The Relationship Between Energy Consumption and Income Inresidential and Commercialsectors of Iran Using STR

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Abstract: Residential and commercial sectors, share a significant portion of energy consumption in Iran; 37 percent of the total per capita consumption. Therefore, identification of the relation between revenue and energy consumption could be a great assistance to policy makers for clarification of policies employed in energy sector. This paper attempts to explore and analyze the relationship between revenue and energy consumption in residential and commercial sectors for the years 1969 to 2009 in Iran by Smooth Transition Regression Models. Smooth transition regression model is a nonlinear time series model which can be considered as a developed form of Switching Regression Model. The obtained results indicate that in the long and short term there is a nonlinear and inverse relationship between energy consumption in residential and commercial sectors and gross domestic production while there is a direct and nonlinear relationship between energy consumption in residential and commercial sectors and value-added of residential sector and population. Ultimately, if a gross domestic production, residential sector value added and population increase, energy consumption in residential and commercial sectors will decrease about 0.66 and increase about 17.72 and 1.15 respectively.

Key words: Energy Consumption in Residential and Commercial Sectors · Gross Domestic Production (GDP) · Smooth Transition Regression (STR) · Elasticity · Iran

INTRODUCTION

Energy is one of the components of technical and economic infrastructure of the society and the progress of production and service sectors. The improvement of people's life depends on the adequate provision of various types of energy. Energy plays a more significant role as the economy progresses. Residential and commercialsectors are the two main consumers of energy who use it for heating, cooling and cooking purposes. These sectors have been the largest users of the country during 70's to the late 90's. The energy consumption of residential sector has been 28.2% of the total amount of consumed energy; while the reported rates for industry, transportation and agriculture has been 21.4, 20.7 and 5 percent respectively. The energy consumption for these sectors has always, save for some years, taken an upward trend. The average increase rate of energy consumption during these three decades has been 7.8 percent. The energy consumption of Iran in these sectors proves to be three times the global energy consumption. An analysis of consumption model of different users of the country in comparison to that of other developing countries indicates that the residential and commercialsectors use more than 37 percent of the total energy and 32.8 percent of total electricity of the country, while industry sector used only 23 percent of the energy and 32 percent of electricity of the country.

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Diagram 1 show the growth trend of energy consumption per family units and then compares it with the growth of energy consumption per capita during the last decade.

In this paper, the effect of actual (nonlinear) income on energy consumption of residential and commercialsectors, based on nonlinear models of smooth transition models,isstudied. This approach is of great flexibility in modeling nonlinear relationship between variables; in this approach the change of parameters during time are modeled with great consistency. Thus, this approach is appropriate for determining the varying relationship between energy consumption in residential and commercial sectors and incomeduring a certain period of time. The current study uses time series data and is for Islamic Republic of Iran for the period between 1969 and 2009.

The second part of this paper reviews the studies conducted on the relationship between energy consumption in residential and commercialsectors and income. The third section introduces the LSTRmodel and presents the basic theories of the relationship between energy consumption in residential and commercial sectors and actual income and concludes with a model determining the relationship between the energy consumption and income. The fourth section reports the results obtained from unit root tests and estimation of LSTRmodels using the NLS method as well as the experimental results. The results are summarized and concluded in the final section.

Research Methodology: The study of energy consumption changes due to incomechanges; price or technology progress has always been a challenging discussion. Simon Kuznets introduced the relationship of income per capita and inequality of income as aninverse U relationship in 1995. Later on, the meaning of Kuznets Curve was applied to other areas. Dinda [1] illustratesthat the relationship between the environmental variables and income per capita is an inverse U. Then, Kuznets curve gained attention for describing the relationship between the quality of environment and income per capita. Some of studies on the relationship of consumption per capita and income per capita have observed the relationship similar to Kuznets curve for these two variables in their results. For instance, Cole *et al*. [2], applying the Panel Models (fixed and random effects) to study OECD countries, illustrated that as income per capita increased between 1970 and 1992, the energy consumption per capita also increased. Granger [3] conducted the first study on

energy consumption and economic growth using the causality analysis. Further to this study, many other studies were conducted on the relationship of energy consumption and economic growth in the United States, England, Germany, Italy, Canada, Singapore and Thailand. Sari and Soytas [4] recommended that total energy consumption can only explain the 21% of prediction error in Turkey's GDP. The severity of parametric energy has constantly been used by energy researchers. Metcalf [5] showed that technological innovations have enhanced the energy application and reduced the energy severity. Drukman and Jackson [6] found out that energy consumption in residential sector is not only a function of personal income but also a function of other factors such as type and building architecture and family status in regard with living in town or village. They also found out that energy consumption in residential sector and its pollution have a close relationship with income level in England.

Various studies have been conducted on the relationship between energy consumption and economic growth in Iran as well. Mehrara [7] studied the granger causality between energy consumption and income in Iran. He administered the Johansson test to determine the co-integration relationship and error correction model. The results showed that there is a one way granger causal relationship from income to energy consumption in the long-run while in the short-run there is a neutral relationship between energy and income; that is, the cost of energy is a small portion of Gross domestic production and therefore it has no considerable or meaningful impact upon production growth. The results obtained by Armen and Zare [8] indicated that there is a one way relationship from energy to economic growth. The current study, utilizing smooth transition regression model which had previously been capable of determining relationships similar to Kuznets Curve for environmental variables, attempts to study the relationship between the actual income and energy consumption in Iran's residential and commercialsectors.

MATERIALS AND METHODS

The problem of cross-section heterogeneous and energy demand model instability is a serious problem. Smith and Pesaran [9] and Hsiao [10] showed that ignoring these issues leads to bias,. Hansen and King [11] also stated that a heterogeneity of cross-country data leads to income elasticity estimation of more than 1.

Simultaneous resolution of these two issues proves difficult. A simple solution can be specifying a Smooth Threshold Regression model which has been introduced and developed by Fok *et al.* [12], Colletaz and Hurlin *et al.* [13] and Fouquau *et al.* [14].

Smooth transition regression model is a nonlinear time series regression model which can be considered as a developed model of regime switching regression model which was introduced by Bacon and Wats [15]. These researchers considered two regression lines and started developing a model in which transition from one line to another line can occur smoothly. In time series literature, Granger and Travstra [16] attempted to describe and propose the smooth transition model in their studies.

The mentioned model can be employed for time series data in two ways: Exponential Smooth Threshold Regression (ESTR) and Logistic Smooth Threshold Regression (LSTR):

$$Y_t = \alpha + \emptyset z_t + \theta Z_t F(q_t) + \varepsilon_t = \alpha + [(\emptyset + \theta F(q_t)]Z_t + \varepsilon_t \quad (1)$$

$$\text{LSTR Model: } F(q_t) = \frac{1}{1 + \exp(-\gamma(q_t - t)} \quad (2)$$

$$\text{ESTR Model: } F(q_t) = 1 - \frac{1}{1 + \exp(-\gamma(q_t - c)^2]} \quad (3)$$

Y_t isthe dependent variable, α is the intercept and Z_t is the vector of explanatory variables. The coefficients of explanatory variables are not a fixed quantity anymore and are a function of $q_t$variable. $F(q_t)$ is the function of transition, q_t is the transition variable, c is the threshold parameter and $\gamma > 0$ is the slope parameter. q_t can be any of Z_t model variables, their halts or any variable outside the model. The above description indicates that the model can also be interpreted as a linear function with coefficients changing randomly over time.

For the LSTR model, the $\emptyset + \theta F(q_t)$, as a function of q_t, changes monotonously from $\emptyset$ to $\emptyset + \theta$ (when q_t moves from ∞-to ∞+). But for ESTR function, the coefficients change symmetrically from $\emptyset$ to $\emptyset + \theta$ around the mid-point c (when q_t moves from c to ±∞). Therefore, LSTR model has the potential to model the symmetric behavior of variables. This model is appropriate and reliable for describing processes showing a different behavior in boom periods in comparison with stagnation period or for smooth switch from one regime to another regime. On the other hand, the ESTR model is appropriate for conditions when the coefficients or dynamic adjustment processes show a similar behavior for extreme values (high and low) and only exhibit a different behavior for mid-values. Where the slope parameter is $\gamma = 0$, the transition function equals $F(q_t) = 1$, therefore STR model turns into a linear model. On the other hand, when $\gamma \to \infty$ then LSTR model changes into a regime switching regression model with two discrete regimes. In ESTR model, if $\gamma \to \infty$, then it will be a linear model.

Smooth transition regression model which are renowned as STR models, have had great success in elaboration of the relationships of the environmental variables. This study attempts to base the experimental approach of this paper, which tries to assess the relationship between energy consumption and actual income in Iran, on the above mentioned models. As a model must be elaborated and assessed before it can be used for evaluation of the relationship between two variables, this section first introduces the LSTR model and the employed parameters and then will analyze the obtained results.

Production: Energy consumption is considered as one of the most important inputs for production Cleveland [17], Furthermore, the Conditional factor demand function for production inputs, such as energy, is always a function of output level or extractable production. Therefore, energy consumption, like any other input, depends on the level of economic activities in a given country. Based on experience, energy consumption in world economies such as developing or upstart countries is most affected by economic growth of that country (Chousa, Tamazin and Chaitanya [18].

Thus, it is anticipated that there is ameaningful relationship between energy consumption and gross domestic production.

Residential Sector Value-Added: Another factor affecting energy consumption in residential and commercial sectors is known as the value-added of these sectors Chaitanya [19]. Creating fixed capital in various sectors such as Industry, Agriculture, Residential and Commercial influence the energy consumption. Studies conducted in Iran have usually dealt more with sectors other than residential sector and the effect of this variable on industry and agriculture sectors has been determined. Taheri and Mousavvi [20] studied in their research that energy has a meaningful effect on the value-added of agriculture sector and a 10 percent increase in energy consumption will increase the production by 4.1 percent. This paper studies the effect of this variable on residential sector.

Population: World population increase and the promotion of lifestyle, especially in developing countries, most generally and quite naturally lead to energy consumption increase. According to the United Nations statistics, the population of the world will exceed 6 billion till the end of the current century. That is, the world witnesses an annual 80-million increase of population whose largest share is owned by the third-world countries. Iran experiences an annual 2-million increase of population. Provision of the energy needed by this huge population is not without challenge. This population need drinking water, electricity and heating energy, fuel for cooking, linking roads, education and job whose realization is not feasible without energy consumption. The population growth rate is another main factor which must always be considered in energy consumption Chaitanya [19]. Population growth demands more services and production for the fulfillment of the increasing population's daily needs. Increased production demands more energy. The rapid growth of commercial energy by oil-exporting countries is due to economic growth, low domestic costs, immigration of villagers to towns and population growth.

If the descriptive value Z_t of relation(1) is replaced with variables introduced above and if the exponential form (relation 2) is employed, the following relations are obtained for the specification of the model.

$$ec_t = \alpha_t + \beta_1 y_t + \beta_2 pop_t + \beta_2 \alpha v_t + (\beta_4 y_t + \beta_3 pop_t + \beta_6 \alpha v_t)g(q_t, \gamma, c) + \varepsilon_t \qquad (4)$$

$$g(q_t, \gamma, c) = \frac{1}{1 + \exp\{-\gamma(q_t - c)\}} \qquad (5)$$

In relation (4), ec_t is the energy consumption logarithm, y_t is the gross domestic production logarithm, α_{vt} is the residential sector value added, pop_t is the annual population logarithm and $\varepsilon_t \sim iid(0, \sigma_3^2)$. [1]Relation (5) is also considered as the function of transition and the transition variable q_t is defined as the first lag of gross domestic production.

Before evaluation of LSTR model, it must be proved that the model is nonlinear. Therefore, the linearity of the model is put to test. In case the null hypothesis for linearity of the model is rejected, then it will be evaluated using the nonlinear least squares method. For linearity test, the null hypotheses must be tested as follows:

$H_0 : \gamma = 0$ or $\beta_4 = \beta_5 = \beta_6 = 0$

But the parameters of the model cannot be identified based on the null hypothesis and the statistic t is not of a standard distribution (the distribution contains intrusive and unidentified parameters). The Lagrange Multiplayer has been recommended for resolution of the above issue.

The results obtained from the linearity test are reported in Table 1. In addition, the results of linearity test based on non-standard test statistics according to $\beta_4 = \beta_5 = \beta_6 = 0$ and $\gamma = 0$ are also illustrated in Table 1. As shown in Table 1, the linearity hypothesis is rejected.

Before evaluation of the model based on Nonlinear least squares, first the stability of ec_t, the logarithm of energy consumption, y_t the logarithm of gross domestic production, αv the logarithm of value-added of residential sector and pop_t the logarithm of annual population is assessed.

Considering the above results, all variables of the model share the same unit root and obtain stability with one-time differencing. The stability test results are shown in Tables 2 and 3.

In co-integration analysis, the existence of economic relationship is tested and estimated. The main idea in co-integration analysis is that although many of economic time series are unstable (containing random trends), there is a possibility that the linear combination of these variables are stable (withoutrandom trends) in long-run. The co-integration analysis helps us to determine and assess this long-run balanced relationship. If an economic hypothesis is correct, a special set of variable which are specified by the hypothesis are related to one another in the long-run. Moreover, the economic theory only states the relationship as long-run and does not reveal anything about the short-run dynamic among variables. In case the theory is validated, it is expected, in spite of instability of variables, that a static linear combination of these variables are stable and without any random trend;otherwise, the validity of the theory is questioned. For this same reason, the co-integration is used for validation of economic hypotheses and estimation of long-run parameters.

Considering the fact that all variables of the model share the same unit root, the Engle Granger co-integration test has been employed.

In the next step, LSTR model is evaluated by NLS model based on equation (4). The results obtained from this evaluation are shown in Table 4. Considering above explanation, a nonlinear relationship between gross domestic production and energy consumption in residential and commercialsectors in observed.

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[1]Identify Independent Distribution

Table 1: Linearity Test

Linearity test	LSTR Model
Value of F related to hypothesis $\beta_4 = \beta_3 = \beta_6 = 0$	11.002(0.001)
Value of LMF related to hypothesis $\beta_4 = \beta_3 = \beta_6 = 0$	33.006(0.000)

Table 2: The test results of the stability of variables according to ADF method

ec_t	-1.41(0.83)
y_t	1.04(0.99)
avt	-2.41(0.36)
pop_t	-2.08(0.53)

Table 3: The test results of stability test for first time differencing of variables according to Dickey- Fuller Method

$D(ec_t)$	-4.96(0.001)
$D(y_t)$	-4.49(0.007)
$D(av_t)$	-4.90(0.002)
$D(pop_t)$	-4.15(0.013)

Table 4: Final Results of LSTR model estimation

Parameter	Results
β_1	7.78(0.04)
β_2	-104.42(0.0005)
β_1	-9.08(0.06)
β_4	-74.15(0.03)
β_3	1877.13(0.0004)
β_6	124.81(0.04)
σ	3.1
γ	1
R^2	0.99
Sum of error square root	0.04
Akaike information criterion	-3.24
Schwarz information criterion	-2.91
Hannan-Quinn information criterion	-3.14
Durbin-Watson statistic	1.76
F Meaningfulness of total regression criterion	699.35(0.000)

Table 5: Results obtained from co-integration test based on Engle Granger method

Test MethodEquation	Result of Engle Granger co-integration test
Eq. 4	-4.62(0.005)

Source: Results obtained from the research

Note: The numbers in parenthesis represent P-Value

The smooth slope parameter of transition function shows that transition function is not too sloped (the obtained number equals 1). Considering the sign of coefficients of the estimated parameters, it is observed that energy consumption shows different behaviors in different levels of gross domestic production, value added of residential sector and population. In other words, in different regimes, energy consumption in residential and commercialsectors exhibit different behaviors. Good statistics have been supplied after the table for the fitness and appropriateness of the model which all indicate the
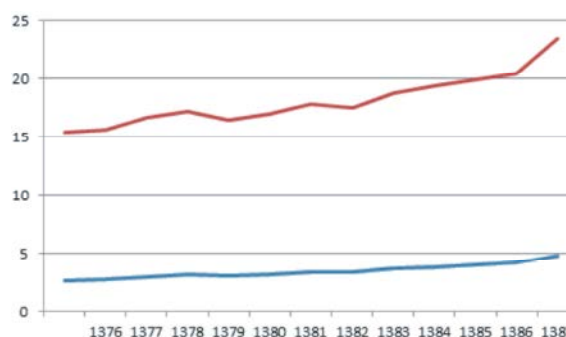

Fig. 1: Growth of energy consumption per capita and energy consumption per family units in the last decade
Note: Red and blue line indicates growth of energy consumption per capita and energy consumption per family units respectively
Source: Ministry of Energy

appropriateness of the model. Also, R^2 of the model equals 0.99 which proves that the explanatory variables explain 99 percent of the variations of the dependent variables.

As the variables of the model share the same unit root, to ensure the evaluated relationships are correct, the above model was tested by the Engle Granger test. The results are shown in Table 5.

As shown in Table 5, the long-run relationship between variables is confirmed by Engle Granger co-integration test. The unit root test is administered to the remnant resulting from the evaluated equation in the previous section according to which the null hypothesis for existence of unit root is rejected. Therefore, the accuracy of the results obtained from the models is verified and confirmed.

RESULT AND DISCUSSION

This paper studied the relationship between energy consumption in residential and commercial sectors, gross domestic production, value-added of residential sector and population, using the annual criteria for Iran economics for the period 1969 to 2009 as well as STR model programming in E-views software. Upon modeling the relationship between energy consumption in residential and commercial sectors and income, considering the nonlinearity and structural changes in the model separately lead to bias in the obtained results. If these issues are not properly noticed in econometrics, the obtained results can be misleading. Considering the nonlinearity and structural changes simultaneously

proves problematic. One solution to this problem is the application of threshold effects in the specification of a nonlinear model. In this approach, the variance of parameters in a certain period of time is modeled continuously. Therefore, this approach is appropriate for the variability of the relationship between energy consumption in residential and commercial sectors and gross domestic production, value-added of residential sector and population in long run. The gross domestic production data and value-added of residential sector were obtained from Central Bank of Iran, the population data from Statistics Center of Iran and energy consumption data were obtained from the energy balance sheet of Energy Ministry. It is worth to note that β_1 and β_4, β_2 and β_5, β_3 and β_6 in different regimes have inverse signs as expected theoretically. That is, the behavior of the variables of energy consumption in residential and commercial sector, gross domestic production, value-added of residential sector and population is well explained by LSTR model. This means that by increasing the gross domestic production, the value added of residential section and population from the threshold on exhibit a behavior different from that below the threshold. The threshold limit is 3.1 according to the estimated model. Considering the parameters estimated in formula 4, the average sensitivity of energy consumption in proportion to gross domestic production, value added of residential sector and population can be calculated for the years 1967 to 2007. To this end, the variables of energy consumption in residential and commercial sectors in proportion to gross domestic production, value added of residential section and population can be differentiated in formula 4. Based on above calculations, a one unit increase in gross domestic production decreases energy consumption for 0.66 percent with a standard deviation of 0.001. Also with a one unit increase in population and value added of residential sector, energy consumption in residential and commercial sectors increases for 17.72 percent with a standard deviation of 0.04 and ultimately a one unit increase in value added of residential sector leads to a 1.15 increase of energy consumption in residential and commercial sectors with a standard deviation of 0.003.

Thus, it can be concluded that there is an inverse relationship between energy consumption in residential and commercial sectors and gross domestic production; there is also a direct relationship between energy consumption in residential and commercial sectors and value added of this sector and population. In fact, one can suggest that based on the above items, if gross domestic production, value added of residential sector and population increase by 1 percent, energy consumption in residential and commercial sections will respectively decrease for 0.66 percent, increase for 17.72 and 1.15 percent. The slope of transfer function in the above model equals 1 which suggests the smooth and un-sudden transition of the model.

With regard to the form of transition function in equation 5 and the calculated threshold (3.1), it can be observed that as per the high economic growth, the effects of nonlinear consumption function increases and the inverse relationship between energy consumption and GDP with more elasticity will be occurred in a way that achieving a full grown economy guarantees the prevention of energy waste. In other words, family income increase in Iran which results their power of purchase will help them to save more energy by substitution of inefficient appliances with efficient ones.

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