Revisiting the relationships between non-renewable energy consumption, CO2 emissions and economic growth in Iran

Nasre Esfahani, Mohammad and Rasoulinezhad, Ehsan

Kharazmi University, State University of Saint Petersburg

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Mohammad Nasre Esfahani
Faculty of Economics, Kharazmi University, Tehran, Iran
Email: mnasr141@gmail.com

Ehsan Rasoulinezhad
Faculty of Economics, State University of Saint Petersburg, St. Petersburg, Russia
Email: erasolinejad@gmail.com

Abstract: Exploring the short-run and long-run relationships between consumption of various sources of non-renewable energy, economic growth and carbon dioxide (CO_2) emissions would be considered as a golden key to provide rational energy policies of Iran in the post sanctions era. The aim of this paper is to find these mentioned relationships by using the Johanesen cointegration approach, the VECM Granger causality test, Generalized impulse responses functions and variance decomposition in Iran for the period 1966-2013. The findings support evidence for the existence of long-run linkage between non-renewable energy consumption, economic growth and CO_2 emissions. The short-run relationship examination proves the causality running from non-renewable energy consumption to economic growth in Iran. The variance decomposition highlights that economic growth changes are explained more by gas consumption than by consumption of other non-renewable energy resources. Furthermore the contribution to CO_2 emissions is mainly from oil consumption. The study recommends some new policy insights for Iran in order to reach a higher economic growth by non-renewable energy resources, while lower carbon dioxide emissions.

Keywords: Economic growth, CO_2 emissions, Energy consumption, Iran.

1. Introduction

Over the last decades, investigating the relationship between energy consumption, CO_2 emissions and economic growth, has received intense attention in a high number of academic studies. On the one hand, it is a common idea that energy resources can be considered as a production factor and can contribute to GDP for a country (Mohammadi & Parvaresh 2014; Baek 2015; Al-mulali & Binti Che Sab 2012; Baranzini et al. 2013). But on the other hand, many previous researches have depicted the relationship between energy consumption and CO_2 emissions(Behmiri & Manso 2013; Chu 2012; Fuinhas et al. 2015; Park & Yoo 2014). So, in sum, it can be concluded that energy consumption would cause a higher level of economic growth, while may lead to a higher environmental pollution.

It is important to note that the contributions of energy sources to economic growth and CO_2 emissions are not similar across countries. In other words, different sources of energy emit various amounts of CO_2 and also have dissimilar impacts on economic growth. The importance and comparison of relationships between consumption of different energy resources, CO_2 emissions and economic growth has been rigorously explored in the many recent studies (Lotfalipour et al. 2010; Wang et al. 2011; Shafiei & Salim 2014; Farhani & Shahbaz 2014; Maji 2015; Bird et al. 2014; De carmoy 1979; Bildirici & Bakirtas 2014; Bloch et al. 2012; Zhang 2012; Sentürk & Sataf 2015; Bloch et al. 2015; Hall et al. 2014).

Based on the mentioned brief state problem and the importance of exploring the relationship between these three variables, Iran has been selected as the case study in this research and both the long-run and the short-run linkages between consumption of non-renewable energy resources, CO_2 emissions and economic growth in this country are investigated by using the Johansen long-run estimation, the VECM Granger causality test, Generalized impulse response functions and variance decomposition over a period of 47 years.

A considerable point is that, this research topic is so crucial for Iran. According to the Joint Comprehensive Plan of Action between Iran and the P5+1, the various sanctions on Iran will be lifted and therefore this country would produce and consume a greater amount of non-renewable energy resources. In this regard, it would be useful for Iran's policy makers to find out consumption of which source of non-renewable energy leads to a higher or lower economic growth and also which one can mitigate CO_2 emissions.

Generally, this research seeks to explore the answers of the following questions through historical analysis of the related data.

1- What is the short-run relationship between non-renewable energy consumption, economic growth and CO_2 emissions?
2- What is the long-run relationship between non-renewable energy consumption, economic growth and CO_2 emissions?
3- How do economic growth and CO_2 emissions react to non-renewable energy consumption shocks?

The remainder of this paper is structured as follows: Section 2 considers a brief literature review, the next section defines the research data and discusses the research methodology. Section 4 represents the results and section 5 concludes the paper.

2. Brief review of Literatures

In the recent years, the significant interest in the relationship between consumptions of various energy resources, CO_2 emissions and economic growth have been dramatically raised. Here, the related literature can be divided into four strands of study: i) Investigation of an energy resource consumption or total energy consumption relationship with economic growth and CO_2 emissions, ii) Comparison of various resources of energy relationship with economic growth and CO_2 emissions, iii) Environmental Kuznets Curve (EKC) investigation and iv) Finding the relationship between energy consumption, economic growth and CO_2 emissions in Iran.

In the first strand of the literature, a high number of the existed literatures concentrated on one type or total amount of energy and investigate the linkage with economic growth and CO_2 emissions (Soytas et al. 2007; Kasman & Duman 2015; Heidari et al. 2015; Apergis & Ozturk 2015; Saidi & Hammami 2015; Akoena et al. 2007; Niu et al. 2011; Arouri et al. 2012; Menyah & Wolde-Rufael 2010; Omri 2013; Baranzini et al. 2013; Sadorsky 2011; Azlina & Mustapha 2012; Ozturk & Acaravci 2010). However, it should be mentioned that a number of the previous empirical studies (e.g. Zhang and Cheng, 2009) did not find the linkage between energy consumption, economic growth and CO_2 emissions.

The second strand of the literature are resulted from the attempts of researchers to compare the relationships between consumptions of different energy sources, i.e. renewable and non-renewable, economic growth and CO_2 emissions (Lean & Smith 2009; Pao & Fu 2013; Tugcu et al. 2012; Long et al. 2015; Shafiei & Salim 2014; Florez-Orrego et al. 2014; Farhani & Shahbaz 2014; Ben Jebli & Ben Youssef 2015; Shabbir et al. 2014). The golden result of most of these studies proves the significant role of renewable energy consumption in the CO2 mitigation in various countries. Eventhough, some studies (e.g. Seker and Cetin, 2015) failed to find any evidence of short or long-run relationship between consumption of different energy resources-economic growth or consumption of different energy resources- CO_2 emissions.

The third literature strand considers the investigation of the Environmental Kuznets Curve (EKC) hypothesis which indicates the relationship between environmental deterioration (e.g. CO_2 emissions) and levels of income per capita. Some of the related studies include Abid (2015), Ahmed and Long (2012), Begum et al. (2015), Borhan et al. (2012), Caviglia-Harris et al. (2009), Coondoo and Dinda (2008), Dinda and Coondoo (2006), Hassan et al. (2015), Kaika and Zervas (2013) , Managi and Jena (2008), Mugableh (2013) and Tang and Tan (2015).

The last strand of literature is related to the previous studies of researchers to explore the relationship between energy consumption, CO_2 emissions and economic group in our chosen case study, Iran. Although, there have not been numerous studies focusing on this country, but some of the existing ones are as bellows:

Omri (2013) studied the CO_2 emissions, energy consumption and economic growth nexus in 14 MENA countries (Iran and 13 other nations). His findings are obtained from a simultaneous equations model for the period 1990-2011. He explored a bidirectional causal relationship between energy consumption and economic growth, while there is a unidirectional causality from energy consumption to CO_2 emissions.

Indeed, Mehrara (2007) investigated the relationship between energy consumption and economic growth of 11 selected oil exporting countries (Iran and 10 other oil exporters) by using panel cointegration analysis. His findings reported a unidirectional causality from economic growth to energy consumption.

Zamani (2007) tried to explore the causal relationship between overall GDP, industrial and agricultural value added and energy consumption in Iran by implying vector error correction morel during 1967-2003. He found a unidirectional causality from GDP to energy consumption and a bidirectional relationship between GDP, gas and oil consumption.

Lotfalipour et al. (2010) examined the economic growth, CO_2 emissions and fossil fuels consumption nexus in Iran by using Granger causality test over the period 1967-2007. Their results showed a unidirectional Granger causality from GDP, oil and natural gas consumption to CO_2 emissions. Furthermore, they did not find any long-run relationship between fossil fuels consumption and CO_2 emissions.

Overall, it can be seen that there is not a serious attempt to examine the economic growth and CO_2 emissions responses to energy consumption shocks and besides explore both the long-run and the short-run relationships between non-renewable energy consumption, CO_2 emissions and economic growth in Iran. Hence, this paper provides more complete and useful results than the earlier related studies for this country.

3. Data description and methodology

3.1 Dataset description

The seven variables used in this study are all in natural logarithmic structure, based on the advantages of this form than using the level of variables (Wooldridge 2013). Furthermore, these variables include economic growth, CO_2 emissions in million tonnes, oil and gas consumption in tonnes and coal consumption in mtoe. In addition,variables trade openness and urbanization growth are used as the control variables which help us to make a multivariate framework to avoid a possible bias problem of omission of any relevant variables (Heidari et al. 2015). Moreover, the three energy sources, i.e. oil, gas and coal, are considered as a proxy for non-renewable energy consumption.

Table 1 depicts the symbols and definitions of these variables.

Table 1. Variables of model

Variable	Definition
LGROW	Logarithm of economic growth in Iran
LCO2	Logarithm of CO_2 emissions in Iran
LOILCON	Logarithm of oil consumption in Iran
LOPEN	Logarithm of trade openness in Iran
LURGRO	Logarithm of urbanization growth in Iran
LCOALCON	Logarithm of coal consumption in Iran
LGASCON	Logarithm of gas consumption in Iran

Source: Author's compilation.

Data on the used seven variables are annually from 1966 to 2013 (47 years). The main sources of the collected data are "BP statistical review of world energy 2015," (2015), "Iran's Economic Time Series Database," (2015) and "World Development Indicators," (2015).

Table 2 reports the summary descriptive statistics of mean, standard deviation, minimum and maximum associated with the above defined variables in Iran. It can be seen that the mean of economic growth in Iran is 5.15, while the mean of global economic growth during 1967-2013 is nearly 3.2. In realizing the CO_2 emissions, Iran has a mean of 253.80 tonnes. In addition, during 1966-2013, this country consumed nearly an average of 50.5, 40.31 tonnes and 1.01 mtoe of crude oil, gas and coal, respectively. As for the trade openness, Iran has a mean of 43.01 which is higher than the global trade openness degree (41.11). In addition, over the period of 1966-2013, urbanization growth in Iran has a average of 56.9,whereas the average of global urbanization growth is about 41.01.

Table 2. Descriptive statistics, 1966-2013

Variables	Mean	Standard deviation	Min	Max
Iran	-	-		
Economic growth	5.15	6.96	-13.22	17.73
CO_2 emissions	253.80	191.2	25.20	633.20
Oil consumption	50.54	27.6	7.30	95.60
Coal consumption	1.01	0.37	0.20	1.60
Gas consumption	40.31	47.38	0.80	146.20
Trade openness	43.01	13.04	13.77	76.77
Urbanization growth	56.09	10.26	37.75	72.32
World				
Economic growth	3.28	1.60	-2.07	6.37
CO_2 emissions	22799	6247.41	12137.30	35311.80
Oil consumption	3157.89	634.99	1645.10	4179.10
Coal consumption	2270.90	719.88	1387.50	3867.00
Gas consumption	1751.21	681.14	640.20	3052.80
Trade openness	41.11	10.17	24.55	59.85
Urbanization growth	41.01	4.70	33.55	49.98

Source: Author's compilation.

3.2 Methodology

In this study, we follow the applied empirical models of previous studies (e.g. Huang et al., 2008; Lee and Chang, 2008; Sadorsky, 2011; Shabbir et al., 2014; Shahbaz et al., 2013b; Squalli, 2007; Zhang and Cheng, 2009) who included CO_2 emissions, economic growth, trade, energy consumption and urbanization growth in a model to investigate the linkages during various time periods and empirically explored the importance of these variables on CO_2 emissions. Therefore, our suggested model which is in line with the previous mentioned studies can be considered as bellows:

$$CO2_t = f(Econ_t, growth_t, trade\ openness_t, urgro_t) \quad (1)$$

Equation (1) illustrates that variable CO_2 emissions can be a function of energy consumption, economic growth, trade openness and urbanization growth in Iran.

In addition, the above equation can be transformed into a natural logarithmic form and written in a regression model as follows:

$$lco2_t = c_0 + C_1 lgrow_t + C_2 lecon_t + C_3 lopen_t + C_4 lurgro_t + \mu_i \quad (2)$$

Where lCO2 indicates CO_2 emissions, lgrow denotes economic growth, lecon represents non-renewable energy consumption (In this research, oil, gas and coal are used as proxies for this variable). The variable of Lopen is trade openness and lurgro indicates urbanization growth in Iran. Lastly, μ_i represents the error term of the model.

Since we have more than one energy resources, to find a better result(Lotfalipour et al. 2010), three various models can be defined based on oil, gas and coal consumptions as bellows:

$$\begin{cases} Model1: lco2_t = c_0 + C_1 lgrow_t + C_2 loilcon_t + C_3 lopen_t + C_4 lurgro_t + \mu_i \\ Model\,2: lco2_t = c_5 + C_6 lgrow_t + C_7 lgascon_t + C_8 lopen_t + C_9 lurgro_t + \varphi_i \\ Model\,3: lco2_t = c_{10} + C_{11} lgrow_t + C_{12} lcoalcon_t + C_{13} lopen_t + C_{14} lurgro_t + \sigma_i \end{cases} \quad (3)$$

Prior to implementation of short-run and long-run examinations, the variables need to be analyzed for stationarity. In this study, the stationary analysis is carried by the Augmented Dickey Fuller (Dickey & Fuller 1981; Dickey & Fuller 1979) and the Phillips-Perron (Phillips & Perron 1988) tests. After applying the stationary tests, the lag length selection should be performed to find out the lag length for our three models. Then, to explore the long-run relationship between variables, the Johanesen cointegration test is performed. This test reports if there is any long-run equilibrium linkage between variables of the models. Moreover, Johansen test results are our direction to choose the Vector Autoregression model or the Vector Error Correction approach to perform the Granger causality test, Generalized Impulse Response Functions (GIRF) and variance decompositions.

4. Results and discussion

As explained in the subsection 3.2 of methodology, this study implies the cointegration approach and Granger causality test to explore the short-run and the long-run relationship between non-renewable energy consumption, economic growth and CO_2 emissions in Iran. Moreover, Generalized Impulse Response Functions and variance decompositions are applied to analyse the responses of economic growth and CO_2 emissions to any non-renewable energy consumption shocks.

4.1 Unit root tests

Prior to the implementation of the cointegration test, the stationary analyses should be applied to investigate the time series properties of all variables in the model. In order to analyze the stationarity of variables, the ADF unit root and Phillip - Perron tests on all variables at levels, first differences are done. The ADF unit root test results reporting in Table 3 reveal that variables CO_2 emissions, economic growth, oil consumption and coal consumption are significantly stationary at levels, while variables urbanization growth, trade openness and gas consumption are not stationary at levels. The PP unit root results show that economic growth, oil consumption, urbanization growth and coal consumption have integration of order zero,while the rest ones have integration of first order. In sum, all variables are stationary at I(0), I(1) and I(2) [variable urbanization growth is the second difference stationary through the ADF, while it is stationary at level through PP test].

Table 3.ADF unit root test results

Variable	ADF	1% level	5% level	10% level	H0	Stationary
LCO2	-3.54	-3.57	-2.92	-2.60	Reject at 5% and 10%	Yes
D(LCO2)	-5.03	-3.58	-2.92	-2.60	Reject	Yes
LGROW	-4.00	-3.57	-2.92	-2.60	Reject	Yes
D(LGROW)	-8.73	-3.58	-2.92	-2.60	Reject	Yes
LOILCON	-4.13	-3.57	-2.92	-2.60	Reject	Yes
D(LOILCON)	-3.95	-3.58	-2.92	-2.60	Reject	Yes
LOPEN	-1.79	-3.57	-2.92	-2.60	Accept	No
D(LOPEN)	-5.12	-3.58	-2.92	-2.60	Reject	Yes
LURGRO	-2.39	-3.57	-2.92	-2.60	Accept	No
D(LURGRO)	-1.74	-3.58	-2.92	-2.60	Accept	No
DD(LURGRO)	-5.11	-3.58	-2.92	-2.60	Reject	Yes
LGASCON	-1.43	-3.57	-2.92	-2.60	Accept	No
D(LGASCON)	-7.65	-3.58	-2.92	-2.60	Reject	Yes
LCOALCON	2.99	-3.57	-2.92	-2.60	Reject at 10%	Yes
D(LCOALCON)	-7.78	-3.58	-2.92	-2.60	Reject	Yes

Source: Authors' compilation

Table 4. PP unit root test results

Variable	PP	1%	5% level	10%	H0	Stationary

		level		level		
LCO2	2.87	-3.57	-2.92	-2.60	Accept	No
D(LCO2)	-5.49	-3.58	-2.92	-2.60	Reject	Yes
LGROW	-3.37	-3.57	-2.92	-2.60	Reject at 5% and 10%	Yes
D(LGROW)	-15.3	-3.58	-2.92	-2.60	Reject	Yes
LOILCON	-6.44	-3.57	-2.92	-2.60	Reject	Yes
LOPEN	-2.23	-3.57	-2.92	-2.60	Accept	No
D(LOPEN)	-5.12	-3.58	-2.92	-2.60	Reject	Yes
LURGRO	-8.75	-3.57	-2.92	-2.60	Reject	Yes
LGASCON	-1.70	-3.57	-2.92	-2.60	Accept	No
D(LGASCON)	-7.66	-3.58	-2.92	-2.60	Reject	Yes
LCOALCON	-3.01	-3.57	-2.92	-2.60	Reject at 5% and 10%	Yes
D(LCOALCON)	-7.77	-3.58	-2.92	-2.60	Reject	Yes

Source: Authors' compilation

4.2 Lag selection

Table 5 shows the lag order selection criteria of our three models. In this study, the optimal lags are chosen in regards to the Akaike (AIC), Schwarz (SIC) and Hanna-Quinn (HQ) criteria. The results report that our models should contain four lags by AIC and HQ criteria,while SIC suggests one lag in model 1 and 3. The final decision about appropriate lag selection is made in regards to the majority results (Which is the four lags) of the three criteria and also checking the residual Portmanteau test for autocorrelations (The residuals should not be correlated in our models for the selected lag length). Since the majority results are the 4 lags and the Portmanteau test proves no evidence of autocorrelation in the residuals at the 5% level (Table 6), the four lags are chosen and included in our three models.

Table 5. Lag length selection

Model 1	**Lag**	**AIC**	**SIC**	**HQ**
	0	-3.07	-2.86	-2.99
	1	-16.33	**-15.09***	-15.88
	2	-17.22	-14.98	-16.39
	3	-18.08	-14.83	-16.87
	4	**-18.99***	-14.73	**-17.41***
Model 2	0	-1.08	-0.87	-1.00
	1	-13.94	-12.72	-13.48
	2	-14.66	-12.43	-13.83
	3	-15.76	-12.51	-14.56
	4	**-17.30***	**-13.04***	**-15.72***

Model 3	0	-0.52	-0.32	-0.45
	1	-12.6	**-11.40***	-12.17
	2	-13.3	-11.10	-12.50
	3	-13.8	-10.65	-12.69
	4	**-14.5***	-10.32	**-13.00***

Source: Authors' compilation

Table 6. Portmanteau autocorrelation test

Models	**Lags**	**Q-stat**	**Prob.**	**Adj Q-stat**	**Prob.**	**df.**
Model 1	1	16.60	NA*	16.97	NA*	NA*
	2	53.22	0.1871	55.26	0.1405	45
	3	81.86	0.1570	85.89	0.0953	70
	4	96.95	0.4250	102.42	0.2833	95
Model 2	1	15.69	NA*	16.04	NA*	NA*
	2	56.81	0.1114	59.03	0.0954	45
	3	97.06	0.0979	102.08	0.0818	70
	4	111.76	0.1153	118.18	0.0638	95
Model 3	1	17.11	NA*	17.50	NA*	NA*
	2	52.33	0.2106	54.31	0.1609	45
	3	83.66	0.1265	87.83	0.0734	70
	4	110.73	0.1289	117.47	0.0688	95

Source: Authors' compilation

4.3 Cointegration test and long-run relationship

As the ADF and PP unit root tests depicted that the variables are stationary, we can imply a cointegration analysis using Johansen's method by assuming linear deterministic trend and drift, also taking the lagged ratio as 4 according to the lag selection results. Generally, Johansen's technique is done through two likelihood ratio test statistics: the Trace and the Maximum eigenvalue. The Trace and the Maximum Eigenvalue tests findings for the long-run elasticities of CO_2 emissions in three models, in respect to oil, gas and coal consumptions are shown in Table 7. The results report that there are long-run equilibrium relationships between variables in all three models for Iran.

Table 7. Johansen and Juselius Cointegration Test results

	Trace test			
Model 1	No. of cointegrations	Eigenvalue	Trace statistic	Critical value 0.05
	None*	0.73	115.68	69.81
	At most 1*	0.54	59.15	47.85

	At most 2	0.31	25.18	29.79
	At most 3	0.17	8.60	15.49
	At most 4	0.00	0.10	3.84
	Maximum Eigenvalue test			
	No. of cointegrations	Eigenvalue	Max-Eigen statistic	Critical value 0.05
	None*	0.73	56.52	33.87
	At most 1*	0.54	33.97	27.58
	At most 2	0.31	16.57	21.13
	At most 3	0.17	8.50	14.26
	At most 4	0.00	0.10	3.84
Model 2	Trace test			
	No. of cointegrations	Eigenvalue	Trace statistic	Critical value 0.05
	None*	0.75	144.73	69.81
	At most 1*	0.68	84.56	47.85
	At most 2*	0.37	34.87	29.79
	At most 3	0.23	14.50	15.49
	At most 4	0.07	3.16	3.84
	Maximum Eigenvalue test			
	No. of cointegrations	Eigenvalue	Max-Eigen statistic	Critical value 0.05
	None*	0.75	60.16	33.87
	At most 1*	0.68	49.69	27.58
	At most 2	0.37	20.36	21.13
	At most 3	0.23	11.33	14.26
	At most 4	0.07	3.16	3.84
Model 3	Trace test			
	No. of cointegrations	Eigenvalue	Trace statistic	Critical value 0.05
	None*	0.75	143.88	69.81
	At most 1*	0.68	83.80	47.85
	At most 2*	0.37	38.82	29.79
	At most 3	0.23	12.53	15.49
	At most 4	0.07	1.35	3.84
	Maximum Eigenvalue test			
	No. of cointegrations	Eigenvalue	Max-Eigen statistic	Critical value 0.05
	None*	0.75	60.08	33.87
	At most 1*	0.68	44.97	27.58
	At most 2*	0.37	26.29	21.13
	At most 3	0.23	11.18	14.26
	At most 4	0.07	1.35	3.84

Source: Authors' compilation

According to the normalized cointegrating equations (as shown in Table 8), there is a long-run positive relationship between economic growth and CO_2 emissions. Furthermore, there is a long-run negative linkage between gas consumption and CO_2

emissions, while oil and coal consumption have a positive long-run relationship with CO_2 emissions.

Table 8. The Normalized cointegrating coefficients

Models	Dependent variable	Independent variables	
Model 1	LCO2	LOILCON	LGROW
	1.00	+1.47	+0.24
Model 2	LCO2	LGASCON	LGROW
	1.00	-0.32	+0.31
Model 3	LCO2	LCOALCON	LGROW
	1.00	+0.15	+0.23

Source: Authors' compilation

In brief, a 1% increase in economic growth positively can increase CO_2 emissions. This finding is in line with Ang (2007), Chandran Govindaraju & Tang (2013), Heidari et al. (2015), Kasman & Duman (2015), Salahuddin et al. (2015), Shahbaz et al. (2013a) and Wang et al. (2011) who find the positive long-run economic growth-CO_2 emissions nexus.

Furthermore, oil consumption has the highest positive effect on the CO_2 emissions in Iran among other non-renewable energy resources, while gas consumption has a negative long-run relationship with CO_2 emissions.

4.4 Short-run relationships

Granger (1998) stated that if the variables in a research were cointegrated, the error–correction model should be implemented to find out the direction of causality. Hence, in this section, according to our cointegration results in section 4-3, the Granger Causality test is preceded for Iran. The results of the Granger test show a bidirectional short-run Granger causality between oil consumption-economic growth and gas consumption- CO_2 emissions as well. Moreover, there is a unidirectional causal relationship running from oil consumption to CO_2 emissions and from coal and gas consumption to economic growth. It can be seen from Table 9, that economic growth has a unidirectional relationship with CO_2 emissions in Model 2, while there is a unidirectional causality relationship from CO_2 emissions to economic growth in Model 1 and 3.

Table 9. Short-run causality test

	Null Hypothesis	χ2 Statistic	P-value	Null Hypothesis at 10%	Causality
Model 1	loilcon does not Granger cause lgrow	12.9	0.01	Reject	Loilcon ↔Lgrow
	Lgrow does not Granger cause loilcon	9.5	0.04	Reject	
	loilcon does not Granger cause lco2	6.0	0.1*	Reject	Loilcon→LCO2
	Lco2 does not Granger cause loilcon	2.5	0.6	Accept	
	lgrow does not Granger cause lco2	2.4	0.6	Accept	LCO2 → Lgrow
	Lco2 does not Granger cause lgrow	12.4	0.01	Reject	
Model 2	lgascon does not Granger cause lgrow	11.1	0.02	Reject	Lgascon →Lgrow
	Lgrow does not Granger cause lgascon	4.6	0.3	Accept	
	lgascon does not Granger cause lco2	21.6	0.0	Accept	Lgascon ↔ LCO2
	Lco2 does not Granger cause lgascon	15.7	0.0	Accept	
	lgrow does not Granger cause lco2	3.2	0.5	Accept	Lgrow →LCO2
	Lco2 does not Granger cause lgrow	14.4	0.0	Reject	
Model 3	lcoalcon does not Granger cause lgrow	11.8	0.01	Reject	Lcoalcon → Lgrow
	Lgrow does not Granger cause lcoalcon	4.1	0.3	Accept	
	lcoalcon does not Granger cause lco2	3.2	0.5	Accept	-
	Lco2 does not Granger cause lcoalcon	2.5	0.6	Accept	
	lgrow does not Granger cause lco2	3.2	0.5	Accept	LCO2 →Lgrow
	Lco2 does not Granger cause lgrow	14.3	0.0	Reject	

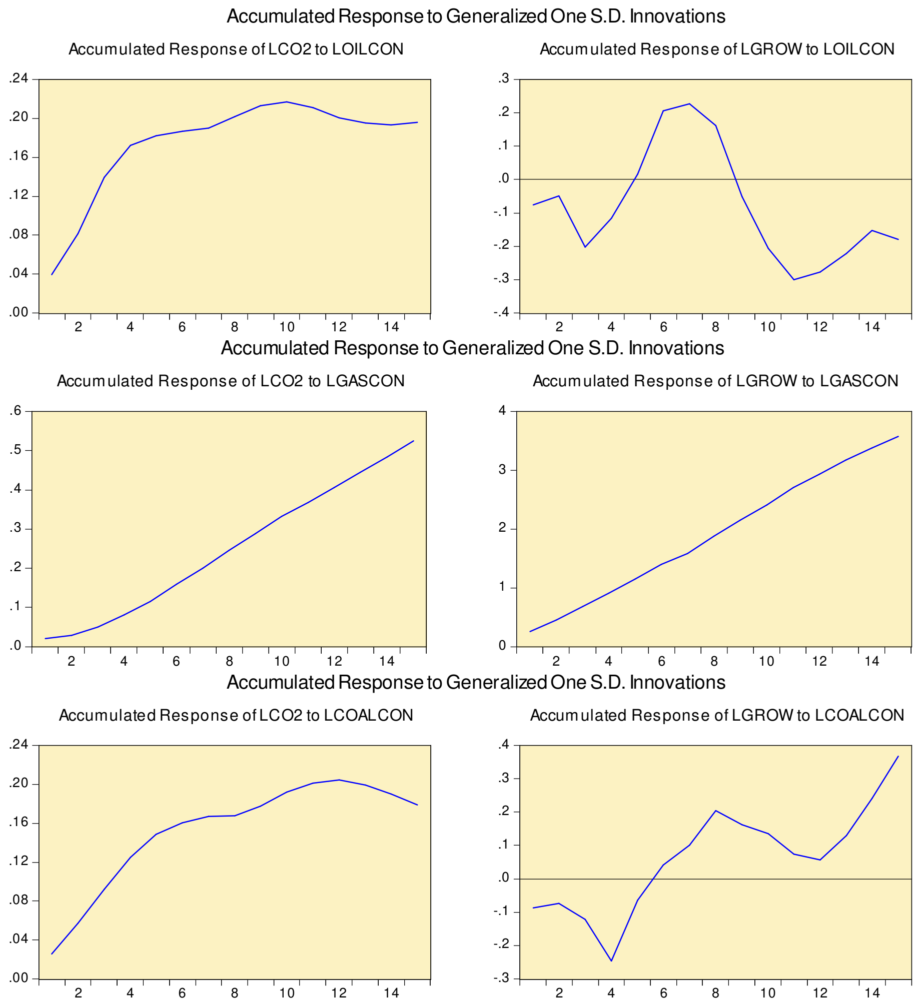
Source: Author's compilation.

It can be concluded that Granger causality test proves the short-run relationship between non-renewable energy consumption and economic growth. This finding is in line with Ang (2007), Apergis & Payne (2009), Belloumi (2009), Bildirici & Bakirtas (2014), Chu & Chang (2012), Kesikoglu & Yidirim (2014), Mo & Kim (2003), Park & Kim (2013) Stern (1993), Wang et al. (2011), Yuan et al. (2008), Zou & Chau , (2006) who found short-run causality between non-renewable energy consumption and economic growth, and is in contrast with some previous studies that failed to find directional relationship between oil consumption and economic growth (e.g. Long et al., 2015). In addition, it has been found that in the short-run, there is a Granger causality between oil and gas consumptions and CO_2 emissions (it is in parallel with the results of Apergis & Payne (2009), Halicioglu (2009), Lean & Smyth (2010), Zhang & Cheng (2009), while there is not any evidence of short-run relationship between coal consumption and CO_2 emissions.

4.5 Generalized Impulse Response Function (GIRF)

We test and visualize the responses of the variables, i.e. economic growth and CO_2 emissions to shocks from oil,gas and coal consumption. According to Lutkepohl and Reimers (1992), impulse response functions (IRFs) are the appropriate tool to find out the reactions of economic variables to the impulse of an indicator. Furthermore, according to Osorio and Unsal (2011), GIRF considers shocks to individual errors an integrate out the other shocks influences based on historical distributions of all errors which can provide better results than common IRF. Figure 1 portrays the Accumulated Generalized IRF results when there is a pulse in consumption of three types of non-renewable energy resources in Iran over 15 periods.

Fig 1. IRF results



Source: Author's compilation based on Eviews 8.0 software

It is clear that after a shock of coal and oil consumptions, CO_2 emissions react positively and go up from the first year until the 11th period. This response moves with a negative slope in the long-run. In contrast, a shock of gas consumption causes a sharp positive response of CO_2 emissions. In regards to economic growth in Iran, it can be seen from Figure 1 that the response of this variable to a shock of gas consumption is significantly positive. In case of a shock of oil and coal consumptions, economic growth reactions are similar in the short-run and the middle-run. It means that it decreases in the short-run and then in the middle-run it goes up with a positive slope. In the long-run, economic growth has a decrease-increase response. Although, the reduction of economic growth in response to a positive innovation in oil consumption is significantly sharper than the reduction caused by unanticipated positive innovation in coal consumption.

4.6 Variance Decomposition

In this section, to strengthen the evidence from Granger causality results, the variation an endogenous variable is separated into the component shocks for exploring the importance of each random innovation (Here are non-renewable energy resources consumptions) in affecting the variables, i.e. economic growth and CO_2 emissions. Table 10 reports the decomposition of variables CO_2 emissions and economic growth. It is obvious that the contributions to CO_2 emissions are mainly from oil consumption, gas consumption and coal consumption respectively during the fifteenth variance period. In respect of economic growth, during the changes of this variable in Iran, the gas consumption effect is 33.70% in the 15^{th} period. Furthermore, nearly 11% of economic growth changes could be interpreted by oil consumption in the last period, while coal consumption has the lowest contribution to economic growth changes among non-renewable energy sources.

Table 10. Variance decomposition of CO_2 emissions and economic growth

Variance period	**Decomposition of LCO2**			**Decomposition of Lgrow**		
	Loilcon	Lgascon	Lcoalcon	Loilcon	Lgascon	Lcoalcon
1	0.00	0.00	0.00	0.00	31.39	9.18
2	6.96	4.40	2.47	10.38	28.32	6.24
3	8.47	2.80	1.70	8.13	39.35	7.33
4	6.49	3.92	2.70	8.00	40.85	14.40
5	9.05	8.30	2.39	7.37	37.80	11.51
6	15.17	15.96	2.06	8.33	30.49	10.19
7	19.26	19.85	2.39	8.42	26.86	9.11
8	21.08	22.78	3.70	7.91	27.75	7.75
9	21.95	23.14	3.95	8.52	32.58	7.37
10	23.37	23.94	3.73	9.21	35.86	7.62
11	25.57	24.52	3.56	9.40	38.31	8.67
12	27.83	25.53	3.50	9.63	37.66	9.38
13	29.01	26.94	3.85	10.33	35.61	9.05

14	29.77	28.27	4.55	11.25	33.95	8.53
15	29.87	29.51	5.48	11.16	33.70	8.27

Source: Author's compilation based on Eviews 8.0 software

In sum, we can highlight the high significance of oil consumption and gas consumption in explaining the variation in CO_2 emissions and economic growth, as well. It is interesting that the influence on economic growth changes comes from gas consumption more than oil consumption. It means that the total contribution of oil consumption accounts for the economic growth lower than the total contribution of gas consumption in any given variance period.

5. Conclusion and policy implications

Since the sanctions in related to the Iran's energy sector will be lifted under the nuclear agreement reached by Iran and P5+1 in July 2015, many scholars expect accelerating economic growth in Iran which stands for a higher level of energy producing and consuming. Besides, Iran will be able to promote its National Climate Change Action Plan (NCCAP) to reduce carbon dioxide emissions, while increasing economic growth rate. Therefore, in regards to making energy production and consumption decisions, it is important for Iranian policymakers to find out the contributions of consumption of various non-renewable energy resources to economic growth and CO_2 emissions. Thus, this study has attempted to examine empirically the relationships between consumption of different resources of non-renewable energy, CO_2 emissions and economic growth for Iran over the period 1966 -2013 (47 years) under three different models based on the type of non-renewable energy resources, i.e. oil, gas and coal.

Considering the Johanesen cointegration test, it is found that there exist long-run relationships with respect to CO_2 emissions as the dependent variable in all three models. Economic growth has a positive long-run linkage with CO_2 emissions. It means that a higher economic growth leads to an increase in carbon pollution.

Furthermore, among three non-renewable energy resources in Iran, oil is the major contributor to CO_2 emissions, while gas has a negative impact on CO_2 emissions in Iran.

Under the VECM Granger causality test, there is a short-run causality relationship between non-renewable energy consumption and economic growth in Iran. Moreover, the results prove a Granger causality relationship between oil and CO_2 emissions, as well as gas consumptions and CO_2 emissions, while there is not any evidence of the short-run relationship between coal consumption and CO_2 emissions.

The results from the Generalized Impluse Response Functions revealed that CO_2 emissions and economic growth do significant react to a positive shock to oil, gas and coal consumptions. However, it was found that the responses of CO_2 emissions and economic growth are similar in the case of oil and coal consumption, while a shock of gas consumption lead to a significant positive response in these two variables.

The variance decomposition findings concluded that the economic growth changes are explained more by gas consumption than by oil consumption. Furthermore the contributions to CO_2 emissions are mainly from oil, gas and coal consumptions, respectively.

Following the above experimental conclusions, we can present some policy implications as bellows:

- Since there is a short-run relationship between oil, gas and coal consumptions and economic growth, Iran should care more the energy conservation policies in the case of these three renewable energy sources.
- Extending the current policies of gas consumption such as seasonal gas consumption in power plants, seasonal injected fas in oil reservoirs and gas consumption in transportation sector (Kiani & Pourfakhraei 2010) can be suggested in the post sanctions era, due to the negative effect of gas consumption on CO_2 emissions and its high contribution to economic growth in Iran.

- Thanks to the likely sanctions lifting , Iran will face an opportunity to decrease its oil consumption by improving the energy efficiency based on global success experiences. Besides, Iran can import better equipments, materials and products to use in buildings, vehicles and industries which lead to an oil consumption reduction.
- The post-sanctions era may prepare favorable circumstances for Iran to develop its cooperation with international institutions and countries in dealing with Greenhouse Gas (GHG) emissions reduction.

The major limitation of this research is that it only concentrated on the long-run and the short-run relationships between variables, impulse response function and variance decomposition. So,we recommend the researchers to study further the macro energy model of Iran through some methods such as ISM (Interpreted Structural Model). This may be helpful to find out the inner and outer relationships between energy approaches, energy dimensions and energy sectors in Iran.

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