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The Threshold Effect of Economic Complexity on Energy Consumption in Iran Using Smooth Transition Regression Model

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Abstract
The economic complexity index is one of the latest published indicators to measure the level of knowledge and technology in countries. In this paper, using a smooth transition regression model, the effect of economic complexity on energy consumption is evaluated for the first time in the Iranian economy during the period 1971-2013. The results of the model estimation confirm the existence of a nonlinear relationship between income per capita, real energy price index, and the complexity of the economy with energy consumption per capita. Also, economic complexity leads to a two-regime structure with a threshold of -1.15. In the first regime, which is related to the low levels of economic complexity, the effect of this variable on energy consumption was positive, that could be due to the rebound effects of technology on energy consumption. In the second regime, which is related to higher levels of complexity, the relationship was negative. Therefore, in the second regime, improving the level of complexity can help to save energy. However, the elasticity of income and price in both regimes was less than one, but as the complexity passing the threshold, the elasticity has increased in particular with respect to price, which indicates that with the increase of technology and knowledge of the country, the power of the reaction of consumers to the price changes will increase.

Keywords: Energy Consumption, Energy Demand Elasticity, Economic Complexity, Technological Progress, Nonlinear Model Smooth Transition Regression.

JEL Classification: Q41, O33, O30, C24.

1. Introduction

The level of technology is one of the most important factors affecting energy consumption. Technology advances can improve energy efficiency and so reduce energy consumption; on the other hand, it boosts economic growth, which results in more energy consumption (Yuan et al., 2009).

On the other hand, the relationship between technology and energy consumption can also depend on the nature of technology development (Khan et al., 2016). For this reason, the type of technology and index used to measure it may be another reason for the differences in empirical results in studies in this field (Jacobsen, 2001).

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This paper uses the index of economic complexity to measure technological knowledge and progress. It has all the capacities, levels of technology, skilled workforce and knowledge required for production, and it can encompass wider aspects of technology and technical improvement.

The present paper is innovative from two perspectives. First, it examines the relationship between economic complexity and energy consumption in the Iranian economy for the first time. Secondly, it uses a nonlinear smooth transition regression model to investigate this relationship, because in recent years, some researchers have shown that the energy demand pattern can follow a nonlinear process (Balke & Fomby, 1997; Gately and Huntington, 2002; Dargey et al., 2007; Hu and Lin, 2008 and Omay et al., 2014). Therefore, in this paper, using a smooth transition regression model, the threshold effect of economic complexity, as an appropriate indicator of the level of knowledge and technology, on energy consumption is estimated and the role of this variable in the price and income elasticity of energy is examined.

2. Literature

Energy carriers are demanded by both consumers as final goods and firms as inputs. From the perspective of producers, demand for energy input comes from maximizing production by a certain amount of cost. Thus, the demand for energy depends on its price, the price of other inputs, the amount of production, and the level of technology (Bhattacharyya, 2011). From the consumer's point of view, the use of many consumer goods is combined with energy consumption. Energy can, therefore, be also counted among consumer goods, which, according to microeconomic theory, is demanded as a function of relative price and real income. The level of technology also affects the amount of energy consumption. Using more advanced technology can improve energy efficiency and reduce consumption. On the other hand, changing the type of consumer goods to energy consuming can increase energy consumption (Jacobsen, 2001). There are two main theories about the impact of technology on energy consumption. In the first theory, technology improvement can reduce energy consumption, thereby providing new technology tools and techniques to reduce and save energy (Ahmed & Arshad Khan, 2009). According to the second theory, improvement in technology will increase production and economic growth as well as increase efficiency, lowering the cost of energy use, and thereby increasing energy consumption. This is called the rebound effect (Lin & Du, 2015). Various indexes have been proposed to measure the improvement of technology. One of the newest indicators that reflect the amount of knowledge and technology used in a country's production structure is the index of economic complexity that has been used in recent years in some studies as a measure of technology advancement (e.g., Can & Gozgor, 2017 and Neagu & Teodoru, 2019). The index of economic complexity was presented by Hidalgo and Haussman (2009). The index of economic complexity as a measure of innovative production has certain advantages over other indexes (Hausmann et al., 2013).

3. Model and Data

In this paper, a smooth transition regression (STR) model was used to investigate this relationship. In this model, the transitions between different regimes are explained by the logistic function. Energy consumption based on this model can follow the form below.

$$LE_t = \pi' w_t + (\theta' w_t) G(s_t, \gamma, c) + u_t \qquad (1)$$
$$w_t = (1, Ly, Lp, Leci)$$

Where LE_t is log-transformed per capita consumption of energy, w_t is explanatory variables vector including log-transformed real GDP per capita (Ly_t), log-transformed energy price index (LP_t), and log-transformed of economic complexity[1]. π represents the vector coefficients of the linear part and θ is non-linear coefficients vector.

For the empirical estimation of this relationship in Iran, the annual data of Iran during the period 1976-2013 was used. The Economic Complexity Index was obtained from the MIT Atlas Database. To calculate the per capita energy consumption, the total final consumption of total energy carriers in oil equivalent barrels was extracted from the Iranian energy balance sheet. Also, data on GDP at constant price of the year 2004 were obtained from central bank statistics. Real energy prices, as in the article by Li and Lin (2014), were calculated.

4. Empirical Results

4.1. Evaluation of Stationary and Cointegration

Before estimating the model, it is necessary to evaluate the degree of stability of the variables. The generalized Dickey-Fuller test (ADF) was used for this purpose. Table (1) presents the stationary test results.

1. The index of economic complexity varies from -3 to 3. Since the logarithm of negative numbers is not significant, all of the complexity index values were added to 3, so all values were positive and logarithmic without losing order.

Table 1: Unit-Root Test

Variables	Test stats for level	Test stats for first order difference
LE	-1.82	-5.87
Leci	-2.18	-7.03
LP	-1.76	-5.66
Ly	0.74	-6.17

Note: The critical value at 95% level is -2.94

Source: Research Findings

As shown in Table (1), all variables are non-stationary but the first-order differences of all variables are stationary. So, it is necessary to ensure the existence of a co-integration relationship between the variables.

Table 2: Trace Test

Null Hypothesis	Trace Statistics	critical value	Prob
$r = 0$	68.04	63.87	0.021
$r \leq 1$	33.85	42.91	0.295
$r \leq 2$	14.05	25.87	0.652
$r \leq 3$	4.29	12.51	0.698

Critical values are calculated at 95% level

Source: Research Findings

Table 3: Lmax Test

Null Hypothesis	Lmax Statistics	critical value	Prob
$r = 0$	34.18	32.11	0.027
$r \leq 1$	19.79	25.82	0.254
$r \leq 2$	9.75	19.38	0.644
$r \leq 3$	5.13	14.12	0.687

Critical values are calculated at 95% level

Source: Research Findings

Based on the trace and Lmax tests at 95% confidence level, the existence of at least one cointegration vector in the relationship between the model variables was confirmed.

4.2. Linearity Test

The existence of a nonlinear relationship between the variables should first be tested. The results of the test for appropriate transition variables are presented in Table 4.

Table 4: Linearity test

Column 1 Transition Variable	Column 2 Prob F	Column 3 Prob F4	Column 4 Prob F3	Column 5 Prob F2	Column 6 Suggested Model
LE(t-1)	-	-	0.0880	0.2108	Linear
Leci(t)*	0.0057	0.0490	0.2504	0.0013	LSTR1
Ly(t)	-	-	0.5411	0.3206	Linear
Lp(t)	0.1599	0.3413	0.2805	0.1038	Linear
Trend	0/0242	0.0019	0.9482	0.5351	LSTR1

Source: Research Findings

The first column in Table (4) lists the potential variables that can be considered as the transition variable. The values presented in the second column represent the level of uncertainty in rejecting linearity of the model. Based on the results, linearity of the model for the complexity index and time trend at 95% confidence level can be rejected. But since the level of uncertainty is smaller for the complexity index, this variable has the greatest impact on the change in the coefficients and should be considered as the transition variable and appropriate functional form is LSTR1 for the transition function.

4.3. Model Estimation

The final estimation of the model with the logarithmic variable of economic complexity considered as the transition variable and the transition function in the form of LSTR1are presented in Table (5).

Table 5: Energy consumption estimation by the LSTR1 model

Variable	Coefficient of linear part	Coefficient of nonlinear part
intercept	-2.291** (-2.597)	0.942 (0.693)
LE(t-1)	0.605*** (3.174)	0.254 (1.018)
Leci(t)	0.443* (1.882)	-0.570** (-2.014)
Ly(t)	0.174** (2.483)	0.042** (2.372)
Lp(t)	-2.90*** (-3.717)	-0.192*** (-3.224)
Gamma	4.179* (1.872)	
C	0.617*** (17.736)	
$R^2 = 0.97$		
The numbers in parentheses represent the t-statistic. ***Significant at 99% level, ** Significant at 95% level and * Significant at 90% level.		

Source: Research Findings

Table 5 has two parts. In the first column, linear coefficients and in the second column nonlinear coefficients are reported. This model follows two regimes. The first regime is a state with zero transition function, with only linear part of the coefficients. The next regime is a state in which transition function is equal to one and the model coefficients are equal to sum of the linear and nonlinear part coefficients

The magnitude of the coefficients of other variables in each period depends on the amount of transfer function in that period. To illustrate this, we used Figure (1), which shows the relationship between the transition function and transition variable (logarithm of economic complexity index) over the period of the study.

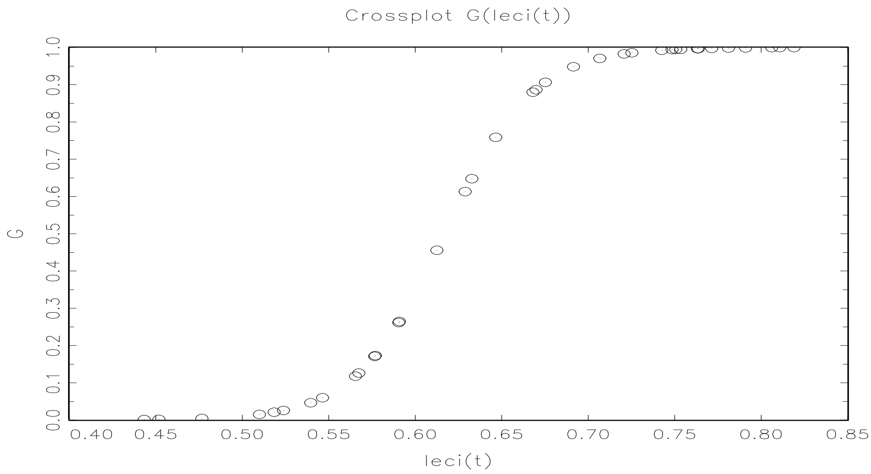

Fig. 1: Relationship between transition function and transition variable

By returning the obtained threshold value to a non-logarithmic value, the value -1.15 is achieved. Figure 2 shows the value of the economic complexity index over the period under study. By comparing the economic complexity values with the threshold value, in the periods above the threshold value, the value of transition function approaches one. As a result, the second regime has dominated the energy consumption model.

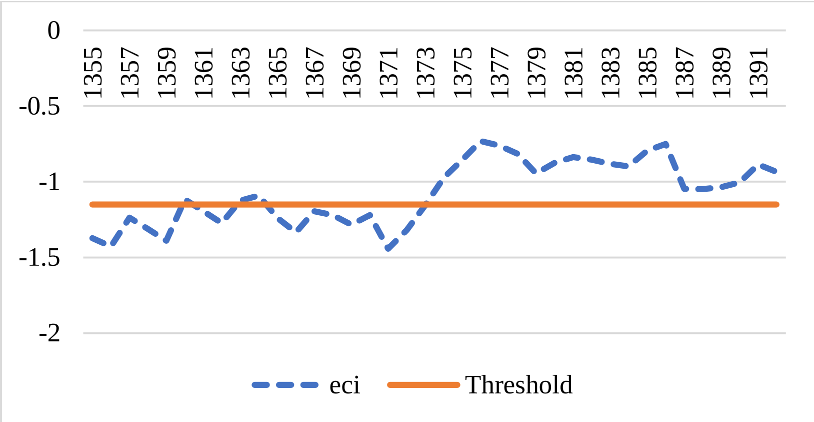

Fig. 2: Economic complexity in Iran and its threshold

In Table 5, the estimated coefficient of economic complexity in the linear part is positive and equal to 0.443. This means that as technology increases, per capita energy consumption also increases, indicating a rebound effect at low levels of technology. However, the negative sign of this coefficient in the nonlinear part indicates that as the level of technology increases, the coefficient of this variable decreases and approaches -0.127. Under these conditions, increasing economic complexity leads to lower energy consumption. Thus, more favorable effects on energy consumption can be expected. To ensure the results of the estimated equation, misspecification tests were investigated and the results showed that the estimation of this model has been performed appropriately and properly.

5. Conclusion

The results of the present study confirmed the existence of a nonlinear relationship in energy demand. The findings showed that the economic complexity variable can play an important role in changing the coefficients in the energy consumption model, so that the income and price elasticity of energy consumption were smaller than one, but at higher levels of economic complexity, which reflect higher levels of technology in the country, the elasticity of both variables increased slightly. Economic complexity had a positive effect in the first regime and a negative effect in the second regime on energy consumption. Thus, by increasing the level of complexity in the economy, we can hope for the favorable effects of technology growth on energy consumption. Given the validity of the nonlinear relationship in energy demand function, in order for a proper policy making in this regard to meet the needs of the country, policymakers need to pay a special attention to correctly identifying the relationship between variables and energy consumption and the factors affecting it. This can help policymakers in the field to anticipate future needs and plan appropriately for efficient use of its capacities.

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