altinay and Karagol, 2004), Korea(Glasure and Lee, 1997), Taiwan(Yang, 2000), Malaysia, Philippines and Singapore(Masih and Masih, 1996), and some African countries (Akinlo, 2008).[1] Therefore, in an international context, the empirical results on the energy-growth nexus have been mixed and conflicting. Depending on the different countries

[1] The review of related literature on the causality between energy consumption and economic growth is not intended in this paper, since there is compact review pointed out in some other studies (e.g. Chontanawat et al., 2006; Huang et al., 2008 and Akkemik and Göksal, 2012).

and time periods, the econometric methods, the variables included in the model and the structure and types of energy used, direction of causal relationship between energy consumption and economic growth vary among studies (Mandal and Madheswaran, 2010). The conflicting evidences from empirical studies cited above have major energy policy implications especially in conservation. As Asafu-Adjaye(2000) indicates, if there is a uni-directional relationship from energy consumption to GDP growth, energy conservation may cause to a decrease in country income. But in inverse status, energy conservation would not an adverse effect on GDP growth. On the other hand, no causal relationship between energy consumption and GDP growth indicates that, reducing energy use may not affect economic growth, and energy conservation policies may not affect economic growth (Wolde-Rufael, 2004).

The purpose of this paper is to examine the existence and direction of the causal relationship between industrial energy consumption and regional economic growth for a panel made up of 31 Iranian provinces for the period from 2004 to 2014. This paper adds three major contributions to the existing literature. First, this is one of the very first paper to investigate the relationship between industrial energy consumption and regional economic growth for the case of Iranian provinces.[2] Thus, an advantage of our framework is that it allows us to analyze regional-level data. Second, as noticed before, the causal relationship between energy consumption and economic growth has investigated in the most existing studies at the national or aggregate-level data and few empirical studies investigate on the energy-growth issue with focusing on industrial sector. Therefore, due to great differences in energy use observed across industries, it would be valuable to investigate the energy-growth nexus at the industrial level and may provide new insights. Third, to reach to robust energy conservation policy implications, we test the relationship between various forms of industrial energy consumption (Diesel fuel, Natural Gas, Gasoline, Kerosene, LPG&LNG, Petroleum and Electricity) and economic growth by focusing on regional level data. The results of this study may have important implications for both regional policy makers and industries ownerships. Based on our results, the amount of natural gas and electricity consumption improve the manufacturing sector's contribution to the regional growth in Iran. If these types of energy appear to be significant in explaining regional growth, then manufacturing industries should attention to expanding generation capacity and/or using advances technologies with a more efficient usage of natural gas and electricity.

The rest of the paper is structured as follows. Data construction, sources and summary descriptive are explained in Section 2. Section 3 outlines the methodology. The empirical evidences are presented in Section 4. Summary and conclusion remarks are given in the final section.

[2] In fact, to the best of our knowledge, this paper is the first attempt to examine the causal relationship between industrial energy consumption and economic growth at the regional-level data in Iran.

2. Data

This section presents a brief overview of the data as a prelude to the estimation of the panel vector autoregressive (PVAR) model. The annual data on the variables for 31 Iranian provinces over the period 2004–2014 are collected and used in our empirical study. The source of the data on Regional GDP PerCapita (thousand Rials) and Industrial energy consumption (barrel of oil equivalent) is the Iranian Statistical Center (ISC). The data on energy consumption for each province are estimated from the industrial energy consumption breakdown by each fuel category. The data on nominal GDP PerCapita were collected from the regional information of ISC and deflated to real. The real GDP PerCapita was adopted as the indicator for regional economic growth and all variables are converted into their natural logarithms for use. Table (1) shows the summary statistics of the variables (in nature logarithm) for the selected years. Stacked column charts display the comparison of the percentage each part of the category brings to the whole category. We can understand that Natural gas has the largest share of energy consumption in seven different types of energy and its' consumption enhanced from 88 million BOE to 201 million BOE during 2004 to 2014. Moreover, it reveals that the electricity consumption has an upward trend, however, other fuels experience decreasing trend through mentioned period.

Figure 1. Energy consumption by fuel types in Iranian manufacturing sector (2004-14)[3]

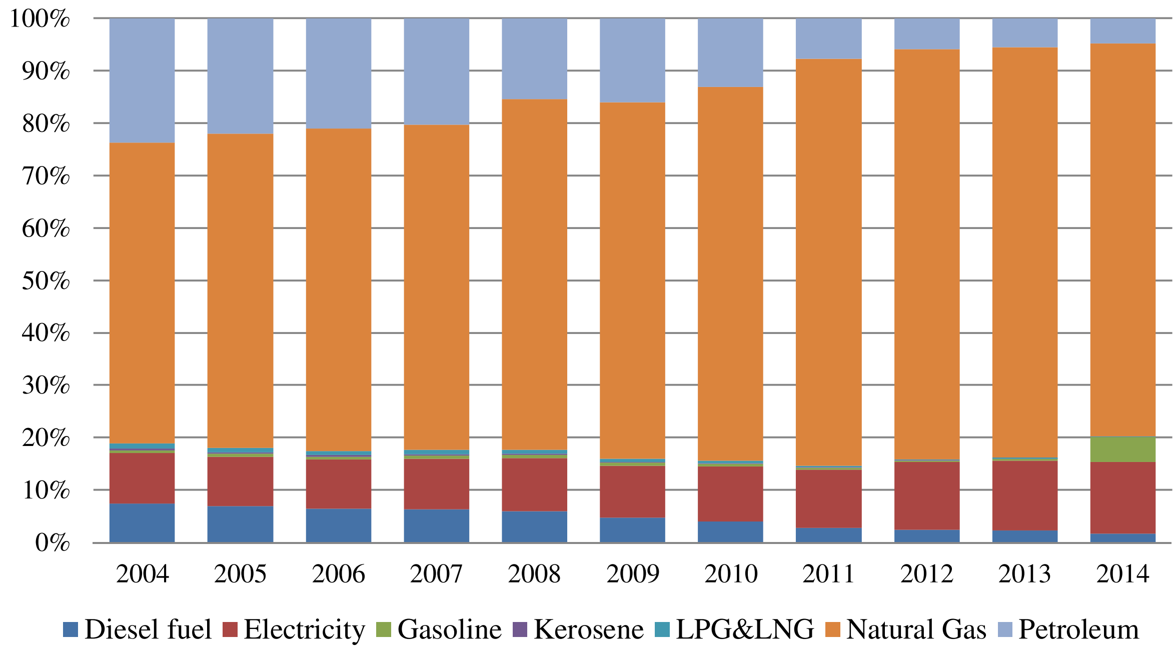


Table 1. Summary of descriptive statistics

Variable	Mean	Std. Dev.	Skewness
Total Energy	14.93072	1.266279	-0.07756
Diesel fuel	11.99235	1.123049	-0.20743

[3] Authors' calculation based on ISC database.

Table 1. Summary of descriptive statistics

Variable	Mean	Std. Dev.	Skewness
Natural Gas	13.71003	3.132793	-2.65234
Gasoline	9.569605	1.21213	-0.02736
Kerosene	8.201952	1.41724	-0.11619
LPG&LNG	9.076704	1.744261	-0.08588
Petroleum	12.94399	1.362482	-0.72501
Electricity	12.57827	1.429806	-0.08846
GDP PerCapita	9.972464	0.501402	0.943796

Note: number of observations =335.

Appendix (1) shows the Annual changes in GDP PerCapita and Industrial energy consumption PerCapita by fuel types (2004=100). As the figure shows, long-run relationship between some types of energy (total, electricity and natural gas) and regional economic growth is likely to be present, since all the series increased continuously, while, some other fuels (Diesel fuel, Gasoline, Kerosene, LPG&LNG and Petroleum) tend to decrease during the sample period.

3. Methodology

We analyze the pairwise causal relationship between industrial energy consumption and GDP PerCapita as a measure of economic growth across 31 provinces of Iran from 2004 to 2014. For this purpose, initially, panel unit root tests are run for all variables in logarithmic form. Then, Cointegration test is established for integrated variables in the same degree. Finally, Granger causality test is used. In this paper, we also employ a panel vector auto-regression (PVAR) methodology that joins the panel data approach with the traditional VAR method (Love and Zicchino, 2006). There are three major advantages of the PVAR method: firstly, this method makes a flexible framework that combines the traditional VAR approach with panel data and increases the efficiency and the power of analysis while capturing both temporal and contemporaneous relationship among variables (Mishkin and Schmidt-Hebbel, 2007). Secondly, the PVAR method can takes into account complex relationship and identifies dynamics responses of variables following exogenous shocks using both impulse response functions and variance decompositions. In that way, it provides a systematic way of capturing the rich dynamic structures and comovements between different variables over time (Omojolaibi et al., 2014). Thirdly, traditional VAR approach treats all the variables in the system as endogenous, while the PVAR technique allows for unobserved individual heterogeneity and can tackle the data limitation problems (Kandil et al., 2015). The following sections reveal the results presented in Tables 2 through 7.

4. Empirical Results

4.1. Panel Unit Root Tests

Several procedures exist for testing the presence of unit roots in panel data, notably the individual series unit roots tests (Augmented Dickey Fuller (ADF) and Phillips and Perron, among others) which are known to have low power against the alternative of stationarity of the series, particularly for small samples. Panel data provide a larger number of point data, increasing the degrees of freedom and reducing the collinearity between the regressors. Therefore, panel data allow for more powerful statistical tests and the test statistics asymptotically follow a normal distribution instead of unconventional distributions.

In this paper, we choose the two panel unit root tests, namely Levin–Lin–Chu (LLC) (2002) and Im–Pesaran–Shin (IPS) (2003) tests are used to enhance the robustness of the results. The LLC test takes into account the heterogeneity of various sections, but it has low power in small samples because of the serial correlation, which cannot be completely eliminated. The IPS test considers the heterogeneity among the sections and also eliminates the serial correlation, thus, it has a strong ability of testing in small samples.Therefore, the IPS test is less restrictive and more powerful compared to the traditional ADF test (Lu, 2017). The null hypothesis of the above two unit root tests is that the panel contains unit root (i.e. the variables are non-stationary), and the alternative hypothesis is that no unit root exists in the series (i.e. the variables are stationary) (Wang, 2011). The basic model for the IPS panel unit root test is as follows:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t} + \sum_{j=1}^{\rho} \varphi_{ij}\, \Delta y_{i,t-j} + \varepsilon_{i,t} \qquad (1$$

Where the subscripts i=1,2,…,N and t=1,2,…,T refer to individual provinces and the time period. Also, $y_{i,t}$ is a vector of variables in the model, α_i is the individual fixed effect, and ρ is the uncorrelated residuals over time. The null hypothesis means that for all i, $\rho_i = 0$ and the alternative hypothesis means that $\rho_i < 0$ for some i=1,2,…,N and $\rho_i = 0$ for i=N_1+1, …, N (Lu, 2017).

Levin et al. (2002) generalized the individual unit root test to panels with heterogeneous serially correlated errors, fixed effects and individual deterministic trends (Hamit-Hggar, 2012).

This test imposes homogeneity on the autoregressive coefficient that indicates the presence or absence of unit root problem, while the intercept and the trend can vary across individual series (Kandil et al., 2015). However, IPS proposed a panel unit root test that allows for a heterogeneous autoregressive coefficient under the alternative hypothesis (Hamit-Hggar, 2012). The general equation of the LLC test, is as follows:

$$\Delta y_{i,t} = \gamma_{0i} + \rho . y_{i,t-1} + \sum_{j=1}^{p_i} \gamma_{1i} \,. \Delta y_{i,t-1} + \mu_{i,t} \qquad (2$$

Where γ_{0i} is the intercept term that varies across cross-sectional units, ρ is the homogenous auto-regressive coefficient, p_i is the lag order, and $\mu_{i,t}$ is the error term assumed to be independent across panel regions and follow a stationary ARMA process for each cross-sectional (Kandil et al., 2015). In this test, the null hypothesis means that for all i, $\rho_i = \rho = 0$ and the alternative hypothesis means that $\rho_i = \rho < 0$.

The results of the LLC and IPS tests are presented in Table (2). As the results show, the hypothesis of presence of unit root for the variables are not rejected at level I (0) at none and intercept; however, the null hypothesis is rejected for all variables at level I (0) at intercept with trend.

Table 2. LLC and IPS panel unit root tests

Variables	At level		
	None	Intercept& No Trend	Intercept & Trend
LLC test (null: unit root)			
Total Energy	4.25	-6.66[a]	-10.50[a]
Diesel fuel	-6.62[a]	0.03	-5.93[a]
Natural Gas	5.32	-6.27[a]	-10.53[a]
Gasoline	-4.21[a]	-1.49[b]	-8.24[a]
Kerosene	-5.81[a]	-0.87	-11.20[a]
LPG&LNG	-3.17[a]	-5.36[a]	-11.46[a]
Petroleum	-4.91[a]	-3.84[a]	-9.18[a]
Electricity	6.83	-7.88[a]	-15.06[a]
GDP PerCap	5.48	-11.25[a]	-11.36[a]
IPS test (null: unit root)			
Total Energy	N/A	-2.82[a]	-2.34[a]
Diesel fuel	N/A	2.44	-0.15
Natural Gas	N/A	-1.67[b]	-2.22[b]
Gasoline	N/A	0.12	-1.63[b]
Kerosene	N/A	1.27	-1.94[b]
LPG&LNG	N/A	-2.31[b]	-2.37[a]
Petroleum	N/A	-0.99	-1.70[b]
Electricity	N/A	-1.25	-3.69[a]
GDP PerCap	N/A	-5.15[a]	-2.27[a]

Note 1: [a] Indicates rejection of the null hypothesis of non-stationary at the 1% significance level.
Note 2: [b] Indicates rejection of the null hypothesis of non-stationary at the 10% significance level.
Note 3: N/A means not available.

4.2. Panel Cointegration Tests

It can be seen from Table (2) that all series are stationary at level, which meets the requirements of the Cointegration test. Consequently, we use the panel Cointegration to test whether there is a long-run relationship between the variables. To test for Cointegration among the variables, we employed the heterogeneous panel Cointegration test proposed by Pedroni (1999, 2004) because of its' popularity. The Pedroni Cointegration tests are composed ofthe panel Cointegration tests (within-dimension) that include four statistics, namely, panel *v*-statistic, panel *rho*-statistic, panel PP-statistic, and panel ADF-statistic, and the groups mean panel Cointegration tests (between-dimension) that include three statistics: group *rho*-statistic, group PP-statistic, and group ADF-statistic. All the tests are distributed asymptotically as standard normal. The variables are cointegrated if the statistics reject the null hypothesis of no Cointegration. The general form of panel Cointegration is as follows:

$$y_{i,t} = \alpha_i + \theta_i . t + \beta_i^k . x_{i,t}^k + \varepsilon_{i,t} \qquad (3$$

Where i=1,…,N; t=1,…,T and $y_{i,t}$ and $x_{i,t}$ are the observable variables with dimension of $(N * T) \times 1$ and $(N * T) \times m$. In addition, k indicates the number of independent variables and $\varepsilon_{i,t}$ is the error term with I(0) process.

The results of our Cointegration analysis between industrial energy consumption and regional economic growth are reported in Table (3), which indicate that most of the statistics admit the null hypothesis. In fact, most statistics to test panel data Cointegration conclude for the absence of a long run relationship between energy consumption and regional GDP PerCapita. Thus, we proceed to the estimation of the panel vector autoregressive model.

Table 3. Panel Cointegration tests

Panel (within dimension)			**Group (between dimension)**		
Statistic	Value	Prob	Statistic	Value	Prob
Panel *v*-stat	-1.36	0.913			
Panel rho-stat	1.04	0.851	Group rho-stat	2.38	0.991
Panel PP-stat	-1.07	0.140	Group PP-stat	-3.67	0.000[a]
Panel ADF-stat	-0.35	0.362	Group ADF-stat	-1.43	0.075

Note 1: Statistics are asymptotically distributed as normal.

Note 2: [a] Rejection of the null hypothesis of no Cointegration at 1% significant level.

4.3. Panel Granger Causality Tests

A variable is said to be Granger-caused by another variable if including the second variable in the information set will improve the forecast of the first variable. The validity of causal test was conditional upon testing the unit root and Cointegration among the variables. It is well-known that pre-tests for unit root and Cointegration might suffer from size distortions, which often imply the use of an inaccurate model for the non-causality test (Clarke and Mirza, 2006). Toda and Yamamoto (1995), based on augmented VAR modeling, introduced a modified Wald (MWALD) test statistic that asymptotically has a chi-square (χ^2) distribution irrespective of the order of integration or cointegration properties of the variables. This approach fits a standard vector auto-regression model on levels of the variables (not on their first differences). Therefore, we utilize a causality procedure suggested by TY. To undertake the TY version of the Granger non-causality test, we estimate the following system of equations:

$$GDPPC_{it} = \alpha_1 + \sum_{j=1}^{m+1} \beta_{1j} GDPPC_{i,t-j} + \sum_{j=1}^{m+1} \gamma_{1j} EC_{i,t-j} + \eta_{1i} + \mu_{1it} \quad (4$$

$$EC_{it} = \alpha_2 + \sum_{j=1}^{m+1} \beta_{2j} GDPPC_{i,t-j} + \sum_{j=1}^{m+1} \gamma_{2j} EC_{i,t-j} + \eta_{2i} + \mu_{2it} \quad (5$$

Where η_{1i} and η_{2i} are region-specific effects for the i^{th} individual in the panel and μ_{1it} and μ_{2it} are the disturbance terms. Moreover, the subscript i=1,…,*N* denotes the region, while the t=1,…,*T* denotes the time period.

The next step is to pick optimal lag order. One of the most successful criteria according to the simulation results presented in the literature is Schwarz' Bayesian Information Criterion (BIC) which is displayed in Table (4). According to the BIC lag selection criteria, the number of lags was determined as one.

Table 4. Optimal lag selection

Variable	**Lag(1)**	**Lag(2)**	**Lag(3)**
Total Energy	-39.44*	-23.87	-18.69
Diesel fuel	-45.07*	-26.50	-15.93
Natural Gas	-38.98*	-27.00	-15.35
Gasoline	-42.98*	-25.40	-17.02
Kerosene	-50.95*	-33.82	-19.14
LPG&LNG	-37.50*	-26.25	-16.10
Petroleum	-43.17*	-23.50	-11.30
Electricity	-39.18*	-23.40	-16.10

Note: Optimal lag for all variables is one, which selected by Modified Schwarz' Bayesian Information Criterion (MBIC).

Table (5) presents the results from the panel Granger causality tests based on the PVAR method. With regard to the full panel, industrial energy consumption (EC) granger causes real GDP PerCapita (GDPPC), and real GDP PerCapita granger causes industrial energy consumption, which means the existence of bi-directional causal relationship running from industrial energy consumption to real GDP PerCapita. This implies that industrial energy consumption and regional economic growth are interconnected and may very well serve as complements to each other, which also indicates that the regional growth of Iran is energy dependent. This in turn suggests that the policy regarding energy conservation should be considered carefully. This finding is also supported by the results of the studies of Chen et al. (2007), Lee and Chang (2007), Mahadevan and Asafu-Adjaye (2007) and Ozturk et al. (2010).

Table 5. Granger non-causality test

From	To	Modified WALD	P-value	Causality
GDP PerCapita	Energy Consumption	13.03	0.000[a]	GDPPC → EC
Energy Consumption	GDP PerCapita	7.91	0.005[a]	EC → GDPPC

Note 1: GDPPC → EC denotes causality running from GDP PerCapita to industrial total energy consumption, and EC → GDPPC denotes causality running from industrial total energy consumption to GDP PerCapita.
Note 2: [a] Rejection of the null hypothesis of no causality at 1% significant level.

Furthermore, the Granger causality results from different fuel types reported in Table (6). The results indicate bi-directional causality between industrial electricity consumption and regional growth. The majority of the individual Granger causality results (Diesel fuel, Kerosene, LPG&LNG and Petroleum) show that these types of fuel does not support the findings obtained from the full panel, due to the fact that each one have a negligible share in total industrial energy consumption. In particular, there is a uni-directional causality running from GDP PerCapita to gasoline and from natural gas consumption to GDP PerCapita. By considering that the natural gas covers the major energy demand in the industrial sector, it is referred to the growth hypothesis which suggests that an increase in energy consumption may contribute to economic growth.

Table 6. Granger non-causality test by fuel type

From	To	Modified WALD	P-value	Causality
GDP PerCapita	Diesel fuel	2.28	0.131	No
Diesel fuel	GDP PerCapita	0.03	0.862	No
GDP PerCapita	Natural Gas	1.26	0.261	No
Natural Gas	GDP PerCapita	6.29	0.012[a]	NG → GDPPC
GDP PerCapita	Gasoline	10.58	0.001[a]	GDPPC → GA
Gasoline	GDP PerCapita	0.10	0.745	No
GDP PerCapita	Kerosene	0.35	0.554	No
Kerosene	GDP PerCapita	0.04	0.835	No
GDP PerCapita	LPG&LNG	1.64	0.199	No
LPG&LNG	GDP PerCapita	0.23	0.628	No
GDP PerCapita	Petroleum	0.44	0.507	No
Petroleum	GDP PerCapita	0.12	0.723	No
GDP PerCapita	Electricity	15.15	0.000[a]	GDPPC → EL
Electricity	GDP PerCapita	7.33	0.007[a]	EL → GDPPC

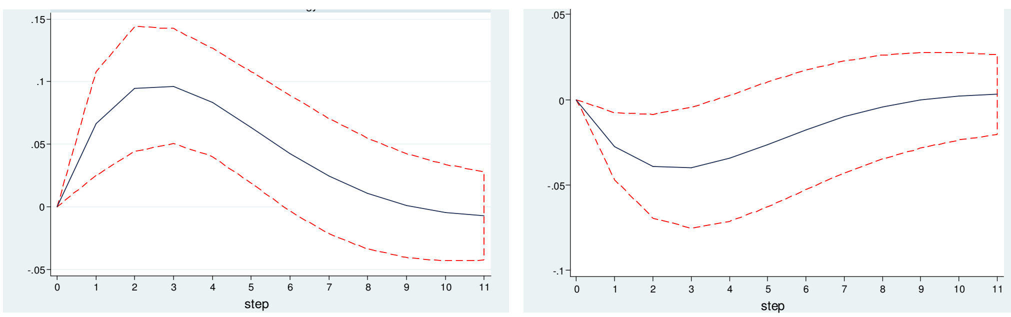
*Note*1: [a] Rejection of the null hypothesis of no causality at 1% significant level.
Note 2: For the all tests one lag was used.

4.4. Impulse Response Functions (IRFs) and Variance Decompositions (VDCs) Results

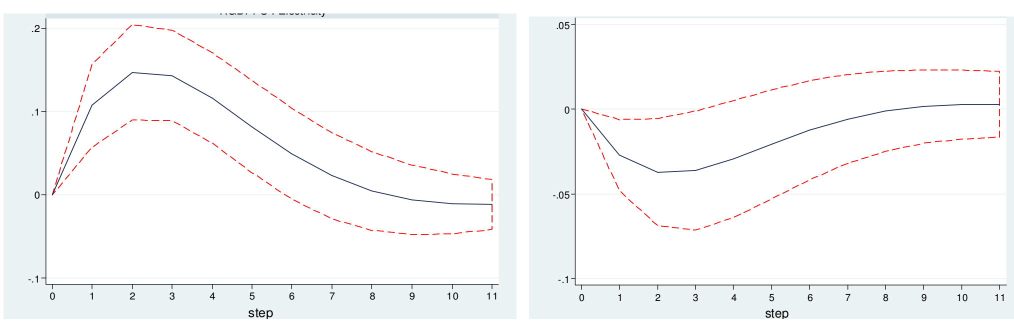
Figure (2) reports the graphs of the impulse responses of all endogenous variables as an alternative way to analyse the causality between model variables. An impulse response function shows the dynamic responses of the variables at a time to various shocks within the PVAR system. These types of functions are used to analyse how shocks in any variable in the system filter thorough to affect every other variable (Fakih and Marrouch, 2015). Among the key findings, the effect of GDP PerCapita shock on total and electricity consumption is positive in Figs (2-A) and (2-B) and negative on gasoline in Fig (2-D) during the three initial years and eliminated after approximately 10 years. These findings imply that for Iranian regions, GDP PerCapita shock has different effects on manufacturing energy use in sample period. On the other hand, the real GDP PerCapita response to the shocks from different types of energy use is depicted in Fig (2-A to 2-H). As the findings show, the response of GDP PerCapita to total, electricity and natural gas shocks is negative in the first three periods and then becomes positive afterwards (although, the effects of total and electricity energy use are stronger than natural gas).

Figure 2. Impulse response functions of the PVAR

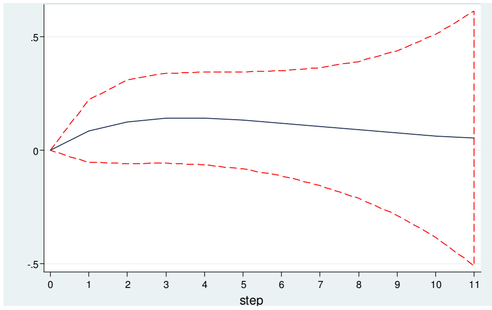
(A) Response of energy consumption to GDPPC Response of GDPPC to energy consumption



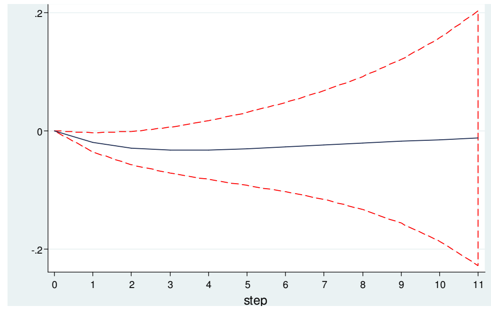
(B) Response of electricity to GDPPC Response of GDPPC to electricity



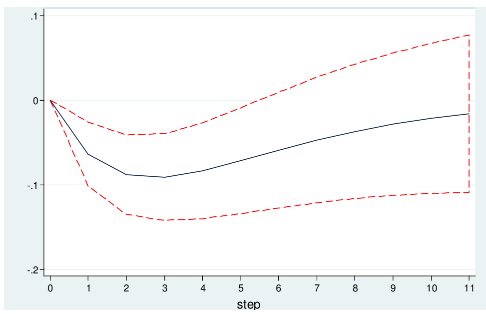
(C) Response of natural gas to GDPPC



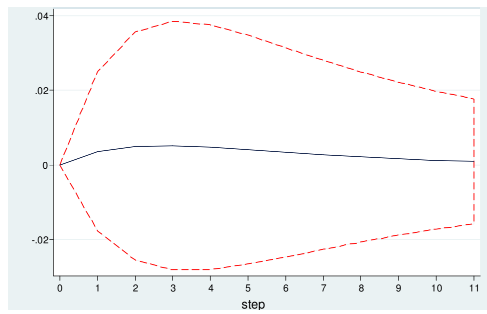
Response of GDPPC to natural gas



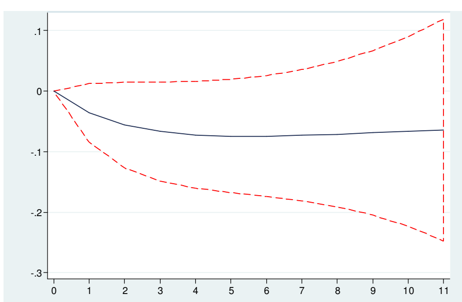
(D) Response of gasoline to GDPPC



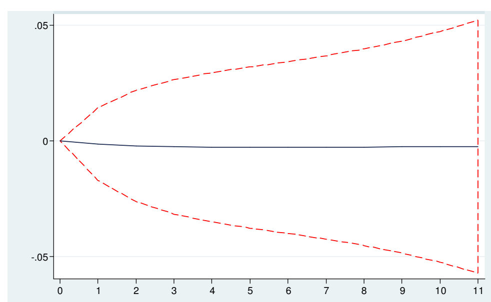
Response of GDPPC to gasoline



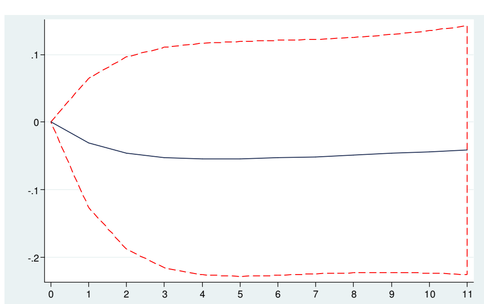
(E) Response of diesel to GDPPC



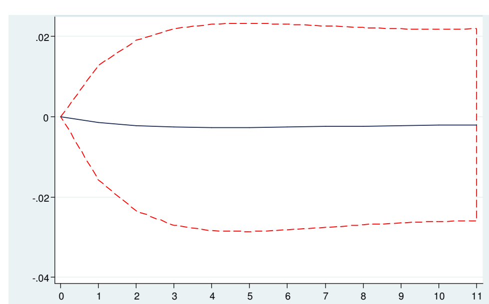
Response of GDPPC to diesel



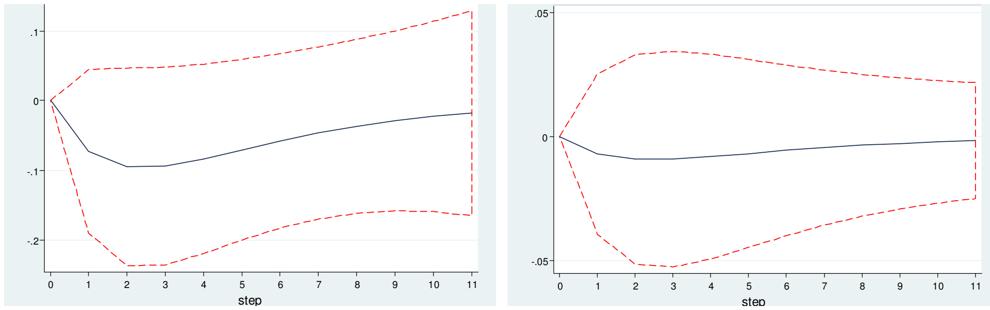
(F) Response of kerosene to GDPPC



Response of GDPPC to kerosene



(G) **Response of LPG&LNG to GDPPC** **Response of GDPPC to KPG&LNG**



(H) **Response of petroleum to GDPPC** **Response of GDPPC to petroleum**

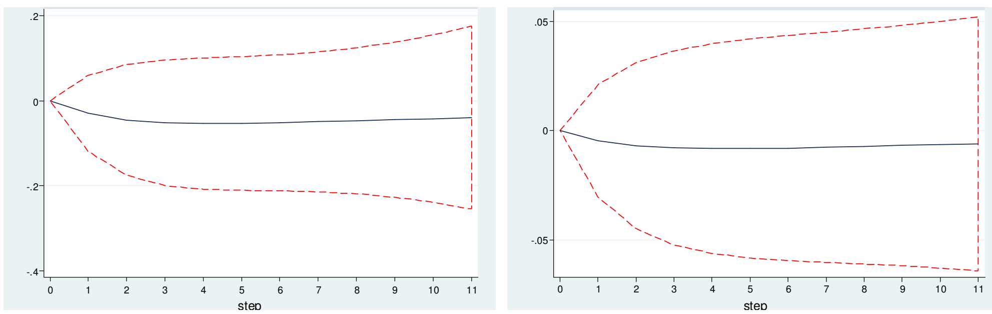


Table (7) presents the summary of the VDCs results for the selected variables. VDCs describe how much the predicted error variance of a variable is explained by innovations generated from each independent variable in a system over the sample period. The results show that for two selected variables (GDP PerCapita and TEC), the biggest portion of variations is typically explained by the variable's own trend over the 11-year horizon. It means that the historical trend of each variable explains a large part of its own variations. Based on the results, about 94.8% of the GDP variance is explained by its own innovations and this amount decreases to 72.68% after 11 periods. While after eleven periods, about 27.3% of the variance in GDP is explained by the total energy consumption. Thus, we perceive a decreasing trend regarding the contribution of the GDP shocks, while the contribution of TEC follows an upward trend over time. The result for the case of TEC is more surprising. In the first period, TEC explains a big part of its' own variation (about 99.7%) and the contribution of GDP is at a very minimal level (about 0.2%). In the second period, 4.6% of the variability in TEC is explained by GDP, approximately. The highest variability of 21.2% in the eights period is explained by GDP shocks. After the sample period, TEC keeps its' main role in its' own innovation(about 78.9%) and the contribution of GDP increases to 21%.These results generally point to the fact that a large proportion of the variations in GDP PerCapita and TEC are explained by their own innovations in the long run.

Table 7. Variance Decompositions (VDCs) analysis

Period	GDP PerCapita	Total Energy Consumption
Variance decomposition of GDP PerCapita	*Panel I*	*Panel II*
1	1.0000	0.0000
2	0.9483	0.0516
3	0.8726	0.1273
4	0.8059	0.1940
5	0.7610	0.2389
6	0.7370	0.2629
7	0.7275	0.2724
8	0.7253	0.2746
9	0.7258	0.2741
10	0.7265	0.2734
11	0.7268	0.2731
Variance decomposition of TEC	*Panel III*	*Panel IV*
1	0.0026	0.9973
2	0.0464	0.9535
3	0.1036	0.8963
4	0.1537	0.8462
5	0.1872	0.8127
6	0.2046	0.7953
7	0.2110	0.7889
8	0.2121	0.7878
9	0.2114	0.7885
10	0.2108	0.7891
11	0.2106	0.7893

5. Summary and Conclusion Remarks

The aim of this paper was to determine whether or not a causal relationship exists and determining its nature (size, direction, and pathways) between industrial energy consumption and economic growth at the Iranian regional-level data. The analysis covered the period 2004 to 2014. After finding no Cointegration among variables, a PVAR is estimated and the Granger causality test was carried out based on a PVAR. A novel aspect of our study is that we consider not only total industrial energy consumption, but also seven types of energy consumptions in manufacturing industries to provide a more detailed analysis of such relationship. Using data from all regions as a whole, we discover that there is a bi-directional relationship between total industrial energy consumption and regional economic growth. The results also confirmed that there is a bi-directional causality between electricity consumption and regional economic growth. This bi-directional causality implies industrial electricity consumption and GDP PerCapita growth are jointly determined and affect each other simultaneously. According to our findings, there was uni-directional Granger causality running from natural gas consumption to GDP

PerCapita and from GDP PerCapita growth to gasoline consumption, but no Granger causality running in any direction between diesel fuel, kerosene, LPG&LNG and petroleum to regional economic growth. These findings have some major policy implications. First, the lack of a link between diesel fuel, kerosene, LPG&LNG and petroleum consumption and economic growth in Iranian regions suggests that increase or decrease in the mentioned fuels consumption in industrial sector will not affect the regional GDP PerCapita growth. On the other hand, natural gas consumption in industrial sector appears to be an important driver for regional economic growth. Therefore, natural gas shortages and conservation in manufacturing sector may have a harmful effect on the growth in Iranian regions. In other words, positive impact of energy consumption on income suggests that the benefit of energy consumption is more than the externality cost of energy use (e.g. pollution). Conversely, if an increase in economic growth leads to energy consumption positively, the externality of energy consumption will prevent economic growth. Under this situation, a conservation policy is necessary.

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Appendix 1. Annual changes in GDP PerCapita and industrial energy consumption PerCapita by fuel types.