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Nonlinear Impact of Energy Consumption on Economic Growth and Emissions in Iran: Smooth Transition Regression Model

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ABSTRACT

The present study investigates the effect of energy consumption on the economic growth and emissions through applying nonlinear frameworks, namely smooth transition regression and threshold auto regressive, using the annual data from 1969 to 2017. Therefore, the impact of energy consumption on the economic growth and emissions has been examined using two models. In both models, the breakpoint and effects of the included variables depend on the value of energy consumption. The growth of the fossil fuel energy consumption is considered as a transition variable at a value of 12%. For emissions, in addition to the energy variables, total population was used as the control variable, and for the economic growth, the physical capital was employed as the control variable. The prominent point in this framework is that in both models, the growth of the fossil fuel consumption is chosen as a threshold which is in fact a policy-making variable. Due to the asymmetric impacts of the included variables on the emissions and economic growth, which are highly crucial, a nonlinear approach captures the dynamics much better and provides clear descriptions to the policy maker on how to react according to the state economy.

1. Introduction

Energy is one the most significant factors in production which plays an important role in the economic development and in the improvement to countries all over the world. The economic growth highlights the role of energy more and more significantly. The changes in the history of energy demonstrate that the pace of growth and the economic development of countries depend on efficient energy consumption (Ockwell, 2008). Energy sources are limited and exhaustible. Also, the related emissions and problems have made energy consumption more significant for energy suppliers. The ancillary issues of the consumption of and the demand for energy have had so profound effects that almost no country is ignorant of it.

It is worthy of mentioning that the energy resources can be effective in the development of the countries if they are used in an efficient and optimal way. The inefficient use of energy resources leads to some deficiencies in other parts which causes lack of development in the process of economic growth. Therefore, it is vital to accept that energy has a leading role in economy and economic growth, which makes it

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inevitable to preserve and take advantage of energy resources in the best way.

Many researchers have studied the cause and effect relation between the energy consumption and examined determining the direction of the relationship since the emergence of oil shocks in 1970s. In addition to the price fluctuations and scarcity of energy resources, the environmental issues are the other factors which necessitate the urge to investigate the relation between energy production and consumption. Global warming caused by greenhouse gases can be among 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 production of greenhouse gases such as CO_2. However, the rate of production of these pollutants has a direct relation with energy consumption (Biligli, 2016), and energy is one the factors in production and an important drive for 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, has 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 nonlinear behavior caused by structural failure. The investigation of the consumption of energy conduits in Iran has revealed one or several failures, and 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 behaviors well. The present study aims at investigating, first, the effect of energy consumption on economic growth and, second, the effect of energy consumption on emissions.

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 demonstrate 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 the production of goods (Stern, 2000). Also, it is one the fundamental resources for industry and a significant factor in domestic uses of energy. The role of energy consumption in economic growth and vice versa is related to policy making because there is a positive relation between energy consumption and the related price, and the growth caused by that can have an adverse effect on economic growth. On the other hand, the reinforcement of growth policy especially in countries which have constraints on the use of renewable energy sources may have serious consequences for the environment. Further, it may endanger the effects of perseverance policy on the 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 consumption and economic growth (Apargis and 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 of 1971–2005 in Iran's 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 gross domestic product (GDP) growth and carbon dioxide emissions. Moreover, 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 proves that the environmental hypothesis (Kuznets) is true in Iran (Fotros, 2011).

In addition, energy as an important production factor has significant effects on economic growth. Identifying the relationship between energy and economic growth can help improve governmental energy policies. Amadeh et al. (2009) examined the long-run and short-run causality relationships of the energy consumption and economic growth with energy consumption and employment in various economic sectors of Iran's economy for the period of 1971–2003. Their results showed that there is a long-run and short-run unidirectional causality relationship between energy consumption and economic growth, a short-run unidirectional causality relationship between economic growth and natural gas consumption, a unidirectional causality relationship between energy consumption and the added value in the industrial sector, and a short-run and long-run unidirectional causality relationship between electricity consumption and the added value in the agricultural sector(Amadeh et al., 2009)

Explaining the relationship between energy consumption and economic growth can play a significant role in setting and adjusting the policies on the energy sector. Given the close relationship between energy consumption and economic growth in Iran, the determination of the quality of the relationship between these two variables helps effectively explain the policies on the energy sector. Damankeshideh et al. (2013) used the data on GDP and energy consumption of the selected countries of Iran's twenty-year outlook during the years 1990–2009; panel data were used in this model. The results of this study showed that there is a significant and positive relationship between economic growth and energy consumption in the selected countries of Iran's twenty-year outlook.

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 is not as 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 defined as $Q = F(G(K.E), L)$.

They believe that energy and capital combine and create production factor G. Then, they are combined with work for the production of goods. 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 minor role in production, and it is just a mediating factor; 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 created by Ayres and Nair (1984), it is expressed that the production of economic goods requires a 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, then $Q = f(K, L, E)$, where, Q is the GDP, K is the capital input, L the labor input, and E stands for energy appears. Also, it is presumed that there is a direct relation between the amount of the energy input and the production level. In other words, the increase in any of them leads to an increase in production.

The energy input can be provided by different common energy carriers such as oil, gas, electricity, coal, etc.; therefore, the relation between the variables can be summarized as follows:

- Energy consumption has a positive and significant effect on economic growth;
- Energy consumption has a negative and significant effect on emissions.

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

After Asafu (2000), there has been countless studies which have tried to present evidence to show that there is a cause and effect relationship between energy consumption and economic growth; they have focused on one group in several countries at different development levels (Mahadevan and Asef, 2007; Apargis and Payne, 2011), on some individual countries (Abbasi and Choudhury, 2013; Gurgul and Lack, 2013) or on some economic areas (Romano and Scandura, 2011). More recent studies have considered more variables such as the 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 a time series approach to unit root tests and the cointegration to the traditional cointegration test. Therefore, the present study aims at investigating the effect of nonlinear energy consumption on economic growth and emissions.

We present 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). Thus, we consider the following general production function:

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

where Y is the 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 the real output is given by:

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

where GY is the growth rate of the 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 an energy–growth nexus which is empirically tractable can be found. The model is set up as follows. We assume that the economy is composed of two sectors: the energy sector (G) and the nonenergy sector (C). The production functions of both sectors are expressed in:

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

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

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

$$L_C + L_G = L \qquad (5b)$$

$$L_C + L_G = L \qquad (5b)$$

$$K_C + K_G = K \qquad (5c)$$

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

Equation (3) indicates the production function of the nonenergy sector, and Equation (4) is the production function of the energy sector. Equation (5a) provides that the total output (Y) is the sum of C and G, and Equation (5b) shows that the total labor force (L) is the sum of the nonenergy labor input (L_C) and the energy labor input (L_G). Equation (5c) indicates that the total capital stock (K) is the sum of the nonenergy sector capital input (K_C) and the energy sector capital input (K_G). Equation (3) denotes that the energy sector output (G) creates an externality effect to the nonenergy 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 Equation (6) indicates the marginal production of the 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 the capital input in the energy sector, and $C_K = \frac{\partial C}{\partial K}$ is the marginal productivity of the capital input in the nonenergy sector.

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

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

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

According to the growth theory, α_1 and α_2 are both positive coefficients given that the investment rate and the 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: the direct contribution of the energy sector and the indirect effect of the energy sector through the nonenergy sector (the externality effect) (Lee and Chang, 2007)

3. Environmental Kuznets Curve (EKC)

Recent studies have revealed that there is U-shaped relation between the quality of the environment and the level of income per capital. This phenomenon is called environmental Kuznets curve in economy. The analyses have demonstrated that in the beginning phase of the economic growth, the quality of the environment is reduced. However, as soon as the income exceeds a definite level, the quality of the environment increases too. The idea which indicates that economic growth leads to the improvement in the environment has contributed to the idea that economic growth is the most necessary and convenient way to preserve and enhance 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 an automatic relation between the environment quality and the income. There is no reason to agree that economic growth can be a perfect alternative to environmental policies. Also, the environmental issues have been different in various countries which brings about the idea that there are some other variables apart from the income that can influence the environment.

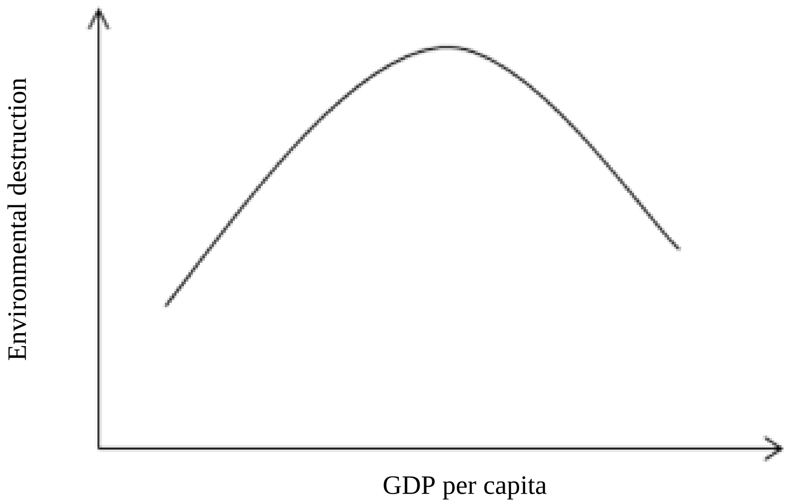

Figure 1. Environmental Kuznets curve.

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

On the other hand, the demand for environmental facilities (or the quality of the environment) has more elasticity than the 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 experts believe that the environment is a commodity with a high elasticity compared to the income. Based on this assumption, in the process of development, people find the quality of the environment important and can guarantee the execution of environmental instruction through political pressure leverage or the increase in the 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 the environment. However, the income supplies elasticity for the environmental facilities, and the effect of the availability of information on the quality of the environment has to be tested because the increase in the income per capital does not necessarily indicate an increase in the income for the average class of people. It implies that if there is lack of proper income distribution, the economic growth may lead to a reduction of the demand for the perseverance of the environment. Moreover, a 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 about the environmental issues. From the analyses and studies, it can be concluded that the perseverance of the environment increases with economic growth as well.

Some countries are willing to follow the U-shaped path, but it should not be concluded that economic growth cannot replace the environmental policies completely. The environment perseverance requires proper and right environmental policies. Further, it cannot depend only on the income variable. In fact, the only way to guarantee the stable development is to increase the level contribution. In other words, people's contribution paves 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 the improvement to the income distribution, education, and having access to information is the necessary requirement to guarantee the stable growth (Dinda, 2004).

4. Empirical Background of Study

Danish and Wang (2019) investigated if the biomass energy consumption can help control the emissions. For this purpose, they used the annual data from Brazil, Russia, India, China, and South Africa from 1992 to 2003 and applied the generalized method of moments. Their results revealed that the biomass energy consumption can reduce the emissions. Furthermore, this investigation demonstrated an N-shaped relation between the income and pollution. Moreover, the business freedom is the only pollutant in the abovementioned 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 autoregressive distributed lag (ARDL) model. Their results indicated that the individual new energy consumption had a positive impact on economic growth. Also, urbanization rate, export, import, and foreign direct investment influenced the individual new energy consumption. The cause and effect test revealed that there was one-way causality from the individual new energy consumption to the economic growth, from the urbanization rate to the energy consumption, and from the 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, namely Indonesia, Thailand, Singapore, the Philippines, and Malaysia. They used the annual data from 1980 to 2015, applied the J test of Hocker and Hatmi (2006) to investigate the causality of symmetry, and used the J test of 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 economic growth.

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

Mehrara et al. (2016) carried out a research on the effect of energy consumption on the economy of Iran by applying the Bayesian model of average. In this study, they tried to investigate 16 variables influencing the economic growth from 1961 to 2014. Their results revealed that the first to fifth factors in the economic growth are GDP ratio, population growth rate (negative), the increase in the import of the 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 on energy consumption is not considered as a threat to the economic growth.

Kohansal and Shayanmehr (2017) performed a research in order to investigate the interaction between energy consumption, economic growth, emissions, and the spatial communication among nine developing countries by applying spatial synchronous equations framework for panel data with random effects from 2000 to 2011. Their results indicated that energy consumption, economic growth, and emissions in each country are affected by energy consumption, economic growth, and emissions of the neighboring countries. Further, the results of this study demonstrated that there is a two-way cause and effect relationship between economic growth, emissions and between emissions and energy consumption. 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 will be ideal to use tax tools to decrease the emissions of greenhouse gases and to replace fossil energy with renewable energy.

5. Estimation and Empirical Results

This part is devoted to the estimation and interpretation of the results. To this end, the annual data from 1990 to 2017 were used. The investigated variables in this study are the capital (Cap)[1], fossil fuel energy consumption (EC)[2], electricity consumption (Elec)[3], emissions (EM)[4], gross domestic product (GDP)[5], and population (Pop)[6]. After developing the relationship between the variables and determining the estimation of the model, the stationary state of the abovementioned variables had to be tested. Therefore, the stationary states of all the variables in the model were tested by applying Philips and Perron unit root test. According to the test, the included variables are stationary and all are integrated at a 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	Emissions	Em
I(1)	–4.18	–5.57	–1.09	Gross domestic product	GDP
I(2)	–4.18	–2.51	–0.81	Population	Pop

Source: Calculations in this work

The levels of variables, including energy consumption logarithm, real GDP, and capital have been tested by the cointegration test. It is proved that there is a long-term relation between the variables. According to Granger theorem, a long-term equilibrium relation requires the inclusion of mechanism or error correction patterns. In fact, the error correction mechanism guarantees the achievement of a long-term relation.

Table 2. Trace and maximum eigenvalues test and cointegrating vectors of economic growth.

<table>
<tr><th>Decision</th><th>Critical Value (1%)</th><th colspan="2">PP First Difference</th><th>PP Level</th><th colspan="2">Explanation</th><th>Variables</th></tr>
<tr><td>I(1)</td><td>–4.17</td><td colspan="2">–5.23</td><td>–0.179</td><td colspan="2">GDP Logarithm</td><td>Ln GDP</td></tr>
<tr><td>I(1)</td><td>–4.17</td><td colspan="2">–6.16</td><td>–3.07</td><td colspan="2">Energy Consumption Logarithm</td><td>Ln EC</td></tr>
<tr><td>I(1)</td><td>–4.17</td><td colspan="2">–5.59</td><td>–1.99</td><td colspan="2">Capital Logarithm</td><td>Ln Cap</td></tr>
<tr><td colspan="8">Included variables: log(GDP), log(EC), and log(Cap)</td></tr>
<tr><td colspan="8">Deterministic Variables: Constant</td></tr>
<tr><td colspan="8">Spatial Cointegration</td></tr>
<tr><td colspan="4">Trace Test</td><td colspan="4">Maximum Eigen Values Test</td></tr>
<tr><td>Critical Value 95%</td><td>Test value</td><td>Alternative Hypothesis</td><td>Null Hypothesis</td><td>Critical Value 95%</td><td>Test Value</td><td>Alternative Hypothesis</td><td>Null Hypothesis</td></tr>
<tr><td>29.73</td><td>29.79</td><td>$r \geq 1$</td><td>$r = 0$</td><td>21.13</td><td>19.54</td><td>$r = 1$</td><td>$r = 0$</td></tr>
<tr><td>15.49</td><td>10.19</td><td>$r \geq 2$</td><td>$r \leq 1$</td><td>14.26</td><td>8.28</td><td>$r = 2$</td><td>$r \leq 1$</td></tr>
<tr><td>3.84</td><td>1.90</td><td>$r = 3$</td><td>$r \leq 2$</td><td>3.84</td><td>1.90</td><td>$r = 3$</td><td>$r \leq 2$</td></tr>
<tr><td colspan="8">Cointegration Vector</td></tr>
<tr><td colspan="4"></td><td>log(GDP)</td><td>log(EC)</td><td colspan="2">log(Cap)</td></tr>
<tr><td colspan="4">$\mathrm{ecm}(\log(\mathrm{GDP}) - \log(\mathrm{GDP}\ *))$</td><td>1.00</td><td>0.64</td><td colspan="2">–0.37</td></tr>
</table>

Source: Calculations in this work

[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

The variable levels, including energy consumption logarithm, real GDP, and capital were tested inspired by economic theory, and we found out that there is a long-run relation.

Table 3. Trace and maximum eigenvalues test and cointegrating vectors of the emissions.

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*), and log(*Em*)							
Deterministic variables: Constant							
Cointegrating 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	$r \geq 1$	$r = 0$	21.13	22.37	$r = 1$	$r = 0$
15.49	17.01	$r \geq 2$	$r \leq 1$	14.26	13.84	$r = 2$	$r \leq 1$
3.84	3.17	$r = 3$	$r \leq 2$	3.84	3.17	$r = 3$	$r \leq 2$
Cointegrating Vectors							
				log (*Em*)	**log(*EC*)**	**log(*Pop*)**	
$\mathbf{ecm}(\mathbf{log}(\mathbf{EM}) - \mathbf{log}(\mathbf{EM}\,*))$				1.00	0.67	0.75	

Source: Calculations in this work

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

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

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

Critical Value	**F Scaled**	**F Value**	**Threshold Specification Test**
18.23	19.45	3.89	Zero versus one
19.91	5.81	1.16	One versus two
Threshold variable: energy consumption growth at 12%			

Source: Authors' calculations

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

Table 5. Estimation.

Probability	Coefficients	Variable
Threshold Variable: fossil fuel energy consumption growth		
Low regime, fossil fuel energy consumption less than 12%		
0.38170	0.082091	Constant
0.0000	0.935105	Dlog(EC(–1))
0.29490	–0.008703	Log(POP)
0.0109	0.201217	DLog(ELEC(–1))
High regime, fossil fuel energy consumption more than 12%		
0.02690	0.491510	Constant
0.0000	1.455748	Dlog(EC(–1))
0 0108	–0.053061	Log(POP)
0.9808	0.001649	DLog(ELEC(–1))
Goodness of fitting		
241.3441= *F* 0.000 = Probability	R^2 = 0.97	Durbin Watson = 2.3579
–6.21= Hannan Quinn	–6.0038 = Schwarz	–6.325= Akaike

Regarding the estimation of coefficients and their significance, the estimated equations for the regimes and significant variables are presented in Table 6.

Table 6. The estimation of equations for the emissions.

Low regime, fossil fuel energy consumption less than 12%
EM_t = 0.935105 Dlog(EC)$_{t-1}$ + 0.201217 Dlog(ELEC)$_{t-1}$
High regime, fossil fuel energy consumption more than 12%
EM_t = 0.49151 + 1.455748 Dlog(EC)$_{t-1}$ – 0.053061 Log(POP)$_t$

Source: Calculations in this work

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 the emission in each of the regimes.

Fossil fuel energy consumption growth in low regime with a coefficient of 0.93 and equal electricity consumption growth with a coefficient of 0.2 are considered as the most important factors in the emissions respectively. It seems that in the low regime, fossil fuel consumption growth has the most significant effect on the emissions in the short term. Fossil fuel consumption growth and electricity are two important factors in the 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 an increase in the emissions. Producing electricity in fossil fuel power plants 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 an 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, as well as in Iran. 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 plants, and fuel oil is used in thermal power plants especially in cold seasons. The impurities, heavy elements, and sulfur in fuel oil increase the environmental issues and related wastes significantly. The use of nonrenewable energy has an adverse and destructive effect on the emissions and global warming. Fossil fuels are the source of sulfur dioxide (SO_2) and carbon dioxide. 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 raises the emissions of these gases and causes air pollution. It is worthy of mention that the growth of fossil fuel consumption and electricity has an impact on the emissions in intervals, and these variables have delayed the impact.

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

In order to investigate the effect of energy consumption on economic growth based on econometrics model findings, the smooth transitions regression has been applied. Energy consumption has an impact on the emissions in the 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 the emissions model. Consequently, threshold model which includes regime fluctuations is used for the emissions model, and smooth transition regression is applied to the 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. To this end, with regard to eight lags and by means of the significance of the driven information criteria in the optimal lag length, the criteria test is determined. According to the optimal lag, 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 to determine the nonlinear relation between the variables. If there is a nonlinear relation, there must be proper transition variable and the number of nonlinear model regimes based on F test, F2, F3, and F4. The results are presented in Table 7.

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 the other transition variables for the nonlinear model. To this end, any potential variable can be selected, but the priority is given to the transition variable by which the null hypothesis is strongly refuted in F test. Accordingly, the most proper transition variable, DLOG(EC)$_t$, the first lag of fossil fuel energy consumption, and the smooth transition regression model with the logistic transition function LSTR1 have been chosen as the transition variable and the best model.

Next, the parameters of the model were estimated by applying the Newton–Raphson algorithm; the results are presented in Table 8. It is worth mentioning that both linear or nonlinear variables which are significant statistically are considered.

Table 7. The model and transition variables.

Suggested Model	F_2 Prob.	F_3 Prob.	F_4 Prob.	F Prob.	Transition Variable
LSTR1	6.9390×10^{-3}	1.1139×10^{-1}	3.8990×10^{-1}	4.8497×10^{-3}	$DLOG(CAP)_t$
LSTR2	6.3283×10^{-2}	1.8677×10^{-3}	1.1139×10^{-1}	1.2171×10^{-3}	$DLOG(EC)_t$ *
LSTR1	2.7034×10^{-3}	1.8019×10^{-2}	6.6084×10^{-1}	8.7877×10^{-3}	$DLOG(ELEC)_t$
LSTR1	3.3259×10^{-3}	5.9279×10^{-1}	1.3101×10^{-1}	2.3071×10^{-2}	$DLOG(CAP)_{t-1}$
LSTR2	7.3710×10^{-1}	2.2798×10^{-4}	4.7617×10^{-1}	1.1341×10^{-2}	$DLOG(EC)_{t-1}$
LSTR2	3.8938×10^{-1}	3.9687×10^{-3}	2.2713×10^{-1}	1.5758×10^{-2}	$DLOG(ELEC)_{t-1}$
LSTR1 (refuting second hypothesis H_{02})		Nonlinearity of the two regimes with one threshold value		$H_{02}: \beta_1 = 0 \mid \beta_2 = \beta_3 = 0$	
LSTR2 (refuting second hypothesis H_{02})		Nonlinearity of the three regimes with two threshold values		$H_{03}: \beta_2 = 0 \mid \beta_3 = 0$	
LSTR1 (refuting second hypothesis H_{04})		Nonlinearity of the two regimes with one threshold value		$H_{04}: \beta_3 = 0$	
Linear (in case not refuting linearity)		Linearity without a threshold value		Nonexistence of nonlinearity	

Source: Calculations in this work

Table 8. Estimation of the 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 90% confidence level; ** Significant at 95% confidence level; *** Significant at 99% confidence level; Source: Calculations in this work.

Table 9. Regime equations.

Low regime, the fossil fuel energy consumption is less than 12%.			
$DLOG(GDP)_t = 1.18426(DLOG(ELEC))_t + 0.09973(DLOG(CAP))_{t-1}$			
High regime, the fossil fuel energy consumption is more than 12%.			
$DLOG(GDP)_t = 0.84777(DLOG(CAP))_t + 3.55750(DLOG(EC))_t$			
SC	HQ	AIC	R^2adjusted
–4.6559	–5.0641	–5.3047	69%

Source: Calculations in this work

After the transition variable was chosen, the first lag of fossil fuel consumption growth, the low regime for the high fossil fuel energy consumption growth, and the low fossil fuel energy consumption growth were identified separately. The threshold value for the change of the regime in fossil fuel energy consumption growth is 12%. As mentioned in the methodology of the research, in the first regime G = 0 and in the second regime G = 1.

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

In the low regime of fossil fuel energy consumption, the electricity consumption co-efficiency equals 1.18426. If the electricity increases by 10%, it will cause the economic growth to rise by 11.8426%. In the 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 the high regime of fossil fuel consumption growth, production uses cheaper energy, and electricity loses its impact on the economic growth. In fact, depending on the intensity of fossil fuel energy consumption in the low regime or the high regime, the impact of electricity or fossil fuel will be different. These two energies are alternative to each other in the process of production and are the inputs to the production. The increase in use of either of them causes an increase in the production and the economic growth.

In the low regime of fossil fuel consumption growth, the fossil fuel consumption growth does not affect the economic growth, and in the high regime, the fossil fuel consumption growth has an influential impact on the economic growth. In other words, if the fossil fuel energy consumption growth increases by 1%, it causes the economic growth to increase by 3.5575%, which indicates that fossil fuel energy consumption leads to the economic growth. In all the economic theories, energy carriers play an 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 an increase in the economic growth. Figure 2 demonstrates that in the model of smooth transition regression, the transition from one regime to another is fast paced.

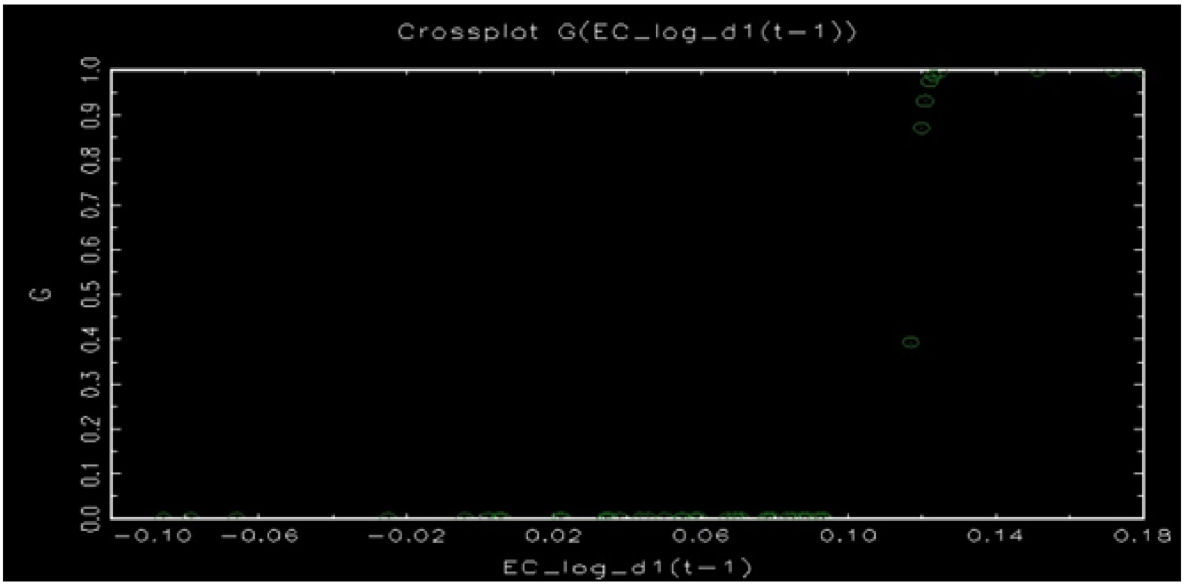

Figure 2. The logistic function related to the regime change.

6. Conclusions

The present study aimed at investigating the nonlinear effect of fossil fuel consumption growth, electricity consumption growth, and population logarithm on the emissions by applying the TAR framework. Also, it tried to examine the effect of capital, fossil fuel consumption growth, and electricity consumption growth by applying the 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 satisfactorily. In other words, nonlinear time series framework by considering the variables changes and their coefficients during the time can have a better ability to describe the emissions and the economic growth compared to the linear framework in Iran.

According to the statistical analysis related to the model specification, the fossil fuel energy consumption with a threshold value of 12% and some optimal equal regimes were selected in which the fluctuations in the coefficients are a function of fossil fuel consumption growth. In the TAR model, which was used for the dependent variable of the emissions, in the low regime of fossil fuel consumption, the first lag of fossil fuel consumption growth and electricity consumption growth are significant at 5% level. An increase in fossil fuel energy consumption and electricity causes emissions. In the high regime of fossil fuel consumption, the first lag in fossil fuel consumption growth and population logarithm both influence the emissions. An increase in fossil fuel consumption growth causes emissions, but an increase in population decreased emissions. On the other hand, in the STR model, which is related to the economic growth, the first lag of fossil fuel energy consumption at 12% is recognized as the parametric break. In the low regime of fossil fuel consumption, the fossil fuel consumption, the electricity consumption growth, and the first lag of capital have an impact on the economic growth which was positive. On the other hand, in the high regime of fossil fuel consumption, the capital variable and fossil fuel consumption growth have an impact on the economic growth at 5% significance level which was positive and significant.

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

In the economy of Iran, there is an interaction between the economic growth and the emissions. The intensity of energy in production economic activities is high, and it leads to more emissions. To decrease the emissions, it is essential to change the nature of energy consumed in industry; Changing the nonrenewable energy to renewable energy is accompanied with a lower amount of emissions. Also, the production units will be supported to pursue their activities. Therefore, paying attention to renewable energies, 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.

References

A.A. Romano, G. Scandura, Dynamics of Economic Growth and Electricity Con Sumption at Regional level: the Italian Case, Energy Syst. 2 (2) (2011) 143–150.

Amadeh H, Ghazi M, (2009), Causality Relation between Energy Consumption and Economic Growth and Employment in Iranian Economy, Tahghighat-e-eghtesadi, Spring, 2009.vol 44 , No 86, Pages 1–38

Apergis, T. Chang, R. Gupta, E. Ziramba, Hydroelectricity consumption and economic growth Nexus: Evidence from a Panel of Ten Largest Hydroelectricity Consumers, Renew. Sustain. Energy Rev. 62 (2016) 318–325.

Bilgili, F., Öztürk,İ., Koçak, E., Bulut, Ü., Pamuk, Y., Muğaloğlu, E., Bağlıtaş, H.H., 2016. The Influence of Biomass Energy Consumption on CO2 Emissions: a Wavelet Coherence Approach. Environ. Sci. Pollut. Res. 23, 19043–19061.

C. F. Tang, M. Shahbaz Sectoral Analysis of the Causal Relationship between Electricity Consumption and Real Output in Pakistan, Energy Pol. 60 (2013) 885 891.

C. Granger, P. Newbold, Spurious Regressions in Econometries, J. Fonam 2 (1974) 111–120.

Carfora, A; Vega Pansini, R and Scandurra, G, The Causal Relationship between Energy Consumption, Energy Prices and Economic Growth in Asian Developing Countries: A Replication, Energy Strategy Reviews, 23(2019) 81–85.

D.I. Stern, A Multivariate Co-Integration analysis of the Role of energy in the US Macroeconomy, Energy Econ. 22 (2000) 267–283.

Danish, Zhaohua Wang, (2019), Does Biomass Energy Consumption Help to Control Environmental Pollution? Evidence from BRICS Countries, Science of the Total Environment 670 (2019) 1075–1083.

Dinda, S. (2004), "Environmental Kuznets Curve Hypothesis: a Survey, Ecological Economics", No. 49, PP. 431–455.

E Bjorndal, M. Bjorndal, P.M. Pardalos, M. Ronnqvist (Eds.), Energy, Natural Resources and Environmental Economics, Springer, Berlin, 2010.

F. Abbas, N. Choudhury, Electricity Consumption Economic Growth Nexus an aggregated and Disaggregated Causality Analysis in India and Pakistan, J. Pol. Model 35 (2013) 539–553.

Feder G. On exports and Economic Growth. J Dev Econ 1982;12: 59–73.

H. Gurgul, L. Lack. The Electricity Consumption Versus Economic Growth of the Polish Economy, Energy Boon 34 (2012) 500–510.

Huang, Zh, and Huang, L, (2019), "Individual New Energy Consumption and Economic Growth in China, The North American Journal of Economics and Finance, Volume 50, 2019, Article 100986.

Ito, K., 2017. CO2 Emissions, Renewable and non-Renewable Energy Consumption, and Economic Growth: Evidence from Panel Data for Developing Countries. Int. Econ. 151, 1–6.

J. Asafu Adjaye. The Relationship between Energy Consumption, Energy Prices and Economic growth Time Series Evidence from Asian Developing Countries, Energy Econ. 22 (2000) 615625.

J. Chontanawat, LC. Hunt, R. Piense, does Energy Consumption Cause Economic Growth? Evidence from a Systematic Study of over 100 Countries, J. Pol Model 30 (2008) 209–220.

J. Kraft, A. Kraft, On the Relationship between Energy and GNP, J. Energy Dev. 3 (1978) 401 403.

J. Mann, P. Sephton, A. Replication of "The Relationship between Energy Consumption, Energy Prices, and Economic Growth Time Series Evidence from Asian Developing Countries', Negative Energy Econ, 2018, https://doi.org/10.1016/j.enec.

2018.05.005.

Kohansal, M., Shayanmehr, S. (2016). The Interactive Effect of Energy Consumption, Economic Growth, and Emissions: Using 2SLS Method. Journal of Iranian Energy Economics, 5 (19), 179–216.

Lee, Ch and Chang, Ch, (2007), The Impact of Energy Consumption on Economic Growth: Evidence from Linear and Nonlinear Models in Taiwan, Energy 32 (2007) 2282–2294.

Marjan Damankeshideh, Ahmad Abbasi, Hossein (Adib) Arabi, Hassan Ahmadi, (2013), Evaluation of The Relationship Between Energy Consumption and Economic Growth (Case Study for Iran Twenty-year Outlook Selected Countries), The Macro and Strategic Policies, Volume 1, Vol1-No2, Summer 2013, Pages 55–69.

Mazini, A.H., Asari, A., Afsharian, B., Rasouli, A., (2015). Redefining the Relationship Between Energy Consumption and Economic Growth in Iran (sectoral- provincial approach). Economic Modeling Quarterly, 2 (3), 67–89.

Mehraara, M., Rezayi Bargoshadi, S., Hamedi, S. (2016). The Impact of Energy Consumption on Iran's Economic Growth; Bayesian Approach. Quarterly Journal of Energy Policy and Planning Research, 2(2), 61–101.

Mohamadi, T., Nazeman, H., Nosratiannasab., M., (2013). Relationship between Economic Growth and Energy Consumption in Iran (Analysis of Linear and Non-linear Causality Models). Journal of Iranian Energy Economics, 2(5), 53–70.

Mohammadhassan Fotros, Air Pollution, Energy Consumption and Economic Growth in Iran, Environmental and Energy Economics, First Year, Winter 2011 No. 1.

N. Apergis, JE Payne, Renewable and Non-Renewable Electricity Consumption Growth Nexus Evidence from Emerging Market Economies, Appl. Energy 88 (2011) 5226–5230.

N. Apergis, JE Payne, Renewable Energy Consumption and Growth in Eurasia, Energy Econ. 32 (2010) 1392–1397.

Nourzad F. The Productivity Effect of Government Capital in Developing and Industrialized Countries. Appl Econ 2000;32(9): 1181–7.

Ockwell, D.G. (2008), "Energy and Economic Growth: Grounding our Understanding in Physical Reality", Energy Policy. 36(12), pp. 4600–4604.

Oh W, Lee K. Energy Consumption and Economic Growth in Korea: Testing the Causality Relation. J Policy Modeling 2004;26(8–9): 973–81.

Pokrovski VN. Energy in the Theory of Production. Energy 2003; 28:769–88.

R. Mahadevan, J. Asaf Adjaye, Energy Consumption, Economic Growth and Prices a Reassessment Using Panel VECM for Developed and Developing Countries, Energy Pol. 35 (2007) 2481–2490.

RE Engle, C.W.J. Granger, Cointegration and Error-Correction Representation, Estimation and Testing. Econometrica 55 (1981) 251–276.

S. Niu, Y. Jia, W. Wang, R. He, L. Hu, Y. Liu, Electricity Consumption and Human Development Level: a Comparative Analysis Based on Panel Data for 50 Countries, Int. J. Electr. Power Energy Syst. 53 (2013) 338–347.

Shokouhifard, S. Salmanour, Z., Mousavai, S.K, (2017). The Effect of Economic Growth, Energy Consumption and Financial Development on Emissions in Iran from 1986 to 2017. Journal of Environmental Sciences Studies, 2 (3), 454–462.

Stern D.I. (2000), A Multivariate Cointegration Analysis of the Role of Energy in the US Macroeconomy. Energy Economics, No. 22, PP. 267–283.

U. Al Mulali. HG Pereidouni, J.Y.M. Lee, Electricity Consumption from Renewable and Non-Renewable Sources and Economic Growth: Evidence from Latin American Countries, Renew. Sustain. Energy Rev. 30 (2014) 290–298 N.