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The Nonlinear Impact of Energy Consumption on Economic Growth and Emission in Iran, Smooth Transition Regression Model

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ABSTRACT

The present study investigates the effect of energy consumption on economic growth and emission through applying non-linear framework, STR† and TAR‡, using the annual data from 1969 to 2017. Therefore, impact of energy consumption on economic growth and emission have been tackled using two models. In both, energy consumption causes the breakpoint and effects of included variables are depending on the value of energy consumption. Discussing the economic growth, the growth fossil fuel energy consumption variable is considered as a transition variable at 12 percent value. For emission beside the energy variables, total population used as control variable and for economic growth, physical capital. The prominent point in this framework is that in both of them, the fossil fuel consumption growth variable has been chosen as threshold variable which is in fact policy making variable. Due to asymmetric impacts of included, variables on emission and economic growth which both are highly crucial, nonlinear approach capture the dynamics much better and gives clear descriptions to policy maker on how to react according to the state's economy is in.

1. Introduction

Energy is one the most significant factor in production which plays an important role in the economic development and improvement of countries all over the world. The economic growth highlights the role of energy more and more significantly. The changes in the history of energy demonstrated that the pace of growth and economic development of countries depends on efficient energy consumption (Ockwell,2008). Energy sources are limited and exhaustible. Also, emission and problems caused by that made energy consumption more significant for energy suppliers. The ancillary issues of consumption and the demand for energy has had a profound effect that almost no country is ignorant of it.

It is worthy of mention that the energy resources can be effective in the development of the countries if they

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† Smooth transition regression
‡ Threshold Auto regressive

are used in efficient and optimal way. The inefficient use of energy resources leads to some deficiencies in other parts which brings bout lack of development in the process of economic growth. Therefore, it is vital to accept that energy has leading role in economy and economic growth which makes it inevitable to preserve and take advantage of energy resources in the best way.

Many researchers had studied the cause and effect relation between energy consumption and also determining the direction of the relationship since the emergence of oil shocks in 1970s. Besides the price fluctuations and scarcity of energy resources, the environmental issues are other factors which necessitate the urge to investigate the relation between energy production and consumption. Global warming caused by green gases can be on these factors (Ito,2017). In recent years, there has been some treatments such as Kyoto Protocol to control this issue among different countries. The purpose of all these treatments and protocols is to decrease the amount of green gas production such as CO2. However, the rate of production of these pollutants has a direct relation to energy consumption (Biligli, 2016) and energy is one the factors of production and an important drive in economic growth. Consequently, by controlling the production of pollutants, the economic growth of countries will decrease which contradicts the goals of countries (Mazini et, al. 2015).

The relation between energy consumption and economic growth is of paramount importance in the economy of countries. Iran, as a developing country, is rich in oil resources, enormous mines and has potential for other sources of energy. Iran is considered as one the examples of growth framework dependent on natural resources. As a result, it is indispensable to stick to an exact program and plan to produce and consume energy (Mohamadi et, al. 2013). The previous studies ignored the non-linear behavior which were caused by structural failure. Investigation of the consumption of energy conduits in Iran revealed one or several failures. There are some structural failures in different intervals. In order to investigate the relation between energy consumption and economic growth, it is necessary to consider the nonlinear behavior, as well. The present study aims at investigating first the effect of energy consumption on economic growth and second, the effect of energy consumption on emission.

2. Theoretical Literature Review

In recent years, there has been substantial discussions about the environmental issues caused by energy consumption and the use of alternative energy resources in developed and developing countries. However, the decrease in the oil price and the high prices of renewable energy sources especially for developing countries demonstrates that the relation between energy consumption, energy price and opportunities for economic growth is of utmost importance. In fact, energy is considered as an important factor in economic growth because it has a direct effect on goods production (Stern,2000). Also, it is one the fundamental resource for industry and a significant factor for domestic uses of energy. The role of energy consumption for economic growth and vice versa is related to policy making because there is a positive relation between energy consumption and the related price and growth caused by that can have an adverse effect on economic growth. On the other hand, reinforcement of growth policy especially in countries who have constraints for the use of renewable energy sources may have serious consequences for environment. Also, it may endanger the effects of perseverance policy of environment (Carfora et, al., 2019). After the first paper published by Kraft and Kraft (1978), there has been increasing interest in investigating the cause and effect relation between energy and economic growth (Apargis & Payne, 2010, Biorndal et, al., 2010).

Numerous studies have been conducted on the relationship between economic growth, energy consumption and carbon dioxide emissions. In one of these studies, a multivariate model including economic growth, energy consumption, carbon dioxide emissions, capital stock, labor force and urban population during the period 1350-1384 in the Iranian economy has been used. Then, using the Toda Yamamoto econometric approach, causality between variables is determined. The results show that there is a two-way causal relationship between GDP growth and carbon dioxide emissions. Also, there is a causal relationship between energy consumption and carbon dioxide emissions. The existence of a humane relationship between GDP growth and carbon dioxide emissions shows that the environmental hypothesis (Kuznets) is true in Iran (Fotros, 2011).

Also, Energy as an important production factor has significant effects on economic growth. Identifying the relationship between energy and economic growth can help to improve governmental energy policies. Amadeh et al (2009) examines the longrun and shortrun causality relationships between (1) energy consumption and economic growth and (2) energy consumption and employment in various economic sectors of Iranian economy for the period 1971-2003. The results show that there is a longrun and shortrun unidirectional causality relationship from energy consumption to economic growth, a shortrun unidirectional causality relationship from economic growth to natural gas consumption, a unidirectional causality relationship from energy consumption to value added in industrial sector and shortrun and longrun unidirectional causality relationship from electricity consumption to value added in agricultural sector(Amadeh et all, 2009)

Explain the relationship between energy consumption and economic growth can play a significant role in setting and adjustment of policies on energy sector. Given the close relationship between Energy consumption and economic growth in Iran, determination of quality of the relationship between these two variables helps effectively to explain of policies of the energy sector. Damankeshideh et al (2013) used the data on GDP and energy consumption for Iran Twenty-year outlook selected countries during the years 1990-2009. Panel data were used in this model. The results of this study show that there are significant and positive relationship between economic growth and energy consumption in Iran Twenty-year outlook selected countries.

According to different economics schools, the factors influencing the economic growth include: the capital and labor both the professional and unprofessional. In the new framework of growth, energy has been added. However, it isn't equally important as others. For instance, Brent and Wood (1979) in their study concluded that in the total production function, energy is the factor of production which has a separable and poor relation with work force. The function is as follows:

$$Q = F(G(K.E), L)$$

They believe that energy and capital combine and create the production factor G. then, they are combined with work for goods production. Therefore, labor is combined with G not with capital and energy, separately. However, some neoclassic economists such as Brent and Denison believe that energy has a little role in production and it is just a mediating factor and labor and field are the only significant factors (Stern, 1993).

On the other hand, some economists believe that energy is constant in nature. It is renewable and changeable to material and it never disappears. Therefore, in the biophysical growth model which were created by Ayres and Nair (1984), it is expressed that the production of economic goods requires substantial amount of energy. Therefore, energy is the only and most important factor in production. The labor and capital are just mediating factors which need energy to be applied (Stern, 1993). Consequently, if production is considered as a function of capital, labor and energy, the following appears:

$$Q = f(K, L, E)$$

In this relation, Q is the GDP, K is the capital input, L the labor input and E stands for energy. Also, it is presumed that there is direct relation between the amount of the use of the input and the production level. In other words, the increase in any of them leads to the increased in production. Mathematically, it is:

The Energy input can be provided by different common energy carriers such as oil, gas, electricity, coal, and etc. therefore, the relation between variable can be summarized as the following:

- Energy consumption had a positive and significant effect on economic growth.
- Energy consumption has a negative and significant effect on emission.

The influential paper by Asafu (2000) focused on the cause and effect between energy consumption and growth in four Asian countries, India, Indonesia, the Philippines, and Thailand. The results were contrary in different countries in short and long term. The results of the study revealed that the growth was evident in long term in India and Indonesia while the feedback hypothesis is true for Thailand and the Philippines. Applying the null hypothesis Granger Casualty was confirmed in short term in Indonesia and India.

After Asafu (2000), there has been countless studies which tried to present evidence to show that there is a cause and effect relationship between energy consumption and economic growth which focused on one group in several countries in different development levels (Mahadevan & Asef, 2007, Apargis & Payne, 2011) or some individual countries (Abbasi & Choudhury ,2013,Gurgul & Lack, 2013) or some economic areas (Romano & Scandura, 2011). More recent studies have considered more variables such as consumption of renewable energy resources (Al Mulali et al., 2014, Apergis et al., 2013, Tang and Shahbaz, 2013) and some other extra control variables (Niu et al., 2013). Recently Mann and Sephton (2018) repeated the paper by Asafu. They added time series approach to unit root tests and co-integration to the traditional co-integration test. Therefore, the present study aims at investigating the effect of non-linear energy consumption on economic growth and emission.

We illustrate our model based on the conventional neoclassical one-sector aggregate production function (referred to as Linear Model 1 hereafter), which represents the relationship between energy consumption and real GDP (Pokrovski, 2003; Lee, 2004; Nourzad, 2000) [47–49]. Thus, we consider the following general production fun0ction:

$$Y_t = F(L_t, K_t, A_t) = A_t^{\alpha} L_t^{\beta} K_t^{\gamma};\ \alpha, \beta, \gamma > 0 \quad (1)$$

Where Y is real output, L is the aggregate labor force, K is the aggregate real capital stock, and A is a measure of technology. In considering the assumption broadly, both the energy consumption and the export sector are likely to have a technological progress effect on economic performance (Feder, 1982). We assume that the effect is multiplicative, and that the growth rate of real output is given by

$$GY_t = \beta_0 + \beta_1 GK_t + \beta_2 GL_t + \beta_3 GEC_t + \varepsilon_t \quad (2)$$

Where GY is the growth rate of real GDP, GK is the growth rate of the real capital stock, GL is the growth rate of the labor force, and GEC is the growth rate of total energy consumption. The term ε_t is assumed to be a Gaussian white noise error process with constant variance. This specification is, however, relatively ad hoc.

We can further consider the two-sector model (Linear Model 2 hereafter) of the economy, which is propounded by Feder (1982), in order to study the effect of the export sector on economic growth. By reformulating the model using an energy sector instead of the original export domestic sector division, a specification for the assessment of the energy-growth nexus which is empirically tractable can be found. The model is set up as follows. Assume that the economy is composed of two sectors—the energy sector (G) and the non-energy sector (C). The production functions of both sectors are expressed as follows:

$$C = C(L_C, K_C, \quad (3)$$

$$G = G(L_G, K_G \quad (4)$$

$$Y=C+G \quad (5a)$$

$$L_C + L_G = L, \quad (5b)$$

$$L_C + L_G = L, \quad (5b)$$

$$K_C + K_G = K, \quad (5c)$$

$$\frac{G_L}{C_L} = \frac{G_K}{C_K} = 1 + \delta. \quad (6)$$

Eq. (3) indicates the production function of the Nonenergy sector and Eq. (4) is the production function of the energy sector. Eq. (5a) provides that total output (Y) is the sum of C and G, and Eq. (5b) shows that the total labor force (L) is the sum of the non-energy labor input (L_C) and energy labor input (L_G). Eq. (5c) indicates that the total capital stock (K) is the sum of non-energy sector capital input (K_C) and energy sector capital input (K_G). Eq. (3) says that energy sector output (G) creates an externality effect to non-energy sector output (C).

In order to understand the difference in the marginal productivities of the factor input in the two sectors, $G_L = \frac{\partial G}{\partial L}$ in Eq. (6) indicates the marginal production of labor input in the energy sector, $C_L = \frac{\partial C}{\partial L}$ indicates the marginal productivity of the labor input to the nonenergy sector, $G_K = \frac{\partial G}{\partial K}$ is the marginal productivity of capital input in the energy sector, and $C_K = \frac{\partial C}{\partial K}$ is the marginal productivity of the capital input in the non-energy sector.

We take the totally differentiated Eqs. (3) and (4) and put the results into Eqs. (5a) and (5b), which are total differentials. From Eq. (6), we can then conclude that

$$dY = C_L dL + C_K dK + C_G dG + \frac{\delta}{1+\delta} dG. \quad (7)$$

$$\dot{y} = \alpha_0 + \alpha_1 \dot{k} + \alpha_2 \dot{l} + \alpha_3 \dot{g} + u_t^* \quad (8)$$

According to the growth theory, α_1 and α_2 are both positive coefficients given that the investment rate and labor force growth have a positive impact on the real aggregate output growth. In addition, we identify the multiple effects through the sign of α_3. This indicates that the energy sector has a reciprocal effect on economic growth through two ways: one is the direct contribution of the energy sector and the other is the indirect effect of the energy sector through the non-energy sector (the externality effect)(Lee and Chang, 2007)

3. Environmental Kuznets Curve

Recent studies revealed that there is U-shape relation between the quality of environment and the level of income per capital. This phenomenon was called Environmental Kuznets Curve in economy. The analyses have demonstrated that in the beginning phase of the economic growth, the quality of environment reduced.

However, as soon as the income goes beyond the definite level, the quality of environment increases, too. This idea which indicates that economic growth leads to the improvement of the environment has contributed to the idea that economic growth is the most necessary and convenient way to preserve and improve the environment. In fact, the environmental issues have been temporary because the economic growth and technological innovations manage to solve the environmental problems. On the other hand, some believe that there is no reason to agree that there is automatic relation between the environment quality and income. There is no reason to agree that economic growth can be a perfect alternative for environmental policies. Also, the environmental issues have been different in different countries which brings about the idea that there are some other variables apart from income can be influential on environment.

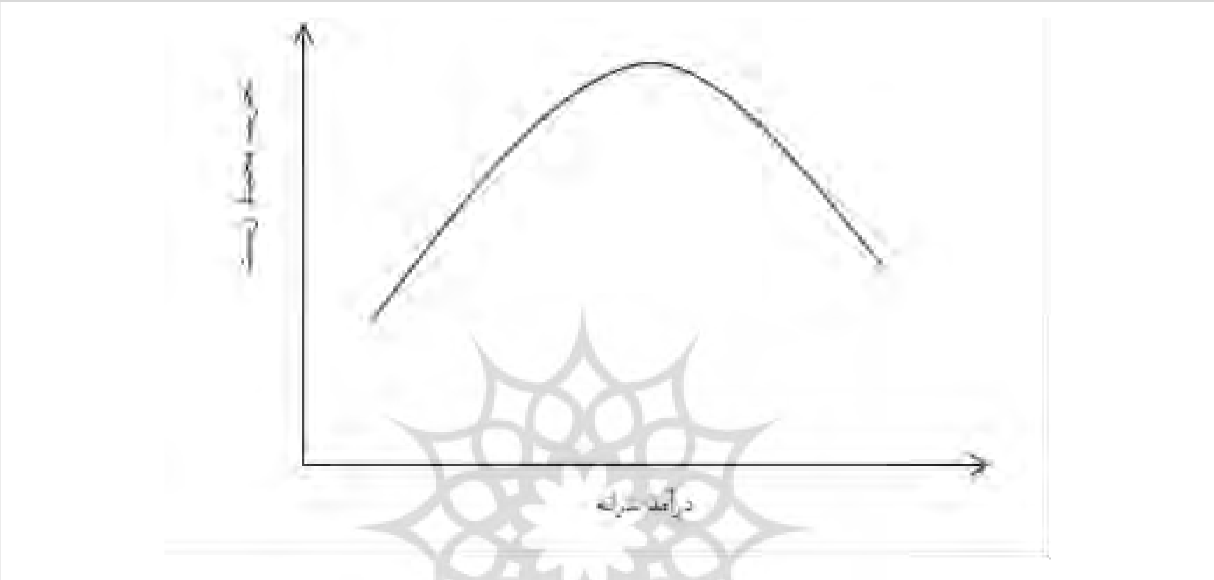

Figure 1. Environmental Kuznets curve.

The point is that the more contribution in the process of development (which means the literate people, the more information and the more equality), the more demand will be for the quality of environment.

On the other hand, the demand for environmental facilities (or the quality of environment) has more elasticity that income. According to economy literature, the relation between the income level and the environmental facilities in developed countries depends on the evolution of supply and demand for measures to preserve the environment. Economic expert believe that the environment is a commodity with high elasticity compared to income. Based on this assumption, in the process of development, people find the quality of environment important and can guarantee the execution of environmental instruction through political pressure leverage or the increase of governmental expenditure. In other words, the economic growth (because of the elasticity for the supply of environmental facilities) and having access to the information can guarantee the execution of policies related to environment. However, the income supply elasticity for environmental facilities and the effect of availability of information on the quality of environment have to be tested because the increase of income per capital does not necessarily mean the increase of the income for the average class of people. It means that if there is lack of proper income distribution, the economic growth mad lead to reduction of demand for the perseverance of environment. Also, high income does not necessarily accompany with having access to information or higher education. Meanwhile, these two have a major role in promoting the awareness of the society to the environmental issues. From the analyses and studies, it can be concluded by economic growth, the perseverance of environment increases, as well.

Some countries are willing to follow the U-shape the path, but it shouldn't be concluded that economic growth cannot replace the environmental policies completely. Environment perseverance requires proper and right environmental policies. Also, it cannot be dependent on only on income variable. In fact, the only way to guarantee the stable development is to increase the level contribution. In other words, people's contribution paved the way for stable development in the process of development which cannot be achieved without giving freedom to people. These days, it is believed that improvement of income distribution, education and having access to information are the necessary requirements to guarantee the stable growth (Dinda, 2004).

4. Empirical Background of the Study

Danish and Wang (2019) investigated if the biomass energy consumption can help to control the emission. For this purpose, they used the annual data from Brazil, Russia, India, China, and South Africa from 1992 to 2003 and they applied generalized method of moments. The results revealed that the biomass energy consumption can reduce the emission. Also, this investigation demonstrated the N-shaped relation between income and pollution. Moreover, the business freedom is the only pollutant in the above-mentioned countries.

Huang and Huang (2019) tried to investigate the individual new energy consumption and the economic growth in China. They used the annual data in china from 2004 to 2017 and applied ARDL[1] model. The results indicated that the individual new energy consumption had a positive impact on the economic growth. Also, urbanization rate, export, import and foreign direct investment had impact on the individual new energy consumption. The cause and effect test revealed that there is one-way causality from the individual new energy consumption to the economic growth and from the urbanization rate and from export and import to the energy consumption.

Tuna and Eder Tuna (2019) studied the asymmetric causality relation between the nonrenewable and the economic growth in five countries such as, Indonesia, Thailand, Singapore, the Philippines, and Malaysia. They used the annual data from 1980 to 2015. They used the J test from Hocker and Hatmi (2006) to investigate the causality of symmetry and applied the J test from Hatmi (2006) for a test of causality. According to the J test from Hocker and Hatmi (2006), there is no relation between the nonrenewable energy consumption and the economic growth. However, the J test from Hatmi (2006) revealed that there is a significant relation between the nonrenewable energy consumption and the economic growth.

Shokohifard et.al. (2017) conducted a study on the effect of economic growth, energy consumption and financial development on emission from 1986 to 2016. First, they extracted the environmental Kuznets curve and investigated it. The emission model was investigated by new methods of econometrics such as the dynamic framework and by the explanation from Johansen Juselius co-integration method. The results indicated that there is a positive relation between income per capital variable and emission. There is a negative relation in the square between income per capital and emission. Therefore, the environmental Kuznets hypothesis can be accurate for Iran and Iran is located in the rising part of the environmental Kuznets curve. There is a positive relation between the oil products consumption and the environmental pollution. However, there was no significant relation between financial development and economic openness with emission.

Mehrara et. al., (2016) carried out a research on the effect of energy consumption on the economy of Iran applying the Bayesian model of average. In this study, they tried to investigate 16 variables influencing the economic growth 1961 to 2014. The results revealed the first to fifth factors in the economic growth are GDP ratio, population growth rate (negative), the increase in the import of capital commodity, the workforce growth, and the increase in the import of intermediate goods, respectively. On the other hand, there is no significant relationship between energy consumption and non-oil GDP growth in Iran. Therefore, the economic policies in energy consumption is not considered as threat to the economic growth.

Kohansal and Shayanmehr (2017) carried out a research in order to investigate the interaction between energy consumption, economic growth, emission and the spatial communication among nine developing countries applying spatial synchronous equations framework for panel data with random effects from 2000 to 2011. The results indicated that energy consumption, economic growth, and emission in each country are affected by energy consumption, economic growth, and emission of the neighboring countries. Also, the results of this study demonstrated that there is a two-way cause and effect relationship between economic growth, emission, and emission and energy consumption, as well. Consequently, there is a two- way relationship between economic growth and energy consumption. The results of the study implied that in order to achieve stable economic growth, it would be ideal to use tax tools to

[1] Autoregressive Distributed Lag

decrease the emission of greenhouse gases and also replacement of renewable energy with fossil energy.

5. Estimation and Empirical Results

This part is devoted to estimation and interpretation of the results. To this end, the annual data from 1369 to 2017 were used. The investigated variables in this study are as follows: capital [1] (Cap), fossil fuel energy consumption [2] (EC), electricity consumption [3] (Elec), emission [4] (EM), Growth Domestic product [5] (GDP), population [6] (Pop). After the relationship between variables and estimation of model, the stationary of the above-mentioned variables had to be tested. Therefore, the stationary of all the variables in the model were tested applying Philips and Perron unit root test. According to the test, the included variables are stationary and all are integrated at zero degree.

Table 1. Unit root test.

Decision	Critical value (1%)	PP (-1)	PP level	Explanation	Variable
I(1)	-4/18	-8/20	-1/88	Capital	Cap
I(1)	-4/18	-5/33	-1/99	Labor	Labor
I(1)	-4/18	-6/76	-0/88	Fossil fuel energy consumption	EC
I(1)	-4/18	-6/03	2/06	Electricity	Elec
I(1)	-4/18	-6/10	-1/32	Emission	Em
I(1)	-4/18	-5/57	-1/09	Growth Domestic product	GDP
I(2)	-4/18	-2/51	-0/81	Population	Pop

Source:rAuthors' Calculations

Levels of variables (including energy consumption logarithm, real GDP, capital) have been tested by co-integration test. It is proved that there is long-term relation among the variables. According to Granger theorem, long term equilibrium relation requires the inclusion of mechanism or error correction patterns. In fact, the error correction mechanism guarantees the achievement of long term relation.

Table 2. Trace and maximum eigen values test and co-integrating vectors – economic growth.

Decision	Critical value (1%)	PP first difference	PP level	Explanation	variables
I(1)	-4/17	-5/23	-1/79	GDP Logarithm	Ln GDP

[1] Time series database of central bank
[2] British petroleum data center
[3] British petroleum data center
[4] British petroleum data center
5 Time series database of central bank
[6] Iran Census Center

Decision	Critical value (1%)	PP first difference	PP level	Explanation	variables
I(1)	-4/17	-6/16	-3/07	Energy Consumption Logarithm	Ln EC
I(1)	-4/17	-5/59	-1/99	Capital Logarithm	Ln Cap

Included variables: *log(GDP) ‹log(EC) ‹log(Cap)*							
Deterministic Variables: Constant							
Spatial Co-integration							
Trace Test				Maximum Eigen Values Test			
Critical value 95%	Test value	Alternative Hypothesis	Null Hypothesis	Critical value 95%	Test Value	Alternative Hypothesis	Null Hypothesis
29/73	29/79	r≥1	r=0	21/13	19/54	r=1	r=0
15/49	10/19	r≥2	r≤1	14/26	8/28	r=2	r≤1
3/84	1/90	r=3	r≤2	3/84	1/90	r=3	r≤2
Co-integration Vector							
				log(GDP)	***log(EC)***	*log(Cap)*	
$\mathbf{ecm(log(GDP) - log(GDP*))}$				1/00	0/64	-0/37	

Source: Authors' Calculations

The variable levels (including energy consumption logarithm, real GDP, and Capital) were tested inspired by economic theory and been found out there is a long run relation.

Table 3. Trace and maximum eigen values test and co-integrating vectors – emission.

Decision	Critical value 1%	PP first deference	PP level	Description	variables
I(1)	-4/17	-6/08	-3/20	Emission logarithm	Ln Em
I(1)	-4/17	-6/16	-3/07	Energy consumption logarithm	Ln EC
I(1)	-4/17	-4/29	-0/77	Population logarithm	Ln Pop

Included variables:

log(Pop) ،log(EC) ،log(Em)

Deterministic variables: Constant

Co-integrating Space

Trae Test				Maximum Eigen Values Test			
Critical value 95%	P value	Alternative hypothesis	Null Hypothesis	Critical value 95%	P value	Alternative Hypothesis	Null Hypothesis
29/79	39/39	r≥1	r=0	21/13	22/37	r=1	r=0
15/49	17/01	r≥2	r≤1	14/26	13/84	r=2	r≤1
3/84	3/17	r=3	r≤2	3/84	3/17	r=3	r≤2

Co-integrating Vectors

	log (Em)	***log(EC)***	*log(Pop)*
$\mathbf{ecm}(\mathbf{log}(\mathbf{EM}) - \mathbf{log}(\mathbf{EM}\ *))$	1/00	0/67	0/75

Source: Authors' Calculations

5.1. Estimation of TAR Model, Impact of Energy Consumption on Emission

The first step in the threshold regression framework analysis is defining the optimal threshold, the number of regimes and threshold value. In table 4, the correct threshold variable with the number of regimes and the threshold value have been calculated by information criteria.

Table 4. the number of regimes and threshold value of threshold variable applying information criteria.

Critical value	F Scaled	F value	Threshold Specification Test
18/23	19/45	3/89	Zero VS. One
19/91	5/81	1/16	One VS. Two
Threshold variable: energy consumption growth at 12 percent			

Source: Authors' calculations

As it is evident in table 4, energy consumption growth is selected as the threshold variable for regime fluctuations. The threshold value of energy consumption growth is estimated 12 percent annually. In fact, after passing the energy consumption growth threshold the coefficient of the framework has had some changes in structure.

Table 5. Estimation.

Prob.	Coefficients	Variable
Threshold Variable: fossil fuel energy consumption growth		
Low regime, fossil fuel energy consumption less than 12 percent		
0/3817	0/082091	Constant
0/0000	0/935105	Dlog(EC(-1))
0/2949	-0/008703	Log(POP)
0/0109	0/201217	DLog(ELEC(-1))
High regime, fossil fuel energy consumption more than 12 percent		
0/0269	0/491510	Constant
0/0000	1/455748	Dlog(EC(-1))
0/0108	-0/053061	Log(POP)
0/9808	0/001649	DLog(ELEC(-1))

Prob.	Coefficients	Variable
Goodness of fit		
241/3441=F **0.000=Prob**	$R^2 = 0.97$	DW =2.3579
-6/21 = HQC	-6/0038= SC	-6/325 =AIC

Regarding the estimation of coefficients and their significance, the estimated equations for regimes and significant variables are presented as follows:

Table 6. the Estimation of Equations for emission.

Low regime, fossil fuel energy consumption less than 12 percent
EM_t =0/935105 Dlog$(EC)_{t-1}$+0/201217 Dlog$(ELEC)_{t-1}$
High regime, fossil fuel energy consumption more than 12 percent
EM_t = 0/49151+1/455748 Dlog$(EC)_{t-1}$-0/053061Log$(POP)_t$

Source: Authors' Calculations

The deficiency in the coefficients of variables in both of the regimes reveals the effect of fossil fuel energy consumption variable, electricity use growth and population rate growth on emission in each of the regimes.

Fossil fuel energy consumption growth in low regime with 0.93 coefficient and equals electricity consumption growth with 0.2 coefficient are considered as the most important factors in emissions, respectively. It seems that in low regime fossil fuel consumption growth is the most significant in emissions in short term. Fossil fuel consumption growth and electricity are two important factors in emissions and their significance in low regime is rising. in power plants, fossil fuels such as coal, gas and oil are used to produce electricity. The electricity consumption growth leads to increase in emissions. Producing electricity in fossil fuel power plant which is based on fuel combustion transforms the chemical energy to heat and then the produced heat is used to move turbines and generators. From environmental perspective, the kind of the fuel and the way of energy production are of utmost importance. Fossil fuels such as coal, natural gas, oil and its derivatives such as gas oil and fuel oil are used to produce electricity. The use of natural gas and its derivatives are on the rise in different power plants for technical and environmental reasons all over the world and also in our country. The use of gas for electricity production reduces the problems related to wastes especially solid wastes and semi-solid wastes significantly. Oil gas is used in gas turbines and diesel power plant. Fuel oil is used in thermal power plant especially in cold seasons. the impurities, heavy elements and Sulfur in fuel oil increased the environmental issues and related wastes significantly. The use of nonrenewable energy has adverse and destructive effect on emissions and global warming. Fossil fuels are the source of Sulfur Dioxide (SO2) and Carbon Dioxide (CO2). These elements can be effective in acidification and climate change. The increase in the use of these kinds of energy directly or indirectly in electricity production, the emissions of these gases rises and causes air pollution. It is worthy of mention that fossil fuel consumption growth and electricity have impact on emission in intervals and these variables have delayed impact.

In high regime of high energy consumption growth, fossil fuel consumption growth and population logarithm with 1.45 and -0.05 coefficients are considered as the most important factors in increase or decrease of emissions, respectively. The effect of energy consumption growth in high regime has increased significantly and the increase in the energy consumption growth in high regime had a destructive impact on emissions. The most notable point is the effect of population logarithm on emissions. In most papers and based on theories the co-efficiency was positive, while in this model is negative. it can be concluded that the energy severity in Iran is so high. Apart from the number of people in a family, the marginal population increase does not lead to the rise in energy consumption and it does not have any impact one emissions.

In order to investigate the effect of energy consumption on economic growth based on econometrics model findings, the smooth transitions regression have been applied. Energy consumption has impact on emissions in short term and some changes can be expected by reducing the consumption while the effect of energy consumption on economic growth with regard to the real part of economy and economic growth can be time-consuming. Therefore, the speed parameter for the economic growth model is far less than emissions model. Consequently, threshold model which includes regime fluctuations quickly is used for emissions model and smooth transition regression is applied for economic growth.

5.2. Estimation of STR Model, Impact of Energy Consumption on Economic Growth

The first step in the estimation of STR model is defining the optimal time for changing the model. For this end, with regard to 8 lags and by the means of significance of the driven information criteria in the optimal lag length criteria test are determined. According to the optimal lag, for capital variable (CAP), fossil fuel energy consumption growth (EC) and electricity consumption growth (ELEC) were specified. It must be noted that in this model the capital growth logarithm or capital is used.

After determining the optimal lag for the included variables, the next step in the estimation of STR model is the test to determine the non-linear relation among variables. If there is a non-linear relation, there must be proper transition variable and the number of non-linear model regimes based on F test, F2, F3, and F4. The results have been presented in table 7.

Table7. the model and transition variable.

Suggested Model	F_2 Prob.	F_3 Prob.	F_4 Prob.	F Prob.	Transition Variable
LSTR1	-03e6/9390	-01e1/1139	-01e3/8990	-03e4/8497	$DLOG(CAP)_t$
LSTR2	-02e6/3283	-03e1/8677	-01e1/1139	-03e1/2171	$DLOG(EC)_t$ *
LSTR1	-03e2/7034	-02e1/8019	-01e6/6084	-03e8/7877	$DLOG(ELEC)_t$
LSTR1	-03e3/3259	-01e5/9279	-01e1/3101	-02e2/3071	$DLOG(CAP)_{t-1}$
LSTR2	-01e7/3710	-04e2/2798	-01e4/7617	-02e1/1341	$DLOG(EC)_{t-1}$
LSTR2	-01e3/8938	-03e3/9687	-01e2/2713	-02e1/5758	$DLOG(ELEC)_{t-1}$
LSTR1(refuting second hypothesis H02)	Non-linearity of two regimes with one threshold value		$H_{02}: \beta_1 = 0 \mid \beta_2 = \beta_3 = 0$		

Suggested Model	F_2 Prob.	F_3 Prob.	F_4 Prob.	F Prob.	Transition Variable
LSTR2(refuting second hypothesis H_{02})	Non-linearity of three regimes with two threshold values			$H_{03}: \beta_2 = 0 \mid \beta_3 = 0$	
LSTR1(refuting second hypothesis H04)	Non-linearity of two regimes with one threshold value			$H_{04}: \beta_3 = 0$	
Linear (in case not refuting linearity)	Linearity without threshold value			Non-existence of non-linearity	

Source: Authors' calculations

Regarding the output of the model, the suggested model is in the form of STR which is used in this part. The next step is to select the proper transition variable among other transition variables for n0n-linear model. For this end, any potential variable can be selected, but the priority is with the transition variable which the null hypothesis is strongly refuted with F test. Accordingly, the most proper transition variable, DLOG(EC)t, the first lag of fossil fuel energy consumption and smooth transition regression model with the logistic transition function LSTR1.

Next, the parameters of model were estimated by applying the Newton-Raphson Algorithm. The results have been presented in table8. It is worthy mention that those variables both linear or non-linear are considered which are significant statistically.

Table8. Estimation of Results.

Coefficients θ	Coefficients ϕ	variable
-0/50373	-0/05708	CONST
0/84777	0/01349	$DLOG(CAP)_t$
-3/55750	0/76158	$DLOG(EC)_t$
1/04353	0/18107	$DLOG(ELEC)_t$
-0/14977	0/09806	$DLOG(CAP)_{t-1}$
3/23831	0/20960	$DLOG(EC)_{t-1}$

Significant at 99%, significant at 95 %, significant 90%

Source: Authors' Calculations

Table 9. Regime equations.

Low regime, the fossil fuel energy consumption is less than 12 percent.			
$DLOG(GDP)_t = 1.18426(DLOG(ELEC))_t + 0/09973(DLOG(CAP))_{t-1}$			
High regime, the fossil fuel energy consumption is more than 12 percent.			
$DLOG(GDP)_t = 0.84777(DLOG(CAP))_t + 3/55750(DLOG(EC))_t$			
SC	HQ	AIC	R^2adjusted
-4/6559	-5/0641	-5/3047	69%

Source: Authors' Calculations

After the transition variable had been chosen, the first lag of fossil fuel consumption growth, the tow regime for high fossil fuel energy consumption growth and low fossil fuel energy consumption growth have been identified separately. The threshold value for the change of regime in gossil fuel energy consumption growth is 12 percent. As mentioned in the methodology of the research, in first regime G=0 and in second regime G=1. As a result, the following equation is defined:

Since the variables are calculated based on the growth rate, the coefficients demonstrate the short term effect. The differences in coefficients in both of the regimes indicate that fossil fuel consumption growth, electricity consumption growth, and capital have different impact on the economic growth in each of the regimes. In low regime of fossil fuel consumption growth, the electricity growth flow variables and capital are significant at 5 percent level. In high regime of fossil feul consumption growth, the coefficients of flow variables of capital and fossil fuel consumption at 5 percent level are significant. The co-efficiency for capital in low regime is 0.09973 which means that if we increase the capital by 10 percent, it causes the economic growth to increase by 0.9973 percent. In high regime, the co-efficiency is 0.84777 which means that the economic growth increases by 8.4777 percent. Capital is one the variables that enter the production equation and growth models and it can increase the production level in short term and long term. Therefore, it is believed that capital has a positive effect on the economic growth in economic theories. However, since production requires huge amount of energy and the energy in different parts of economy is high in Iran, in high regime of fossil fuel energy consumption and low regime of fossil fuel energy consumption when the energy growth is less that 12 percent, capital and fossil fuel energy are not convergent, the capital cannot have strong impact. On the other hand, when the energy consumption growth is more than 12 percent and it is high regime, the impact of capital increases which is rooted in the nature of economic activities in production units in Iran.

In low regime of fossil fuel energy consumption, the electricity consumption co-efficiency equals with 1.18426. if the electricity increases by 10 percent, it will cause the economic growth increase by 11.8426 percent. In low regime of fossil fuel consumption, alternative energies are selected in the process of production. Since electrical and industrial machines have been widely used in production in recent years, it can cause electricity consumption to increase as well which leads to economic growth. However, in high regime of fossil fuel consumption growth, production uses cheaper energy and electricity loses its impact on the economic growth. In fact, it depends on the intensity of fossil fuel energy consumption in low regime or high regime, the impact of electricity or fossil fuel will be different. These two energies are alternative for each other in the process of production and one the inputs of production. The increase in use of either of them causes the increase in production and the economic growth.

In low regime of fossil fuel consumption growth, the fossil fuel consumption growth does not affect the economic growth and in high regime, the fossil fuel consumption growth has influential impact on the economic growth. In other words, if the fossil fuel energy consumption growth increases by 1 percent, it causes the economic growth to increase by 3.5575 percent. It means that fossil fuel energy consumption leads to the economic growth. In all the economic theories energy carriers have outstanding role in the process of production. In the economy of Iran, since its nature is dependent on oil and cheap sources of energy, the increase in the intensity of fossil fuel causes the increase in the economic growth. The following figure demonstrates that in the model of smooth transition regression, the transition from one regime to another is fast-paced.

Figure 2. The logistic function related to the regime change.

6. Conclusions

The present study aimed at investigating the non-linear effect of fossil fuel consumption growth, electricity consumption growth, and population logarithm on emissions applying TAR framework. Also, it tried to investigate the effect of capital, fossil fuel consumption growth and electricity consumption growth by applying STR framework. To this end, the data from 1969 to 2017 were used. The asymmetric effect demonstrates that linear approximation cannot explain the nonlinear effects of variables satisfactory. In other words, non-linear times series framework by considering the variables changes and their coefficients during the time, can have better ability to describe the emission and the economic growth compared to linear framework in Iran.

According to the statistical analysis related to model specification, the fossil fuel energy consumption with threshold value of 12 percent and some optimal equal regimes were selected in which the fluctuations in coefficients are a function of fossil fuel consumption growth. In TAR model, which was used for the dependent variable of emissions, in the low regime of fossil fuel consumption, the first lag of fossil fuel consumption growth and electricity consumption growth have been significant at 5 percent. The increase in fossil fuel energy consumption and electricity cause emissions. In high regime of fossil fuel consumption, the first lag in fossil fuel consumption growth and population logarithm are both influential on emissions. the increase in fossil fuel consumption growth causes emissions and the increase in population decreased emissions. on the other hand, in STR model which is related to the economic growth both high regime and low regime of fossil fuel consumption based on threshold variable, has been identified 12 percent. In low regime of fossil fuel consumption, the variables of fossil fuel consumption and electricity consumption growth and the first lag of capital have impact on the economic growth which was positive. On the other hand, in high regime of fossil fuel consumption, the capital variable and fossil fuel consumption growth have impact on the economic growth at 5 percent which was positive and significant.

The prominent point in this framework is that in both of them, the fossil fuel consumption growth variable has been chosen as threshold variable which is in fact policy making variable. More importantly, the threshold value in both of them has been 12 percent. It means that both real variables (the economic growth) and environmental variables (emissions) can be affected when the growth level is 12 percent. It can have different reasons. One reason is that the economic growth and emission have a significant relation together, and one part of the emissions in Iran are due to the nature of the energy which is used in different units. In fact, threshold value of 12 percent can have political implications for policy makers. Therefore, energy consumption is a political variable which needs attention because both real variables and environmental variables are affected by that.

In the economy of Iran, there is an interaction between the economic growth and emissions. the intensity of energy in production economic activities are high and it leads to more emissions. to decrease the emissions, it is indispensable to change the nature of energy consumed in industry because to change the nonrenewable energy to renewable energy is accompanied with fewer emissions. also, the production units will be supported and provide to pursue their activities. Therefore, paying attention to renewable energies and creating infrastructures and decreasing the nonrenewable energy consumption directly or indirectly can be one the most important challenges and goals for the economy of Iran.

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