Petroleum
Business
Review

Energy Transition Modelling in Iran: An Evidence from the ARDL Bound Testing Method

Mohammad Nasr Esfahani[a] and Ehsan Rasoulinezhad[b*]

[a] *Instructor, Economics and Islamic Banking, Faculty of Economics, Kharazmi University, Tehran, Iran, Email: mnasr121@gmail.com*

[b] *Assistant Professor, Department of Russian Studies, Faculty of World Studies, University of Tehran, Tehran, Iran, Email: e.rasoulinezhad@ut.ac.ir*

ARTICLE INFO

Keywords:

Energy transition

ARDL bound testing method

Iran

Received: 10 March 2020
Revised: 11 May 2020
Accepted: 1 June 2020

ABSTRACT

The challenge of environmental pollution and climate change have made countries to develop energy transition progress meaning move from non-renewable energy sources towards renewable ones. This paper seeks to analyze energy transition pattern in Iran by modeling it using the ARDL bounding testing method over the period of 1993-2018. The empirical estimations depicted that in the long-run economic growth and inflation rate negatively impact on energy transformation of Iran, while increase in carbon dioxide emissions and appreciation of Iran's national currency accelerate the energy transition process in Iran. Regarding the short-run relationship, the major results represented an evidence of positive impact of exchange rate on Iran's energy transition process, while the other variables have negative coefficient. As policy implications, we recommended lowering budget dependency to oil revenues, and issuing short-run de-carbonizing policies in Iran.

1. Introduction

A growing concern on the climate changing chiefly arising from the carbon emissions has been a primary challenge for all the countries in the world. Various countries, specially developed ones, have conducted different policies in order to de-carbonize economic activities. As a major developing country and main fossil fuel producers, Iran is now facing serious level of air pollution. According to BP statistical review of energy 2019, Iran is the most CO2 emitters in the Middle East and produced over 630 million tons in 2018, while other countries such as Saudi Arabia, Qatar and United Arab Emirates have produced CO2 lower than Iran.

---

[*] Corresponding author

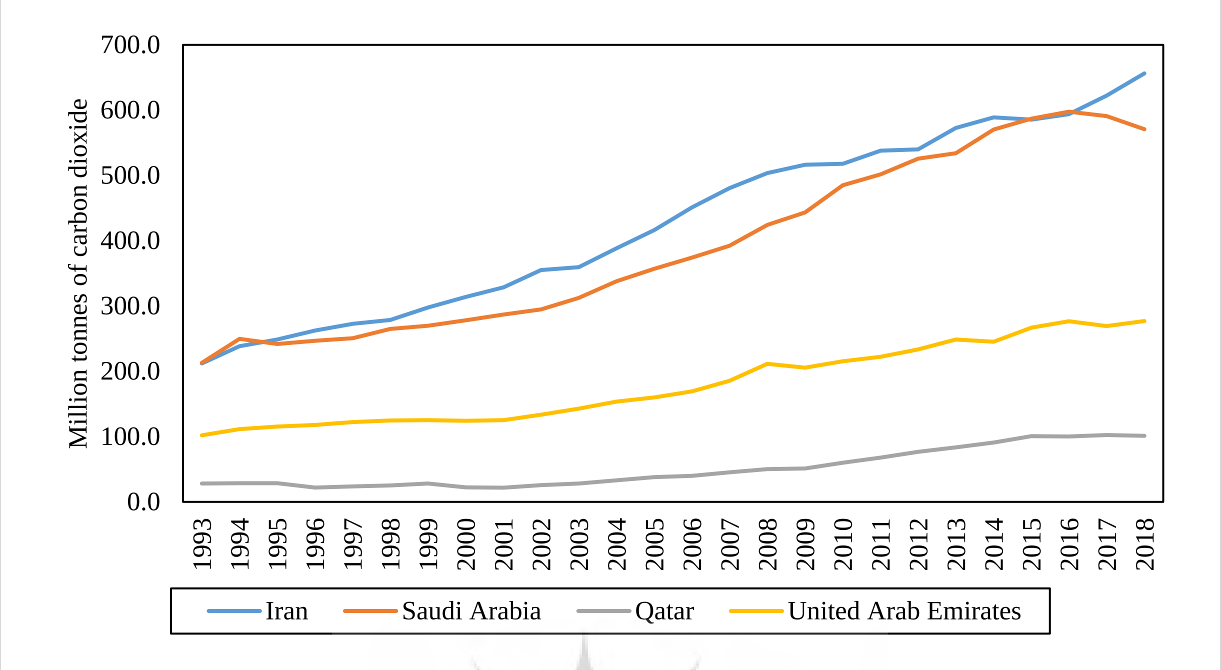

Figure 1. CO2 emissions by Iran, 1993-2018, million tones.

Source: Authors' compilation from BP

This huge amount of carbon dioxide emissions is a cause of high level of fossil fuel consumption in Iran. According to the BP review of 2019 (Figure 2), natural gas and crude oil are two main fossil fuel energy resources in energy consumption basket of Iran. In 2018, Iran used nearly 200 million tones oil equivalent and 100 million tones oil equivalent natural gas and oil, respectively. This large amount of fossil fuel consumption is a major reason polluting environment and emitting carbon dioxide.

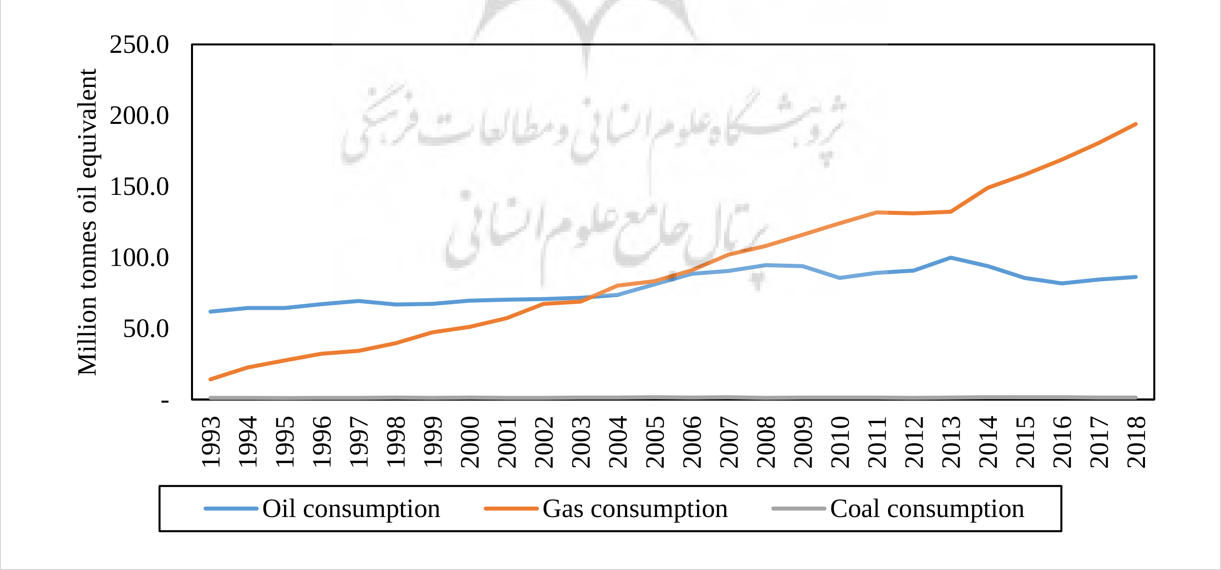

Figure 2. Fossil fuel consumption by Iran, 1993-2018, million tones oil equivalent.

Source: Authors' compilation from BP

A fresh solution to the problem of fossil fuel consumption and climate change in Iran is improvement of energy transition meaning to change the energy basket consumption into the more renewable energy sources rather than fossil fuel ones. Fig 3 represents the energy transition trend in Iran over the period of 1993-2018. It is clear that the process of replacing fossil fuel resources with renewable ones was with a record of nearly 1.6% in 1993 and the lowest level of about 0.4% in 2000. Following Aryanpur et al. (2019), Iran currently is not in a proper place in the road of energy transition because there is not an efficient link between energy planning and policy making in this country.

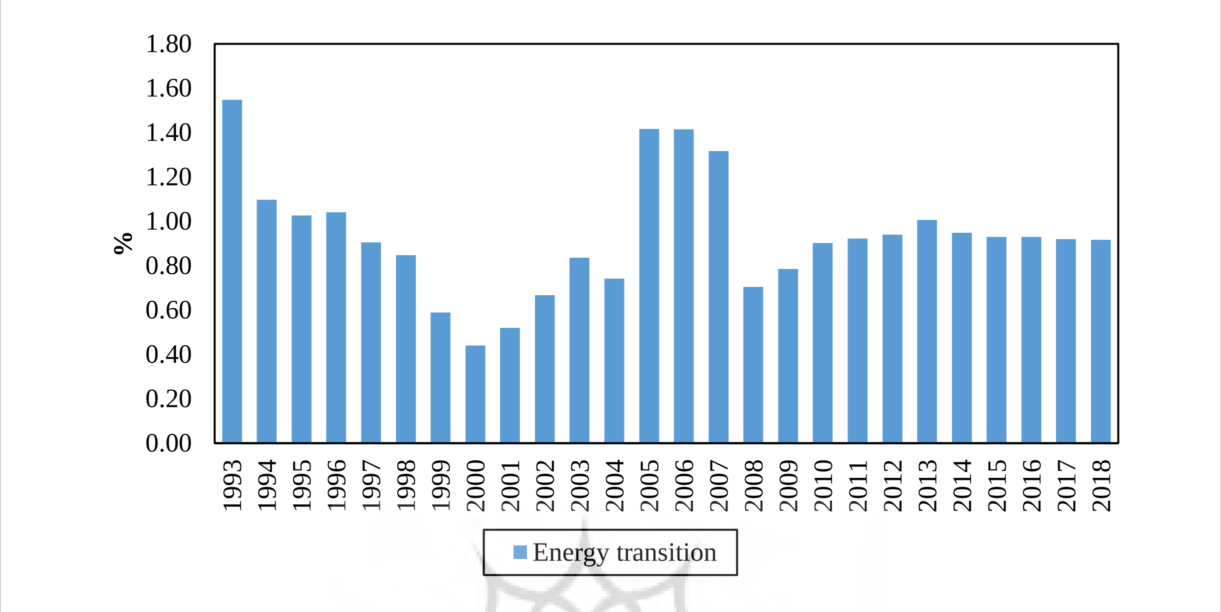

Figure 3. Energy transition in Iran, 1993-2018, %.

Source: authors' compilation from BP and world bank

Tavana et al. (2019) investigated different strategies to develop the renewable power generation share in Iran by year of 2050. They found out that it is the best strategy to have energy transition movement with a rate of 3% to go to reach a full renewable power generation in 2050. In other study, Aryanpur et al. (2019) analyzed energy planning in Iran and the capabilities of using green energy resources in power generation. The main results revealed that increasing the contribution of non-hydro clean energy for power generation in Iran is the best strategy in in near feature. Hafeznia et al. (2017) evaluated natural gas potential for energy transition in Iran. They concluded that to have low-carbon economy, Iran needs to lower the use of fossil fuels to combat environmental pollution and to this end, local energy demand, energy loses in residential sector and high energy intensity should be solved.

Regarding the existing literature, energy transition has drawn attention by a vast number of scholars. In a study, Chapman and Itaoka (2018) tried to find out the relationship between energy transition and electricity market liberalization in Japan. The results depicted that geographic limitation and the Fukushima nuclear incident are two important challenges of Japan to improve the progress of energy transition. Chen et al. (2019) investigated various strategies to generate a sustainable energy transition process. He found out that robust and appropriate plans in governance may boost energy transition in an economy. In line with the Chen et al. (2019)'s argument, Vainio et al. (2019) expressed that households and their images from energy transition play a major role in efficiency of movement from fossil fuels to green energy resources. Kraan et al. (2019) explored the impacts of energy transition on energy intensity and total primary energy consumption. The major results revealed that due to cultural consumption patterns, energy transition cannot impact positively on these energy indicators. Besides the mentioned studies, different energy resources consumption and energy transition in Iran has been drawn attention by some scholars like Yazdanpanah et al. (2015), Ghorbani et al. (2017) and Aryanpur et al. (2019), however, there has not been any in-depth study focusing on energy transition of Iran that proves the novelty of our study. Therefore, this paper seeks to fill in this literature gap.

The rest of paper is organized as follows: Section 2 discusses theoretical background. Next Section represents data description and methodology. Section 4 argues the empirical results and finally Section 5 concludes the paper and gives some policy implications.

2. Theoretical Background

To explain our theoretical framework, we make an assumption of a common economy comprising two sectors of industry and household. The demand side of commodities market in this economy is provided by these two sectors.

Regarding energy demand by industrial sector, we can consider the production function of an industry (Eq.1) in the form of Cobb-Douglas as follows:

$$Y_t^I = F\left(K_t, L_t, ET_t^I\right) = K_t^{\alpha} L_t^{\beta} (ET_t^I)^{(1-\alpha-\beta)} \qquad (1)$$

In Eq.1, overall production of industry, capital, and labor force are represented by Yt, K and L, whereas ETt1 denotes the energy demand of industry for production process. We can assume ET as energy transformation (share of renewables to non-renewables).

Based on microeconomic principles, a firm can maximize the profit as shown in Eq. 2:

$$Max\, \pi_t = P_t^Y Y_t^I - r_t K_t - w_t L_t - e_t(P_t^E + T_t) ET_t^I \qquad (2)$$

The above equation contains π as firm’s profit, P_ ^Y as firm’s commodity price, r as capital’s interest rate, was wage of labor force, e as official exchange rate, P_ ^E as price of energy input and finally T as transportation costs.

The F.O.C. (First order condition) of firms’ profit with respect to energy transition (ET) can be written as Eq.3:

$$\frac{\partial \pi_t}{\partial ET_t^I} = (1-\alpha-\beta)\frac{P_t^Y Y_t^I}{ET_t^I} - e_t(P_t^E + T_t) = 0 \qquad (3)$$

From Eq.3, the demand for energy transformation is calculated as Eq.4:

$$ET_t^I = (1-\alpha-\beta)\frac{P_t^Y Y_t^I}{e_t(P_t^E + T_t)} \qquad (4)$$

According to Eq.4, we can express that energy transformation demand of industry is related to labor force, capital, the real production of industry, energy price, official exchange rate and transportation cost.

Regarding household as the second sector of the assumed economy, we can consider the following utility function shown in Eq.5:

$$U_t = (C_t, ET_t^H) = \frac{1}{1-\gamma}(C_t)^{1-\gamma} + \frac{1}{1-\delta}\left(ET_t^H\right)^{1-\delta} \qquad (5)$$

Based on microeconomic principles, household can maximize Eq.5 with the following constraint:

$$S.t. \quad P_t^C C_t + e_t(P_t^E + T_t) ET_t^H = Y_t^H \qquad (6)$$

Here, P_ ^C and P_ ^E are prices of non-energy and energy commodities, respectively. T represents the transportation costs, while Y_ ^H shows income level of household.

Using the Lagrange function, we can write the maximization of Eq.5 as follows

$$\Gamma = U(C_t, ET_t^H) - \lambda\{P_t^C C_t + e_t(P_t^E + T_t) ET_t^H - Y_t^H\} \qquad (7)$$

Consequently, the F.O.C. with respect to the 〖ET〗_ ^H, C_, and λ is obtained as shown in Eqs. 8–10:

$$\frac{\partial \Gamma}{\partial ET_t^H} = (ET_t^H)^{-\delta} - \lambda\{e_t(P_t^E + T_t)\} = 0 \rightarrow E_t^H = f(e_t(P_t^E + T_t), Y_t^H) \qquad (8)$$

$$\frac{\partial \Gamma}{\partial C_t} = {C_t}^{-\gamma} - \lambda\{P_t^C\} = 0 \qquad (9)$$

$$\frac{\partial \Gamma}{\partial \lambda} = P_t^C C_t + e_t(P_t^E + T_t) - Y_t^H = 0 \qquad (10)$$

Overall, the total energy transformation demand in the assumed economy is a mix of industrial sector and residential sector demands as represented in Eq.11

$$ET_t = ET_t^I + ET_t^H \qquad (11)$$

We can conclude that the energy transformation in an economy is related to inflation rate, carbon dioxide emissions (proxy for transportation cost), population growth, official exchange rate, economic growth.

3. Characteristics of Model and Data

Based on theoretical framework, our empirical model can be written as following function:

$$ENTRAN_t = f(INFL_t, CO2_t, EXCH_t, GROW_t, POPU_t,) \qquad (12)$$

The above function can be transformed into econometric equation as Eq.13:

$$ETRAN_t = \beta_0 + \beta_1 * INFL_t + \beta_2 * CO2_t + \beta_3 * EXCH_t + \beta_4 * GROW_t + \beta_5 * POPU_t + \mu_i \qquad (13)$$

Where, ETRAN and INFL represent energy transition and inflation rate, while CO2 and EXCH are CO2 emissions per capita and official exchange rate in Iran. GROW and POPU denote economic growth and population growth in Iran, respectively.

Prior to run empirical estimations, a number of preliminary tests should be carried out to ensure the reliability and viability of findings. Since Iran's economy has experienced many structural shocks such as war, sanctions, Dutch disease and high inflation rate, Zivot and Andrews (1992) test with following three models is employed to explore the existence of structural breakpoint.

$$\Delta x_t = a + ax_{t-1} + bt + cDU_t + \sum_{j=1}^{k} d_j \, \Delta x_{t-j} + \mu_t \qquad (14)$$

$$\Delta x_t = b + bx_{t-1} + ct + bDT_t + \sum_{j=1}^{k} d_j \, \Delta x_{t-j} + \mu_t \qquad (15)$$

$$\Delta x_t = c + cx_{t-1} + ct + dDU_t + bDT_t + \sum_{j=1}^{k} d_j \, \Delta x_{t-j} + \mu_t \qquad (16)$$

Next, we conduct the ARDL bounds testing approach introduced by Pesaran et al. (2001) to explore the long-run linkage between energy transformation as dependent variable and other independent variables. All the data with the following primary characteristics, represented in Table 2, were gathered from World Bank and BP statistical review of 2020.

Table 1. Primary characteristics of series.

Variables	Unit	Mean	Maximum	Minimum
GDP Growth	%	3.05	13.39	-7.44
Exchange rate	Local Currency Units (LCU) per US$	11428.3	40864.3	1268.07
Energy transition	%	0.93	1.54	0.43
CO2 emissions	Metric tons per capita	6.32	8.38	3.97
Population growth	%	1.27	1.59	1.09
Inflation rate	%	19.32	49.65	8.65

Source: Authors' compilation from World Bank database

According to Table 2, during 1993-2018, Iran's GDP growth has had an average of 3.05%. The highest rate of economic growth was 13.39% in 2016, while Iran experienced the lowest economic growth of -7.44% in 2012. Furthermore, Iranian Rial's value against US $ takes the average of 11428 LCU per US$ over 1993-2018. The Iran's bilateral exchange rate over 1993-2018 takes the maximum of 40864.3 LCU per US$ in 2018 and minimum of 1268.07 LCU per US $ in 1993. Furthermore, the average of energy transformation and CO2 emissions in Iran were 0.93% and 6.32 metric tons per capita over 1993-2018. The general price level of commodities takes the average of 19.32, whereas population in Iran has increased with the average rate of 1.27% over 1993-2018.

Following Taghizadeh-Hesary et al. (2019) who declare the oil-based nature of Iran's economy, Iran economic size highly depends on non-renewable energy sector. Therefore, we can expect that any increase in economic size demotivates renewable energy projects in Iran leading to energy transition reduction in the country. Moreover, it is expected that bilateral exchange rate positively impacts on energy transition in Iran. In other words, Rial's depreciation may increase costs of clean energy projects in the country causing a lower rate of clean energy consumption. Regarding the impact of carbon dioxide emissions on energy transition, our expectation can follow Bilgili et al. (2016) and Bhattacharya et al. (2017) who proved an evidence of positive impact from CO2 emissions on energy transformation. Furthermore, a negative impact of population growth on energy transformation of Iran can be expected because the fact that any increase in population of Iran may become a major factor to aggregate demand raising that requires more consumption of non-renewable energy sources in Iran. Finally, we can expect to find a negative influence of inflation rate on energy transition process in Iran. A higher price of commodities in Iran may lead to higher costs of clean energy projects becoming a major obstacle to substation of fossil fuels with renewable energy sources.

4. Empirical Results and Discussion

As the first step, the Zivot- Andrews structural break test was employed to find out whether there exist structural breakpoints. The results of this test are listed in Table 3 as follows:

Table 2. Findings of structural break test.

Variable	level		D	
	T-stat.	Time break	T-stat.	Time break
GROW	-4.019	1993	-11.428*	2004
EXCH	-2.505	1998	-9.007*	2018
ETRAN	-3.497	2008	-10.382*	2000
CO2	-4.277	2000	-10.433*	1993
POPU	-3.809	2014	-11.382*	2004
INFL	-5.101	2012	-9.099 *	2018

Note: * shows significance of variable at 5% level. D denotes at 1st difference;

Source: Authors' compilation.

The results of the Zivot-Andrews test prove that our series are I(1). Next, we check out the stability of model by conducting CUSUM and CUSUMQ techniques. The results of these two techniques, shown in Fig 4, prove the stability of all coefficients.

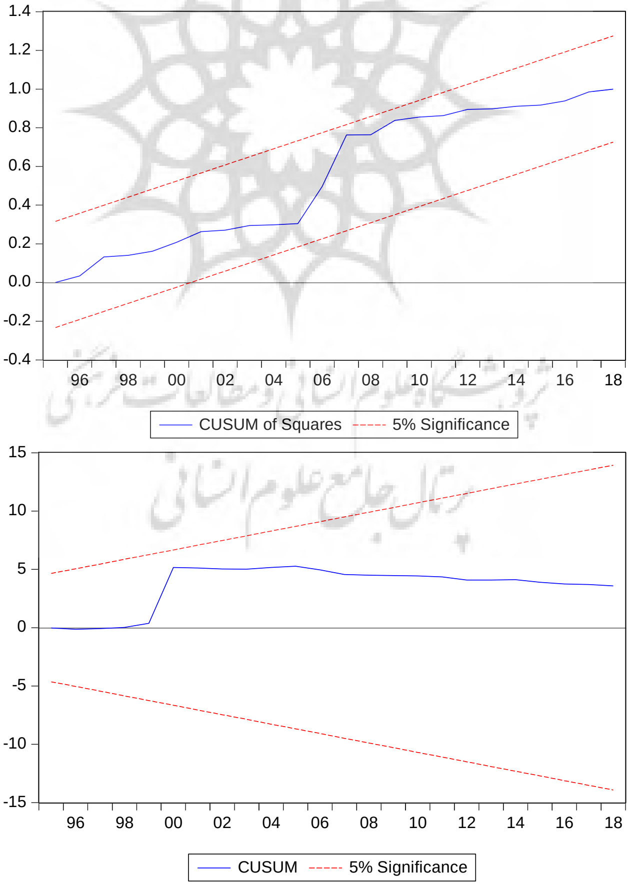

Figure 4. Results of CUSUM and CUSUMQ.

Source: Authors' compilation.

Now we can perform the ARDL bounds testing method which considers the existence of structural break to find out the long-run relationship among series over the period of 1993-2018. This econometric technique needs an appropriate lag length which is determined by the Bayesian information criterion (BIC) here. The results of ARDL bounds testing method for our model are represented in Table 4.

It can be expressed that the calculated statistics are more than upper critical bound at 5% and 1% levels, hence we can consider energy transformation, economic size, bilateral exchange rate, carbon dioxide emissions, growth in population number and price level of commodities as predicted variables. Moreover, the findings of ARDL bound testing depicted that our variables become cointegrated for a long-run relationship between energy transformation, economic size, bilateral exchange rate, carbon dioxide emissions, growth in population number and price level of commodities in Iran's economy.

Table 3. Results of ARDL bound technique.

Estimated models	Optimal lag length	Structural break	F-stats.
F_{GROW} (GROW|ETRAN, EXCH, CO, POPU, INFL)	5,5,5,5,5,6	1993	3.593**
F_{ETRAN} (ETRAN|GROW, EXCH, CO, POPU, INFL)	5,5,5,5,5,5	2009	3.616**
F_{EXCH} (EXCH|GROW, ETRAN, CO, POPU, INFL)	6,5,5,5,6,6	1997	4.728*
F_{CO} (CO|GROW, EXCH, ETRAN, POPU, INFL)	5,5,5,6,6,6	1997	4.639*
F_{POPU} (POPU|GROW, EXCH, CO, ETRAN, INFL)	5,6,6,6,5,5	2014	2.322
F_{Infl} (INFL|GROW, EXCH, CO, POPU, ETRAN)	5,5,5,5,5,5	2009	1.932
Significant level	Lower bounds I (0)	Upper bounds I (1)	
1% level	2.84	3.97	
5% level	2.32	3.38	
10% level	1.83	2.87	

Note 1: * and ** show significant at 1% and 5% at levels.

Source: Authors' compilation

Based on the existence of long-run linkage among variables, as reported in Table 4, we explore marginal impacts of economic size, bilateral exchange rate, carbon dioxide emissions, growth in population number and price level of commodities on energy transformation in Iran's economy. The results are represented in Table 5:

Table 4. Results of estimating coefficients.

Dependent variable	-	Explanatory variables	Coefficient	Prob.
Energy transition	Long-run	GROW	-0.115	0.02
		EXCH	0.028	0.00
		CO_2	0.428	0.02
		POPU	-0.214	0.05
		INFL	-0.229	0.00
Energy transition	Short-run	GROW	-0.012	0.00
		EXCH	0.011	0.00
		CO_2	-0.163	0.02
		POPU	-0.044	0.00
		INFL	-0.179	0.01
Short-run diagnostic tests				
Test	F-stats		P-value	
Chi-2 Arch	2.618		0.21	
Chi-2 White	1.229		0.21	
Chi-2 Ramsay	1.449		0.19	

Source: Authors' compilation

Regarding the short-run impacts, the estimations revealed negative impact of economic size on energy transformation of Iran. A 1% increase in GDP growth of Iran may accelerate energy transformation process in the country by nearly 0.12%. Moreover, exchange rate has negative coefficient meaning that by 1% depreciation in Iranian Rial, the energy transformation process in the country decreases by approximately 0.01%.

- The results confirm that CO2 emissions have negative short-run contribution to energy transition in Iran. A 1% increase in this variable leads to decrease of energy transition in Iran by nearly 0.16%.
- The short-run impacts of population growth and inflation rate on energy transition movement in Iran are negative and a 1 percent increase in them is linked to a 0.04% and 0.17% reduction in energy transition, respectively.

ii) Long-run analysis

- Iran's economic growth has negative and statistically significant long-run impact on energy transition process of the country. The estimation inferred that a 1% increase in economic growth is linked with a 0.11 decrease in energy transition of Iran. The main reason may be the oil-based economic structure of this country which links economic growth and non-renewable energy resources.
- The long-run relationship between exchange rate and energy transition in Iran is found to be positive. Meaning that 1% appreciation of Iranian Rial against U.S. Dollars leads to increase of energy transition process in the country by nearly 0.028%.
- Our empirical estimation showed that any increase in CO2 emissions has negative and statistically significant impact on energy transition in Iran. A 1% increase in CO2 emissions leads to increase of energy transition by approximately 0.42%. In other words, Iranian policy makers consider substitution of fossil fuel consumption with renewable ones (green energy resources) as a solution for air pollution.
- Finally, both population growth and inflation rate have long-run negative and statistically significant impact on energy transition process in the Iran. A 1% rise in population and price level of commodities and services in Iran is linked with a 0.21% and 0.22% decrease in energy transition.

5. Conclusion and Implications

This paper attempted to investigate the effects of various variables, i.e. economic growth, exchange rate, CO2 emissions, population growth and inflation rate on energy transition (consumption of renewable energy resources to consumption of non-renewable ones) in case of Iranian economy over the period of 1993-2018. To this end, we conducted the ARDL bounds testing method to cointegration to check cointegration among the series in the presence of structural breaks for long-run. Our findings of ARDL bounds testing approach proved that our variables are cointegrated for long-run linkage. The empirical estimations revealed long-run negative impact of economic growth, population growth and inflation rate on energy transition of Iran, while CO2 emissions and exchange rate have positive impacts on energy transition movement in the country. Furthermore, we found out that in the short-run the relationship between energy transition improvement and economic growth, CO2 emissions, population growth and inflation rate is negative, while exchange rate is the only variables accelerate energy transition in the country.

In addition, we found out that the magnitudes of impacts of variables on energy transition in Iran are stronger in long-run rather that in short-run. Hence, Iran's policy makers should draw attention to the long-run energy plans in the country. Furthermore, lowering dependency of national budget to the oil and gas revenues would be a useful policy to reduce negative impact of economic growth on energy transition movement in the country. Another recommendation is to determine rapid decarbonizing policies in the country. Since we have found short-run negative and long-run positive effect of CO2 emissions on energy transition, it is suggested to make short-run climate change policy besides the long-run one. In line with our findings, we can point out the efficiency of sustainable energy transition planning in Iran which helps the country to provide sustainable and reliable pathways to move from fossil fuels to renewable energy sources. In addition, conducting feasibility of using green energy resources such as wind and solar can be a good research fields helping policy makers to make the best decisions.

Overall, it is recommended to future studies to compare energy transition model of Iran with other nations. Furthermore, using new control variables such as interest rate would make a new insight for scholars.

References

Aryanpur, V., Atabaki, M.S., Marzband, M., Siano, P., and Ghayoumi, K.2019. An Overview of Energy Planning in Iran and transition Pathways Towards Sustainable Electricity Supply Sector. Renewable and Sustainable Energy Reviews. 112: 58-74.

Bhattacharya, M., Churchil, S.A., and Paramati, S. 2017. The dynamic Impact of Renewable Energy and Institutions on Economic output and CO2 Emissions Across Regions. Renewable Energy. 111: 157-167.

Bilgili, F., Kocak, E., and Bulut, U. 2016. The dynamic Impact of Renewable Energy Consumption on CO2 Emissions: A Revisited Environmental Kuznets Curve Approach. Renewable and Sustainable Energy Reviews. 54: 834-845.

BP. 2019. Statistical Review of World Energy 2019. URL: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf [accessed data 19.11.2019]

Chapman, A., and Itaoka, K. 2018. Energy Transition to a Future Low-Carbon Energy Society in Japan's Liberalizing Electricity Market: Precedents, Policies and Factors of Successful Transition. Renewable and Sustainable Energy Reviews. 81 (Part 2): 2019-2027.

Chen, B., Xiong, R., Li, H., Sun, Q., and Yang, J. 2019. Pathways for Sustainable Energy Transition. Journal of Cleaner Production. 228: 1564-1571.

Ghorbani, N., Aghahosseini, A., and Breyer, Ch. 2017. Transition Towards a 100% Renewable Energy System and the Role of Storage Technologies: A Case Study of Iran. Energy Procedia. 135: 23-36.

Hafeznia, H., Pourfayaz, F., and Maleki, A. 2017. An Assessment of Iran's Natural Gas Potential for Transition Toward low-carbon Economy. Renewable and Sustainable Energy Reviews. 79: 71-81.

Kraan, O., Chappin, E., Kramer, G., and Nikolic, I. 2019. The Influence of the Energy Transition on the Significance of Key Energy Metrics. Renewable and Sustainable Energy Reviews. 111: 215-223.

Pesaran, M.H., Shin, Y., and Smith, RJ. 2001. Bounds Testing Approaches to the Analysis of Level Relationships. Journal of Applied Econometrics.16:289–326.

Taghizadeh-Hesary, F., Yoshino, N., and Rasoulinezhad, E. 2019. Trade Linkages and Transmission of oil Price Fluctuations. Energy Policy. 133: 1-10.

Tavana, A., Emami Javid, A., Houshfar, E., Mahmoudzadeh, A., Ashjaee, M., Shoaee, S., Maghmoomi, A., and Marashi, F. 2019. Toward Renewable and Sustainable Energies Perspective in Iran. Renewable Energy. 139: 1194-1216.

Vainio, A., Varho, V., Tapio, P., Pulkka, A., and Paloniemi, R. 2018. Citizens' Images of a Sustainable Energy Transition. Energy. 181: 606-616.

World Bank Country Profile, https://data.worldbank.org/country/Iran

World Bank Development Indicators (WDI). URL: datatopics.worldbank.org/world-development-indicators/ [accessed on 08.07.2019]

Yazdanpanah, M., Komendantova, N., and Shafiei Ardestani, R. 2015. Governance of Energy Transition in Iran: Investigating Public Acceptance and Willingness to Use Renewable Energy Sources Through Socio-Psychological Model. Renewable and Sustainable Energy Reviews. 45: 565-573.

Zivot E, Andrews D. 1992. Further evidence of great Crash, the Oil Price Shock and Unit Root hypothesis. Journal of Business and Economic Statistics, 10:251–70.