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Nonlinearity in Energy Demand Dynamics in Iran using a Smooth Transition Error-Correction Model (STECM)

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Abstract *– Growing energy consumption in Iran has raised concerns for future energy exports' capacity. Effective policies should be identified for consumers' responses. Since the possibility of nonlinearity in the dynamics of energy demand in existing literature is confirmed, and a linear estimation can be led to specification bias and wrong policies, this paper uses a new nonlinear model, Smooth Transition Error Correction Model (STECM), to examine the energy demand dynamics in Iran. The results of this study indicate that the error-correction term can have the role of the appropriate transition variable in this nonlinear error correction model. Based on the estimated model, two extreme regimes have been identified in the dynamics of energy demand in Iran. In the regime, with a high deviation from long-run equilibrium, the price and income elasticity of demand and the speed of adjustment are higher. But in the other regime which is related to near long-run equilibrium, the consumer's incentive for reaction is less and so, the elasticities and the adjustment rate were small. The price elasticity of demand in both regimes is less than one, and therefore energy in Iran is inelastic. So, policymakers need to use non-price policies to manage energy demand.*

Keywords *– energy demand dynamics, non-linearity, smooth transition error correction model.*

1. INTRODUCTION

In natural resource-dependent developing countries; additionally, energy is the main input of production and is considered to be a financial source for securing national income. Iran, as an oil rich country, employs energy input for production of goods and service activities, and on the other hand, energy plays an important role in the Iranian economic development by which foreign exchange reserves have been secured. Accordingly, due to the relative frequency of energy using, the underlying principle of economic growth and development in Iran is based on the use of energy.

Energy consumption in Iran is growing rapidly. The average annual growth in total energy consumption in Iran during the period of 2000 to 2015 was 4.3 percent, which is almost 2.2 percent higher than the global annual growth. Therefore, serious concerns about the energy export capability have been considered in Iran over the coming decades. For policymaking to reform energy consumption effectively, it is necessary to predict and measure the reaction of consumers to the implementation of this policy. In this case, energy demand analysis, theoretically and empirically, is very important.

Energy is demanded by end-users as final consumption in form of usable energy, as well as by manufacturing enterprises as one of the main factors of production. According to microeconomic theories, the manufacturing firm seeks to maximize production with a certain amount of cost, or to minimize costs with respect to the specified amount of production or to maximize profits. The results of the first and second order conditions indicate that the firm demand for energy depends on its price, the price of other inputs of production (such as labor and capital), the price of the product and the quantity of production. Therefore, the most important economic factors affecting total energy demand can be considered as the actual price of energy and a variable of activity such as real national income or real GDP. Therefore, price and income variables are the two main drivers in determining energy demand [1]. Typically, the demand response to these two factors is analyzed with respect to price and income elasticities.

Based on empirical evidence, a review of literature on energy demand estimation show that various forms of energy demand models are estimated. Meanwhile, many studies such as [2]-[7] employ error correction models for energy demand analysis through dynamic estimation of the energy demand determinants such as income and energy prices according to the microeconomic theory foundations. This approach has also been widely used in Iran for estimating the energy demand function [8]-[10]. However, the case of non-linear functional form of energy demand and relations of energy have been considered by some international studies [11]-[14]. The common characteristic of Iranian studies is the implicit assumption of the existence of linear functional form between the variables. Ignoring the non-linearity form of energy demand can lead to the misleading estimation and specification error of the energy demand and the determinants.

Unlike other Iranian studies that have focused on energy demand dynamics using linear error correction models, this study examines the nonlinearity of energy demand through the use of a smooth transition error correction model. Smooth Transition Regression (STR) is one of the newest available methods which provides nonlinear analysis of energy demand functions and the variability of estimated coefficients in different

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conditions. This method is in fact a more advanced state of the threshold models and it enables the relationships between variables to be in accordance with the conditions of multiple systems.

The system condition is characterized by the transition variable and threshold distance. The advantage of this approach in comparison with threshold model is that change from one system to another is not sudden and this occurs with a smooth slope.

Hence, with specification of the energy demand function in Iran using a smooth transition error-correction model (STECM), the estimation procedures of this study are: first, to statistically examine the stationary of variables following I(0) or I(1) process. The second step is to examine the cointegration of energy consumption, real energy prices and real per capita gross domestic product. Third, to examine the nonlinearity test of the model selection of variable and transition function form. The potential variables which lead to non-linearity of the model are explored by considering the explanatory variables and the lagged values of these variables and the other effective variables including energy intensity, the share of industry to GDP and error-correction term. Among them, a variable is chosen with which the linearity hypothesis is statistically more strongly rejected. Fourth, according to the non-linearity of the model, the transition functional form should be specified and finally the selected model can be estimate. Accordingly, this study is organized as follows: Section 2 reviews the literature of nonlinearity of energy demand dynamics. Section 3 presents the methodology framework and Section 4 presents data and interprets estimation and empirical results. Finally, Section 5 provides conclusions.

2. BACKGROUND AND LITERATURE REVIEW: NON-LINEARITY OF ENERGY DEMAND DYNAMICS

Numerous models have been employed to estimate the energy demand function. Often, these models are specified as a linear functional form. Meanwhile, the most commonly used method for estimating energy demand is error-correction models. For example, Uri [2] investigated the demand function of electricity in the agricultural sector for the United States from 1978 to 1992. The results of this study indicate a low short-run price elasticity compared to its long-run elasticity. Huntington [3] by using an error correction autoregressive distributed lag model, estimated US natural gas consumption based on annual data from 1958 to 2003 and concluded that the natural gas consumption in the long run would increase by 6.7 percent for each 10 percent reduction in real gas prices. Zarranezhad and Ghapanchi [8] have investigated natural gas demand function using the error correction model in Iran. The results show that the demand for gasoline is inelastic with respect to its price and income. It means that gasoline is an essential good in Iran. Akinboade, *et al.* [4] examined the energy demand according to the autoregressive distributed lag model with error-correction term in South Africa during the period of 1974 to 2005. They concluded that gasoline demand is inelastic regarding to the price and revenue variations. Bernstein and Madlener [5] investigated natural gas demand in the residential sector in 12 OECD countries and concluded that the short-run elasticities are approximately half in magnitude compared to their long-run counterparts. Lim and Yoo [6] explored the price and income elasticity of gasoil demand in South Korea during the period of 1980 to 2011 by employing an error correction model. They concluded that demand in the short-run and long-run would be price inelastic while the income is significantly elastic.

In recent years, with the development of employing non-linear approaches in energy models for more accurate estimation of coefficients, many researchers have tended to use non-linear models for energy demand considerably.

These studies show that non-linear energy demand models provide researchers and policymakers with a more accurate and precise picture of the reality of this relationship. For example, Soytas and Sari [15] argue that ignoring the possibility of non-linearity of energy demand leads to estimating a false model with bias results.

Some studies like Altinay and Kragol [13] and Lee and Chang [14] show that ignoring structural breaks in variables and their effect on regime changes in price and income elasticities would lead to unrealistic results. Gabreyohannes [12] shows that the power of specification for energy consumption model increases when it is estimated as a non-linear form.

Some other studies emphasize non-linear demand due to asymmetric energy demand responses to the prices and income. Wirl [16] and Walker and Wirl [17] show higher price elasticity for higher prices and lower price elasticity for lower prices. Gately [18] also shows that the energy demand responses to rising and falling in price would be asymmetric. Also, Balke and Fomby [19] and Hu and Lin [20] consider asymmetric energy demand dynamics from short-run to long-run equilibrium. They believe that the value of demand elasticities will be differentiated based on the magnitude of the error term and the distance from the long-run equilibrium. Hence, the linear approach is not a correct specification for energy demand estimation. Omay *et al.* [11] also indicate that adjustment of variables to the long-run equilibrium level is non-linear. They emphasize that such regime dependent and non-linear dynamics are also important for policy design. Policy authorities must take into account such non-linearity and bear in mind that policy actions will affect economy in a non-linear fashion.

The issue of the nonlinearity of energy demand has been emperically confirmed in a number of studies. For example, Hu and Lin [20] examine the non-linear relationship between energy consumption and real income in Taiwan using a threshold vector error correction model. In this model, including error-correction term as a threshold variable, it is shown that when the error value exceeds the threshold level, the energy consumption response to income increases. Lee and Chang [14] demonstrated the stability of the cointegration relationship between energy consumption and GDP in Taiwan. They show that ignoring structural breaks doesn't make the coefficients in the cointegration relations stable in different periods. They show that events such as oil crises and the Asian financial crisis have significantly affected the coefficients' variations of the cointegration relationship of energy demand in Taiwan. Lee and Chiu [21] examined the non-linear energy demand function for the 24 OECD countries using a smooth transition error correction model. Their results show that energy consumption, real energy prices and real income are cointegrated, and this relationship is non-linear with respect to energy intensity and investment in GDP ratio as a transition variable.

Kani *et al.* [22] estimated Iranian natural gas demand for the period of 1971 to 2009 using the STAR model. In this study, the value added to the industrial sector, the real price of natural gas and petroleum products and the real price of electricity as the variables affecting the consumption of natural gas in the industrial sector, were considered. The results indicate that if the real price of petroleum products is considered as a transition variable, then the natural gas demand specified a two-regime nonlinear model. Also, the added value of industry and the real price of electricity have a positive and significant relationship, and the real price of natural gas has a negative and significant relationship with natural gas demand in the industrial sector. Nawaz, *et al.* [23] also explore a similar study on electricity demand in Pakistan. The results of this study indicate that the electricity price is an appropriate transition variable for Pakistan and electricity demand can be estimated as a two-regime non-linear demand model.

3. METHODOLOGY

One of the most commonly used models in estimating energy demand is error correction model (ECM). The characteristic of error correction models is to express the short-run dynamics of variables and how they react to deviations from long-run equilibrium level. In linear error correction model, the adjustment of deviation to the equilibrium is linear, and the error size does not affect the error correction rate. In fact, the rate of adjustment is constant in linear models. But Balke and Fomby [19] emphasize that moving towards long-run equilibrium does not always necessarily occur alike, and adjustments to equilibrium can be different when error term exceeds the threshold, because the benefits of adjustment are increased by increasing the error. A smooth transition error correction model (STECM) can consider the existence of different adjustment rates for deviations from equilibrium with different sizes. This means that the amount of imbalance can affect the speed and responsiveness of the variables, and adjustment to the equilibrium level. A group of studies that used a threshold regression have considered these changes in the coefficients occurring suddenly from one system to another (for example [20]), but these changes can happen smoothly. Teräsvirta, [24] stated that by changing the variables, consumers adjust their behavior not at the same time, but these changes occur gradually. Hence, smooth switching between the two regimes can be more favorable than sudden change. On the other hand, macroeconomic decisions are taken by different groups, and this is a timely process, which is why he points out that regime change occurs smoothly in nonlinear methods.

Therefore, in this article due to possible nonlinear adjustments in the movement towards long-run equilibrium, the error correction model is estimated using smooth transition regression. For this purpose, we will continue to introduce this method and the estimated model.

3.1 *Smooth Transition Regression*

This model is one of the most prominent and developed modes of switching regression by which the existence of changes in coefficients and the nonlinear relationship between variables are evaluated through the test. The advantages of using this method to estimate energy consumption is that the reaction of consumers to explanatory variables is not necessarily the same under all circumstances, and this relationship may change with the change in the status of some variables. Also, in the smooth transition regression, the rate of change in two extreme regimes is estimated, this is while in most switching models it is considered predetermined and varies from one regime to another occurring suddenly.

In this model, the transfer between different regimes is explained by the logistic function. Based on this method, the function can be considered as follows.

$$\begin{aligned} y_t &= \pi' w_t + (\theta' w_t) G(s_t, \gamma, c) + u_t \\ w_t &= (1, y_{t-1}, \ldots, y_{t-p1}, x_t, x_{t-1}, \ldots, x_{t-p2}) \end{aligned} \qquad (1)$$

Where y_t is a dependent variable, w_t is a vector of regressors, π is the vector coefficients of the linear part and θ is non-linear coefficients vector. s_t is the transition variable, the variation of which causes the coefficient of variables to change. This variable can be a lag of the endogenous variable or exogenous variable and their lags; alternatively, a variable may be selected outside this framework like a trend. $G(s_t, \gamma, c)$ is transition function which usually has a logistic functional form as follows:

$$G(s_t, \gamma, c) = \{1 + exp[-\gamma \prod_{j=1}^{J} (s_t - c_j)]\}^{-1}, \gamma > 0 \qquad (2)$$

This function changes continuously between 0 and 1. The transition function consists of the slope parameter, γ, and the location parameter, *c*. The slope parameter is an indicator of the speed of transition between two extreme regimes, whereas the location parameter (c) determines the threshold between these regimes. The value of the transition variable; and hence, the value of the corresponding transition function, determines the regime in each period.

The two modes $j = 1$ (LSTR1) and $j = 2$ (LSTR2) are usually considered for the transition function. If j=1, the parameters $\pi + \theta G(s_t, \gamma, c)$ change monotonically from π to π +θ , for j=2, the parameters $\pi + \theta G(s_t, \gamma, c)$ vary symmetrically around the mean value of c_1 and c_2. If the two estimated values of the threshold are equal ($c_1 = c_2$) then the exponential transition function (ESTR) is confirmed [24].

Considering that in this paper an error correction model is estimated in the framework of smooth transition regression, the form of energy demand dynamics is as follows:

$$\Delta LE_t = \pi_0 + \pi_1 \Delta LE_{t-1} + \pi_2 \Delta Lrgdp_t + \pi_3 \Delta LP_t + \pi_4 ecm_{t-1} + (\theta_0 + \theta_1 \Delta LE_{t-1} + \theta_2 \Delta Lrgdp_t + \theta_3 \Delta LP_t + \theta_4 ecm_{t-1}) \times G(s_t, \gamma, c) + \varepsilon_t \quad (3)$$

Where LE_t is log-transformed per capita consumption of energy, $Lrgdp_t$, is log-transformed real GDP per capita, LP_t is log-transformed energy price index, and ecm_t is the estimated error-correction term from a long-run relationship that is derived from the following equation:

$$ecm_{t-1} = LE_{t-1} - \alpha_1 - \alpha_2 Lrgdp_{t-1} - \alpha_2 LP_{t-1} \quad (4)$$

In the above relation, α_i represents the long-run coefficients. As already explained, in Equation 3, π_i are the coefficients for the linear part and θ_i is related to the nonlinear part of the model. According to this model, energy demand could follow different regimes, depending on the amount of transition variable and, consequently, the transition function.

In the existing literature, different transition variables are considered. In this paper, in addition to the variables in the model and their lags, variables such as error-correction term, the share of industrial sector of GDP, energy intensity and time trend are considered in the test for the transition variable, and among them, the most suitable variable is chosen.

3.2 Linearity Test, Choosing Variable and Transition Function Form

One of the main steps in the estimation of smooth transition regression is the linearity test of the model against a nonlinear model. If the null hypothesis of linearity is not rejected, it can be said that energy consumption can be explained by a linear model and there is no need for a non-linear one. Here, the null hypothesis of linearity can be defined as $H_0 : \gamma = 0$. In fact, with the assumption that γ is zero, Equation 1 becomes a linear regression, but parameter C and θ are not identified[2]. The solution proposed by Luukkonen, *et al.* [25] and Teräsvirta [24] to solve this problem is to replace the transition function with the Taylor approximation. Therefore, the third order expansion of Taylor is used to perform this test. Thus, the auxiliary regression for testing the linearity of the model will be as follows:

$$e_t = \delta' w_t + \beta_1' w_t s_t + \beta_2' w_t s_t^2 + \beta_3' w_t s_t^3 + v_{3t} \quad (5)$$

In this situation, the null hypothesis on the linearity of the model is $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$. In Equation 5, the transition variable must first be determined for the test. Teräsvirta [24] suggests that this test can also be used to select the appropriate transition variable. First, the linearity test is performed for different potential variables and the one that has the smallest p-value is selected as the appropriate transition variable. In fact, the linearity hypothesis for this variable is more strongly rejected compared to the other variables.

If the model is non-linear, a functional form suitable for the transition function should be selected. To make a decision on this, a sequence of nested hypotheses are performed using Equation 5 and the test statistic values are calculated for the following hypotheses.

$$H_{04} : \beta_3 = 0$$

$$H_{03} : \beta_2 = 0 | \beta_3 = 0$$

$$H_{02} : \beta_1 = 0 | \beta_2 = \beta_3 = 0$$

In this test, if the rejection of the hypothesis H_{03} is the strongest, it is recommended to use the LSTR2 model, otherwise (strongest rejection of hypotheses H_{04} or H_{02}), LSTR1 should be selected.[3]

4. EMPIRICL RESULTS

4.1 Data

In this section, we provide an empirical evidence of energy demand dynamics for Iran using annual data for the period of 1978-2015. To calculate total energy consumption, the total final consumption of energy carriers, based on the equivalent of barrels of oil, has been obtained from [26]. Also, the GDP in 2003 prices has been extracted from the Central Bank of Iran Statistics. The real energy price, such as [27], is calculated based on Iran's Energy Balance Sheet Statistics (2015) as the ratio of the nominal energy price index divided by the general price level. Since the main energy carriers in Iran include petroleum products, natural gas and electricity, the nominal energy price index is obtained as a weighted average of these carriers.

The time series property of data is tested using the unit root test with structural breaks [28]. Table 1 presents the stationary test results for logarithms of energy consumption (LE), real GDP (Lrgdp), energy price index (LP), and their first- order difference.

The results indicate that the absolute value of the test statistic for the level of variables is less than the critical value, so, there is not enough evidence to reject the null hypothesis of the existence of unit root, and therefore all the variables are nonstationary at level.

[2]. For more detail see Teräsvirta (1994)

[3]. For more information, see Teräsvirta (1994)

Table 1. Unit-root test results.

Variables	Test stats for level	Test stats for first order difference
LE	1.59	-5.33
Lrgdp	-1.59	-6.62
LP	-1.53	-9.28

Note: The critical value at 95% level is -4.19.
Source: Results of this research

The unit root test with structural breaks is also performed for the first-order differences of the variables, and the null hypothesis has been rejected for them at 95% level. Therefore, all variables are integrated of order one I (1). So, it is necessary to ensure the existence of cointegration relationship between variables. For this purpose, Johansen - Juselius test is used. The results of this test are presented in Table 2.

Based on the trace and the maximum Eigen value tests, the existence of at least one cointegration vector is confirmed at 95% confidence level. Therefore, the coefficients of the cointegration vector are estimated and based on Equation 4, the error-correction term is extracted to estimate ECM Equation 3.

Table 2. Johansen- Juselius cointegration test results.

	Trace Test		Lmax Test	
Null Hypothesis	Trace Statistics	Critical Values	Lmax Statistics	Critical Values
$r = 0$	35.3871**	29.797	22.7775**	21.1316
$r \leq 1$	12.6096	15.4947	12.4102	14.2646
$r \leq 2$	0.19936	3.84146	0.19936	3.84146

Note: Critical values are calculated at 95% level, and ** denote significance at this level.
Source: Results of this research

Table 3. The result of linearity test.

Transition Variable	F	F4	F3	F2	Suggested Model
ΔLE(t-1)	0.634	0.548	0.637	0.358	Linear
ΔLrgdp(t)	0.644	0.889	0.118	0.858	Linear
ΔLrgdp(t-1)	0.671	0.636	0.678	0.301	Linear
ΔLP(t)	0.582	0.401	0.575	0.511	Linear
ΔLP(t-1)	0.426	0.437	0.603	0.193	Linear
*ecm(t-1)**	*0.041*	*0.311*	*0.029*	*0.087*	*LSTR2*
LS(t)	0.883	0.652	0.991	0.378	Linear
LEI(t)	0.543	0.256	0.955	0.339	Linear
Trend	0.825	0.569	0.981	0.361	Linear

Source: Results of this research

4.2 *Linearity Test*

To test the existence of nonlinearity in the dynamics of energy demand, the test presented in Section 3 is employed. In this test, Equation 5 is estimated for candidate transition variables. In addition to the variables in the model, the transition variable can also be another variable outside the model. In the literature, various variables have been introduced which can lead to non-linearity of the energy adjustment process. Thus, the explanatory variables and their lags, along with the energy intensity, the share of industry to GDP, error-correction term and time trend are tested as potential factors that can affect this relationship. Among them, a variable is chosen in which linearity hypothesis is statistically more strongly rejected. The results of the test are presented in Table 3. The first column shows potential transition variables, and the second column shows the probabilities of F test for null hypothesis of linearity. Columns F4, F3, and F2 represent probabilities for testing hypotheses H_{04}, H_{03} and H_{02} respectively. It is clear that the hypothesis of linearity only for error-correction term can be rejected at 95% confidence level, so, an alternative hypothesis, smooth transition regression, has been accepted. Also, this variable can be selected as the suitable transition variable. This result suggests that the energy demand follows a nonlinear process based on the value of the error- correction term. Therefore, the coefficients and short-term dynamics can change according to the difference from the long-run equilibrium. The suggested model is LSTAR2, based on stronger rejection of hypothesis H_{03}. This functional form indicates the existence of two thresholds for regime change. So that the coefficients are different around the middle value of the two thresholds.

4.3 *Model Estimation*

After performing tests to determine the model, the coefficients of the model are estimated using the error-correction term as the transition variable and the functional form LSTR2 for the transition function. The results of the estimation of Equation 3 are given in Table 4.

Table 4. Estimation of energy demand dynamics by STECM.

Variable	Coefficient	p-value
linear part		
CONST	0.075	0.079
ΔLE(t-1)	0.292	0.040
ΔLrgdp(t)	0.369	0.006
ΔLP(t)	-0.088	0.037
Ecm(t-1)	-0.215	0.050
nonlinear part		
CONST	-0.038	0.383
ΔLE(t-1)	0.499	0.384
ΔLrgdp(t)	0.338	0.053
ΔLP(t)	-0.293	0.012
Ecm(t-1)	-0.159	0.042
Gamma	28.664	0.058
C1	-0.132	0.001
C2	0.077	0.022
R^2: 0.78		

Source: Results of this research.

As already mentioned, the error correction model represents the short-run dynamics of variables and how they react to deviations from long-run equilibrium. Due to the confirmation of error- correction term as a transition variable, it can be concluded that the deviation from long-run equilibrium has affected energy demand coefficients and short-run dynamics of the model in Iran. In other words, the amount of energy demand shock and deviation from equilibrium varies in the response of variables and the speed of adjustment.

Due to the choice of LSTR2 as a functional form, two thresholds are obtained (C1 and C2). In such conditions, there are two extreme regimes for the coefficients of the model. The first regime is for the time when the transition variable is between the two thresholds. On the other hand, in the situation where the transition variable is on both sides of the threshold values and with the distance from them, the second regime will dominate. As can be seen, the lower threshold estimated for the error- correction term is negative (-0.132), and the upper threshold is positive (0.077). The average value of the two estimated thresholds (-0.027) is close to zero. This result shows that the adjustment of the demand function near the long-run equilibrium values is performed with different coefficients relative to the conditions where the distance from equilibrium is high. The coefficient of error-correction term in the linear section is -0.21. While at points far away from the middle value of the thresholds, it is equal to the sum of linear and nonlinear coefficients, that is -0.37, which represents a lower correction rate around the mean value. It means that the convergence speed increases with the size of the deviation from equilibrium. This result is consistent with what Balke and Fombey (1997) have shown, since moving toward long-run equilibrium did not occur in the same way, and as the deviation from the long-run equilibrium level of energy demand function are closer to zero, the incentive for adjustment is less, and demand for energy has been less responsive.

The lag of energy consumption has positive effect on itself. Regarding the insignificance of its coefficient in the nonlinear sector, it can be said that the effect of this variable on energy consumption per capita does not have a significant difference in the two regimes. But the coefficients of logarithm of real GDP per capita and energy price index are significant in both parts, and their values vary according to the size of the error. Price elasticity of demand value varies between -0.088 and -0.381, and income elasticity varies between -0.369 and -0.707. In the middle-level regime where the amount of deviation from the equilibrium is low, the elasticities are lower, and the higher the distances from equilibrium, the larger the elasticities.

In order to clarify the effect of the transition variable (ecm term) on the change of coefficients, we can use the transition function graph. Figure 1 shows the relationship of the transition function with the transition variable, that is, the error- correction term.

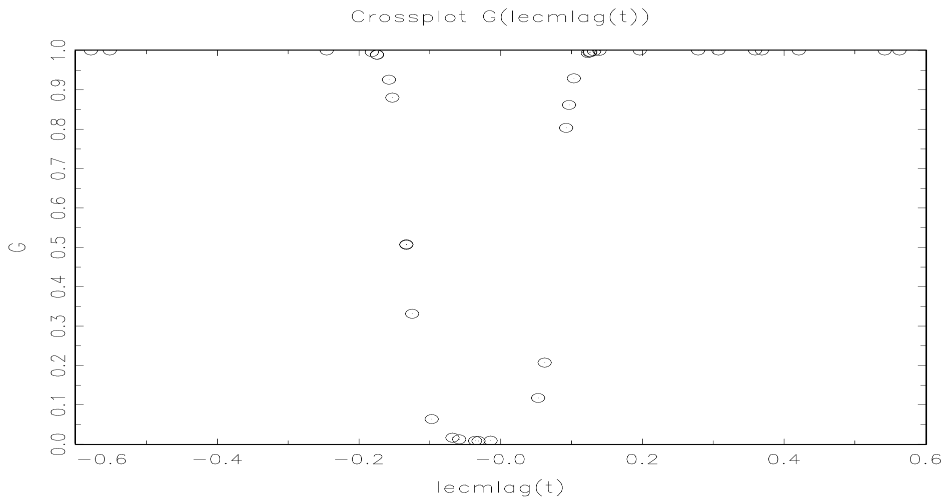

Fig. 1. Transition function ***(Source: Results of this research).***

As shown in the graph, at the midpoint of the two thresholds, namely, between (-0.13) and (0.07), the value of the transition function is zero. This average value is almost zero. But the greater the error value from this midpoint, the transition function is close to one. Therefore, energy demand, depending on the size of the transition variable (error- correction term), has two types of dynamics and reactions. In the regime that is located far away from the thresholds, the deviation from the long-run equilibrium is either too negative or positive and the response of the variables are greater. Therefore, price and income elasticity and speed of convergence are higher in this regime. But in the intermediate regime, where the error- correction term is close to zero and therefore, the deviation from the longer-run equilibrium is low, the motivation to react is less, and therefore, the price and income elasticity and speed of convergence are smaller.

Another point to note is that although the mean value of the thresholds of the error- correction term is close to zero, but the absolute magnitude of the negative threshold represents a larger value. This indicates that consumers react to negative demand shock later.

5. CONCLUSION

In this paper, the dynamics of energy demand were estimated using Iranian economic data during the period of 1978-2015. Given the fact that in the existing literature the non-linearity of energy demand has been emphasized, ignoring this fact can be misleading due to specification error. In this research, a Smooth Transition Error Correction Model (STECM) was used to estimate energy demand dynamics in Iran. The results of the estimation confirm the nonlinearity of the model by considering the error- correction term as the transition variable. So the amount of demand elasticities and the speed of adjustment differed according to the distance from the long-run equilibrium. As a result, the use of the linear error correction model does not provide an accurate specification of the realities of energy demand dynamics in Iran.

The results of this nonlinear model indicate that there are two different regimes in the dynamics of energy demand in Iran. This is a very important issue for designing energy policy. In the first regime, with a high deviation from long-run equilibrium, the response of the variables is higher and the price and income elasticity of demand and the speed of adjustment are higher. But in the near long-run equilibrium, the consumer's incentive for reaction is less and so the price and income elasticity and the adjustment rate are were small.

The results also indicate that income and price elasticity of energy demand in both regimes were less than one. In other words, energy in Iran is an essential good and price inelastic. It can be said that subsidizing energy carriers in Iran and its low prices for many years, has caused the demand elasticity to be very low. This shows that the implementation of pricing policies in these conditions cannot be effective enough to influence energy demand. According to the results of this study, especially in the case of small demand shocks and as a result a slight imbalance, the consumer response to policies is much less. Therefore, if the policy maker wants to help reduce energy consumption by using pricing policies, slight price changes cannot have a significant effect on changing the behavior of energy consumers. In Iran, of course, the elasticities in both regimes are smaller than one, but this may not be the case in other countries. Therefore, given the possibility of nonlinear effects in the dynamics of energy demand, this problem can be evaluated in other economies as well. The STECM model provides a suitable statistical framework for examining such relationships. In addition, non-linear effects in other countries may be influenced by other variables, depending on the economic conditions and structures.

Finally, in this paper aggregate energy data were used. However, this study can also be applied to energy consumption in different economic sectors and for different types of energy carriers. Because the results can be different and can be used in sectoral policy making.

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