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Research Article

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Forecasting the Energy Consumption Growth in Iran's Industrial Sector Using the Fuzzy Linear Regression Method

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Abstract
Regression analysis is a widely used method for investigating relationships between one or more response variables and a set of explanatory variables. This analysis is based on the assumption of the accuracy of the studied variables and the observations related to them, and finally, it specifies the relationships between the variables. in modeling the forecast of energy consumption growth in economic sectors; Generally, the observations are imprecise or the relationships are vague and the relationship between the response variable and the input variables are not precise and well defined. Therefore, it is necessary to use methods of fitting functions that explain the ambiguous structure of data and the relationships between them; Fuzzy regression model, which describes the relationship between output and input data with a fuzzy function. According to this, the purpose of the present study is to forecast the growth rate of energy consumption in Iran's industrial sector using data from 1997 to 2019 by the fuzzy linear regression method. To do so, we collected the necessary statistics and information, and then forecasted the consumption of gas and petroleum products in Iran's industrial sector by 2029. Overall, the results of this research indicate that the growth of gas demand in Industry sector will be positive over time; even though it will have a slow slope. Also, the demand for petroleum products in this sector will be almost constant over time and will not fluctuate much. In addition, electricity demand will experience positive growth as the other parameter under study.

Keywords: Energy Demand, Fuzzy Regression, Forecasting, Energy Carriers, Industry

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1. Introduction

Energy is vital and influential to all aspects of human life, including the economy, and its significance as a worldwide product could be very high. Man's dependence on energy to carry out his/her daily activities such as lighting, making, heating, cooling, moving, transporting, etc. has made it play an important role in promoting welfare and living standards [1].

The role of energy supply is becoming more and more important than before and leading many countries to seek new energy sources to promote economic growth as much as possible, and ensure security after the industrial revolution and movement to use fossil fuels like coal in the 18th century and petroleum in the mid-19th century. Moreover, in economics, energy is considered as a strategic product that plays an essential role in supply and demand and its existence is necessary for consumers and producers. The need to synchronize energy demand with supply has led to the need to study the factors affecting energy consumption, especially the growing demand for different forms of energy in both developed and developing countries is becoming increasingly acute. As a result, industrialization of more and more countries, lifestyle changes, population growth and social changes are among the fundamental factors leading to a more human use of energy sources [2].

The importance of the energy supply along with other supplies and the change in consumption during the development process has prompted the government, as the most powerful institution in society, to play an important role in providing energy. Thus, developing country governments can assess their position between countries by examining the level of energy demand in the country and comparing it with advanced countries and control the level of energy demand by creating laws and regulations such as energy taxes, pricing policies and energy conservation policies. On the other hand, it can be achieved by making investments in various sectors of the economy more efficient. Consequently, the importance of the debate on energy consumption has led politicians in different countries to forecast the necessary measures in order to provide the required level of energy [3].

Estimation of relationships between economic variables plays a key role in empirical research in the field of economic issues. The classical regression method only provides a clear estimate for the relationships of economic variables. However, there are several cases that cause ambiguous traits in the coefficients, parameters, and relationships of these variables. Therefore, using the fuzzy method can be useful to understand these cases. The reason for this is the inherent nature of some components, errors in data collection, and ambiguous nature of variables. In short, the fuzzy nature of economic parameters and relationships makes causal analysis more difficult. Therefore, it is necessary to use a method for economic inference in a fuzzy environment of fuzzy theory**.** In this respect, the current study seeks to forecast the growth of energy consumption in Iran’s economy using fuzzy linear regression.

According to this, the article is organized in five sections. The second part reviews the research literature, including the theoretical underpinnings and empirical records of the research. In the third part, the model used in this research is presented. The fourth part deals with the analysis of the experimental results of this research, while the last part deals with the conclusion and research proposals.

2. Literature review

2.1. Theoretical Underpinnings of Research

Fuzzy regression has a history of more than two decades. The fuzzy set theory was first proposed by Zadeh [4] and has since been successfully applied to many fields, such as fuzzy control, fuzzy expert systems, and fuzzy database systems. Basic concepts of fuzzy sets, fuzzy numbers, linguistic values, and defuzzification methods have been explained in many studies.

Fuzzy regression was first discussed by Tanaka et al. [5]. Their method was later extended by several researchers such as Peters [6], using a different approach, discussed the simplest form of fuzzy regression and predicted the dependent variable by substituting fuzzy values for independent variables in a regression model obtained from normal data. Heshmati and Kandel [7] presented some applications of this fuzzy regression method. Diamond [9] proposed a least-squares fuzzy regression method using triangular fuzzy numbers, and Kandel et al. [7] extended this method to non-triangular fuzzy numbers.

Fuzzy linear regression is a generalization of classical linear regression used to evaluate the functional relationship between independent and dependent variables in a fuzzy environment. This model has been used for a variety of applications including energy forecasts. Actually; Regression models are used to investigate the relationship between the variables of a system. In these models, based on the observations of independent and dependent variables, a function is considered to predict the dependent variable. Independent variables are factors that affect the values of the dependent variable. In ordinary regression, it is assumed that the difference between the observed value and the estimated value is a random variable. If in the studied system, the observations related to the variables are fuzzy or the variables are normal; But if it is felt that the relationship between them is fuzzy, it is natural to use fuzzy regression instead of normal regression.

Traditional econometric models typically assume that the underlying relationships are linear and that the relevant inputs and outputs are well-defined or crisp. Given that well-defined linear empirical models are always just approximations to the relationships suggested by theory, the important question is whether these approximations are sufficient to capture the behavior of real-world systems. In practice, however, there are cases in which observations are fuzzy in nature which cannot be described by probability distributions.

In a general classification, fuzzy regression is divided into two modes. First; Fuzzy regression in the case that the relationship between the variables is assumed to be fuzzy, or in other words, the coefficients of the regression equation are considered fuzzy and the variables are normal. Second; Fuzzy regression in the case where the variables or the observations related to the variables are fuzzy numbers.

In this model, inputs and outputs are non-phased data. The baseline model is regarded as a linear function as follows:

$$\tilde{y} = f\left(x, \tilde{A}\right) = \tilde{A}_0 + \tilde{A}_1 X_1 + \tilde{A}_2 X_2 + \ldots + \tilde{A}_n X_n \quad (1)$$

Here, $\left(\mathrm{i} = 0,1,2,\ldots,\mathrm{n}\tilde{\mathrm{A}}_{\mathrm{i}}\right)$ are the fuzzy coefficients in the form of (p_i, c_i), so that P is the median parameter and C is the range parameter of the fuzzy number. The value of the median parameter indicates the degree of fuzziness. The membership function related to fuzzy coefficient A is shown in Figure 1. The equation (2-4) may be written as:

$$\tilde{y} = (p_0, c_0) + (p_1, c_1)x_1 + (p_2, c_2)x_2 + ... + (p_n, c_n)x_n \quad (2)$$

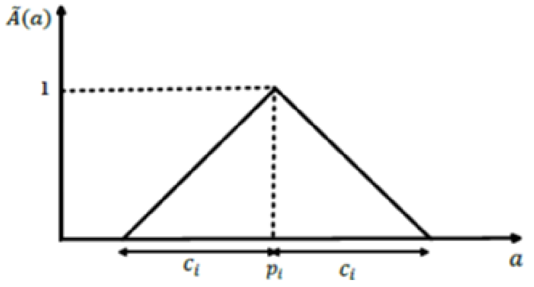

Figure 1- Membership function of the fuzzy coefficient $\tilde{A}_i$

The membership function can be obtained using the extension principle as follows:

$$\tilde{y} = \begin{cases} \max\left(\tilde{A}_i(a_i)\right) & \{a_i / y = f(x_i, a_i)\} \neq \varphi \\ 0 & otherwise \end{cases} \quad (3)$$

From relations (2) and (3):

$$\tilde{y}(y) = \begin{cases} 1 - \dfrac{\left|y - \sum_{i=1}^{n} p_i x_i\right|}{\sum_{i=1}^{n} p_i |x_i|} & x_i \neq 0 \\ 1 & x_i = 0, y = 0 \\ 0 & x_i = 0, y \neq 0 \end{cases} \quad (4)$$

Furthermore, relation (2) can be represented as follows:

$$\tilde{y}_j = (p_0, c_0) + (p_1, c_1)x_{1j} + (p_2, c_2)x_{2j} + ... + (p_n, c_n)x_{nj} \qquad j = 1, 2, ..., m \quad (5)$$

Where m is the number of the observations. Here, the function value is estimated in such a way that the value of the range parameter of the output fuzzy number $\tilde{A}_i(p_i, c_i)$ of the dataset coefficients is minimized. Equation (4-6) shows the objective function:

$$Min \sum_{j=1}^{m} \sum_{i=1}^{n} \left(c_0 + \sum_{i=1}^{n} c_i |x_{ij}| \right) \quad (6)$$

The purpose of the regression model is to determine the optimal values of the parameters so that the observation y_j with the smallest membership degree h belongs to $\tilde{y}(y)$. So:

$$\tilde{y}_j(y) \geq h \qquad j = 1, 2, ..., m \quad (7)$$

The degree of membership h is determined by the user. Equation 7 shows that the result of the phase must be between the two values A and B (Kazemi and Hossein Zadeh ,2013). By replacing relation (4) with relation (7):

$$y_j \geq p_0 \sum_{i=1}^{n} p_i x_{ij} - (1-h)\left(c_0 + \sum_{i=1}^{n} p_i \left|x_{ij}\right|\right) \qquad j = 1, 2, ..., m$$
$$y_j \leq p_0 \sum_{i=1}^{n} p_i x_{ij} + (1-h)\left(c_0 + \sum_{i=1}^{n} p_i \left|x_{ij}\right|\right) \qquad j = 1, 2, ..., m \qquad (8)$$

The above descriptions end in the subsequent linear programming model:

$$Min \quad \sum_{j=1}^{m} \sum_{i=1}^{n} \left(c_0 + \sum_{i=1}^{n} c_i \left|x_{ij}\right| \right)$$
$$y_j \geq p_0 \sum_{i=1}^{n} p_i x_{ij} - (1-h)\left(c_0 + \sum_{i=1}^{n} p_i \left|x_{ij}\right|\right) \qquad j = 1, 2, ..., m \qquad (9)$$
$$y_j \leq p_0 \sum_{i=1}^{n} p_i x_{ij} + (1-h)\left(c_0 + \sum_{i=1}^{n} p_i \left|x_{ij}\right|\right) \qquad j = 1, 2, ..., m$$
$$c_i \geq 0, \quad p_i \geq 0$$

2.2. Literature review

Pao [9] forecasts the energy demand in Taiwan using a nonlinear hybrid approach. This study combines a linear model with an artificial neural network model. In this study, the seasonal crude petroleum and electricity consumption data for the period from January 1993 to December 2007 were used. The results show that the WARCH model is better than the SEGARCH one, and the SEGARCH-ANN model is better than SEGARCH, and finally, the WARCH-ANN model is the best of all.

Lee and Tong use the improved Grey model and mixed with genetic programming (GP) to forecast energy demand in China. The data used in this study is related to the period 1990-2003 and data from 2004-2007 is used to evaluate the model. According to the results of GPGM model (1 & 1), i.e. the improved Grey forecasting model, it is more reliable and more accurate than GM model (1 & 1).

Pao and Tsai [10] tried to model and forecast energy demand, economic growth, and carbon dioxide emissions using data from 1980 to 2007 and present their projection of them during 2008 - 2013 in Brazil. The model used in this study is the Grey Forecasting Model. The results show that there is a strong two-way causal relationship between income, energy consumption and carbon dioxide emissions. In addition, this study argues that Brazil should follow two strategies in order to reduce the adverse effects of economic growth: increased investment in energy infrastructure and energy saving policies, as well as increasing energy efficiency and reducing energy waste.

Stingl and Hopf [11] predicted the annual electricity consumption of enterprises by means of a dataset with 1810 company in a typical town in Switzerland using the fuzzy regression method. These, use the industry branch of the enterprises together with open big data to explain and predict the electricity consumption of such. Linear regression analysis shows that information on the economic branches of the enterprises, basal area of buildings, number of opening hours and social media data can explain up to 19% of variance in electricity consumption. Economic trends e.g., in labor market and turnover statistics, reflect changes in the electricity consumption in the investigated years 2010–2014 for several economic branches.

In their study, Honor and others forecast the energy consumption in the European Union's industrial sector using the fuzzy regression for the years 2021 to 2030. The results of this study indicate that by 2030, the energy consumption in agriculture and industry will increase the most compared to other economic sectors; And the lack of proper investment can lead to economic stagnation in these sectors. The service sector is also expected to experience the lowest growth in energy consumption.

In the field of national studies, Heidary; In research, he estimated the energy intensity in Iran's industrial sector using the fuzzy regression method. The results of this research show that the lagged energy intensity values are the only factor which has a positive effect on the industrial energy intensity attitude, whereas other explanatory variables including energy price, value added share and technical efficiency score have negative effect on energy intensity trend in the period (1982-2006). Moreover, the estimation results indicated the numerous potential energies saving in Iranian industrial sector which is mainly emerged from pure energy intensity in short-run [12].

Kazemi and Hossein Zadeh forecast the demand for energy carriers in Iran's different consumption sectors using the fuzzy linear regression. In this study, the demand for petroleum products, gas and electricity in various consumer sectors, including domestic-commercial, transportation, industry, agriculture, and power plants, as well as taking into account economic and social indicators using the regression and the fuzzy linear regression models is forecasting. Data from 1993 to 2010 are used to select the appropriate model and check its validity, and the demand for different energy carriers in each different field is estimated over the period from 2012 to 2021 [13].

In another study, Taghizadeh et al. [14] designed a fuzzy linear regression model to forecast the transportation sector energy in Iran. In this study; Using the fuzzy linear regression (FLR) as well as taking into account the economic, social and transport indicators, the energy demand in the country's transportation sector has been forecasted for the years 2016 to 2021. Data from gross domestic product, population and the number of cars between 1993 to 2005 were used to study the impact of economic and social indicators on the energy demand in the transportation sector. In this study, the amount of energy in the transportation sector has been forecasted to be 628 million barrels of crude petroleum equivalent in 2021. The forecasting results with this method compared with the multivariate regression method show much smaller errors, so that the mean absolute percentage error is reduced from 12.33% to 5.72%.

3. Methodology

In this study, demand forecasting models for petroleum and gas products in Iran's industrial sector (industrial and mining) are designed. The inputs of the different models have been selected based on the other studies and according to the conditions of Iran's economy. In addition, data from 1997 to 2017 were used to design an appropriate forecasting model. Data from 2016 to 2019 were also used as test data. To check the validity of the designed models, the percentage index of the mean absolute percentage error for the examined test data as well as an appropriate model has been developed based on this index. The statistics and information needed for this study were obtained from the statistics and information published by the Iran's Statistical Center as well as the energy balance sheet.[1]

4. Analyzing the Experimental Results of The Research

In this study, forecasting the energy demand in Iran's industrial sector in three gas sectors; Petroleum products and electricity demand are taken into account. The industrial gas demand forecasting model is designed based on the economic and social indicators and using the hierarchical fuzzy linear regression model. The inputs of this model include energy prices; growth rate and household (population); the growth rate of GDP and gas consumption in the industrial sector compared to the previous year and the output of it is also the gas consumption in the domestic and commercial sectors. Each input is forecasted using the fuzzy linear regression model. It should be noted that different models with different inputs were tested and the model with less error test data was selected as the appropriate model. Fuzzy models used to forecast industrial gas demand are presented in Table 1:

Table 1. Fuzzy linear regression model to forecast the Gas demand in the industrial sector

$INV(t)=(p_0,c_0)+(p_1,c_1)INV(t-1)+(p_2,c_2)INV(t-2)+(p_3,c_3)INV(t-3)$	**1**
$ADV(t)=(p_0,c_0)+(p_1,c_1)ADV(t-1)+(p_2,c_2)ADV(t-2)+(p_3,c_3)ADV(t-3)$	**2**
$NUM(t)=(p_0,c_0)+(p_1,c_1)NUM(t-1)+(p_2,c_2)NUM(t-2)+(p_3,c_3)NUM(t-3)$	**3**
$GC(t)=(p_0,c_0)+(p_1,c_1)\alpha INV(t-1)+(p_2,c_2)\alpha INV(t-2)+(p_3,c_3)\alpha ADV(t)+(p_4,c_4)NUM(t)+(p_5,c_5)GC(t-1)$	**4**

Source: Research Findings

where INV (t) is the amount invested in machinery for the industrial sector in year t; ADV (t) Value added of the industrial sector in year t; α INV investment growth rate in machinery; α ADV Growth rate of industrial value added; NUM: Number of industries and GC (t) Gas consumption in the industrial sector in year t. Based on the software results and significance of coefficients at 95% probability level; a suitable fuzzy model to forecast the gas demand in the industrial sector is according to The following equation:[2]

$$GC(t)=(0,0.345)\alpha ADV(t)+(0.658,0)NUM+(0,0.345)\alpha INV+(0.9539,0)GC(t-1)$$

Also, a fuzzy linear regression model similar in structure to the industrial gas demand forecasting model was used to forecast the demand for petroleum products in the industrial sector. The explanatory variables of this model include; the amount invested in machinery; the growth rate of added value in the industrial sector; the number of active industries in Iran's industrial sector, the consumption of petroleum products in the industrial sector in the previous year, and the output of this model also corresponds to the amount of petroleum products consumed in the industrial sector.

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[1] In this research, the forecast of energy consumption in Iran's industrial sector has been made using the statistical data of Iranian factory industries, which are classified based on the four-digit codes of the international industry standard classification system (ISIC).

[2] Statistical results of this study were analyzed and extracted using MATLAB software.

Table 2 Fuzzy linear regression model to forecast the consumption of petroleum products in the industrial sector

$INV(t)=(p_0,c_0)+(p_1,c_1)INV(t-1)+(p_2,c_2)INV(t-2)+(p_3,c_3)INV(t-3)$	**1**
$ADV(t)=(p_0,c_0)+(p_1,c_1)ADV(t-1)+(p_2,c_2)ADV(t-2)+(p_3,c_3)ADV(t-3)$	**2**
$NUM(t)=(p_0,c_0)+(p_1,c_1)NUM(t-1)+(p_2,c_2)NUM(t-2)+(p_3,c_3)NUM(t-3)$	**3**
$OIL(t)=(24.52,0)+(0.852,0)\alpha INV(t)+(0.06,0.042)\alpha ADV(t)+(0,0.528)NUM +(0.264,0)OIL(t-1)$	**4**

Source: Research Findings

Based on the statistical results; The appropriate model to forecast the demand for petroleum products in the industrial sector is according to the following equation:

$$OIL(t)=(24.52,0)+(0.852,0)\alpha INV(t)+(0.06,0.042)\alpha ADV(t)+(0,0.528)NUM \\ +(0.264,0)OIL(t-1)$$

A fuzzy linear regression model similar in structure to the petroleum and gas product demand forecasting model was used to estimate the electricity demand in Iran's industrial sector. The explanatory variables of this model include; the amount invested in machinery; the growth rate of added value in the industrial sector; The number of active industries and the amount of electricity in the industrial sector in the previous year and the output of this model is the amount of electricity consumed in the industrial sector ELC (t):

Table 3. Fuzzy linear regression model to forecast the consumption of electricity demand in the industrial sector

$INV(t)=(p_0,c_0)+(p_1,c_1)INV(t-1)+(p_2,c_2)INV(t-2)+(p_3,c_3)INV(t-3)$	**1**
$ADV(t)=(p_0,c_0)+(p_1,c_1)ADV(t-1)+(p_2,c_2)ADV(t-2)+(p_3,c_3)ADV(t-3)$	**2**
$NUM(t)=(p_0,c_0)+(p_1,c_1)NUM(t-1)+(p_2,c_2)NUM(t-2)+(p_3,c_3)NUM(t-3)$	**3**
$ELC(t)=(p_0,c_0)+(p_1,c_1)\alpha INV(t)+(p_2,c_2)\alpha ADV(t)+(p_3,c_3)NUM(t)+(p_4,c_4)ELC(t-1)$	**4**

Source: Research Findings

Here, an appropriate model to forecast the electricity consumption in the industrial sector based on the statistical results is also according to the following equation:

$$ELC(t)=(0.532,0.0821)+(0,0.0364,c_1)\alpha INV(t)+(0.0239,0.576)\alpha ADV(t) \\ +(0.0066,0)NUM(t)+(0.082,0.332)ELC(t-1)$$

Demand for petroleum products and natural gas in various consumer sectors has been forecasted using the above models between 2020 to 2029. In charts Figurer 2-4, the results of implementing these models in forecasting the demand for natural gas; Petroleum products and electricity consumption are shown at the average level:

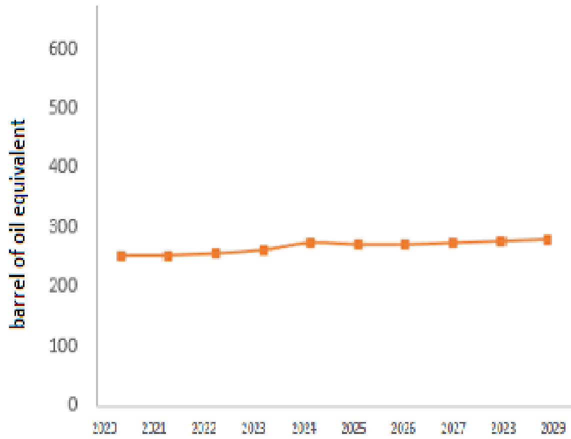

Figure 2. Forecasting the natural gas demand in industrial sector (average limit)

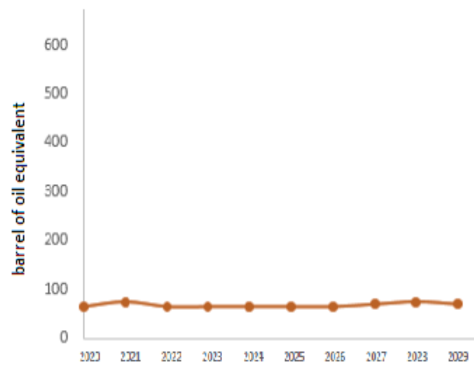

Figure 3. Forecasting the petroleum products demand in industrial sector (average limit)

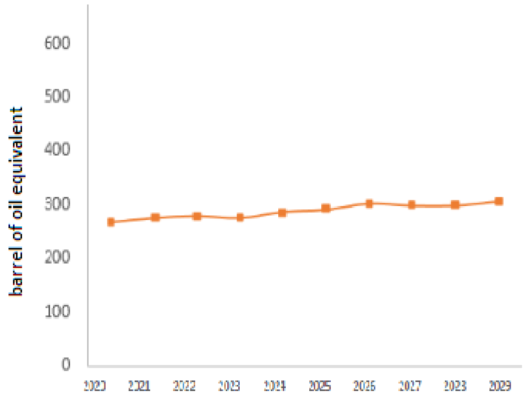

Figure 4. Forecasting the electricity consumption in industrial sector (average limit)

Based on these results, growth of gas demand in industry sector will be positive over time; even though it will have a slow slope (Figure 2). In the other, the demand for petroleum products in this sector is almost constant over time and will not fluctuate much (Figure 3). In addition, electricity demand in industry sector will experience positive growth (Figure 4).

5 - Conclusion

In this study, the demand for gas and petroleum products in Iran's industrial sector is forecasted using the fuzzy linear regression model by 2029. According to the results of experimental research analysis; the evidence indicates that gas consumption in Iran's industrial sector will tend to increase in the projected years; even though the slope of this increase will be slow. In addition, these results suggest that the average demand for petroleum products in Iran's industrial sector tends to be stable and the prospect of demand for petroleum products in this sector of Iran's economy will not be very upward.

On the other; forecasting the electricity consumption in Iran's industrial sector also indicates that electricity consumption in this sector will tend to increase with a slight slope during the forecast years. Overall, the above results show that energy consumption in Iran's industrial sector tends to increase by 2029. This shows the need to invest in this energy sector in order to meet this growing demand. On the other hand, the development of energy demand in this sector shows the need to move towards energy saving and use of clean and renewable energy.

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