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Fuzzy Linear Regression Method for Analyzing Profits and Stock Returns in Selected Industries in Tehran Stock Exchange

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Abstract In recent years, the use of fuzzy linear regression has expanded significantly in economics, accounting. and financial mathematics. In this type of regression, for data analysis, there is no need to meet the prerequisites that are required in normal linear regression. In addition, it is necessary to solve a linear programming problem to find coefficients of this type of regression. Since, in examining the status of stability and the cash and accrual components of companies' profits, the calculation of accruals is based on forecasts and estimates and is measured by less reliability, so implied greater stability of profit due to its cash component. Among the cases that have an accrual basis, the non-objectivity of the amount, especially the cash amount of the earnings, is very important for the future profitability. In this study, focusing on profit cash components, and the stability, the profitability of the company and its efficiency compared to the accrual basis are investigated using fuzzy linear regression. In the issue of technical analysis and to check profits sustainability, a sample of four selected industries, vehicle manufacturing, pharmaceuticals, basic metals, and ceramic tiles during the years 2011-2016, has been selected in the Tehran Stock Exchange market. In this study, sign constraints are added to the set of constraints in the main linear programming problem so obtained solutions can be interpreted and justified. The results confirmed the hypothesis "cash components of profit have more stability of profit than accrual components", but the hypothesis "more stability of profit

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due to cash components of profit has a greater impact on the amount of cash and the rights Stockholders" and also the hypothesis "the profit expectations implicit in the stock price fully reflect the stability of the profit related to the cash components of the profit", was not confirmed.

Keywords Fuzzy linear regression · Profit stability · Stock returns · Linear Programming

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1 Introduction

Among the statistical tools, regression analysis is one of the most useful methods for data analysis, which is an efficient method for investigating and modeling the relationship between variables. These regression models are used in data description, estimation of unknown parameters, prediction, and control. Regression is a statistical method that explains and predicts changes in dependent variables through independent variables. Despite the widespread use of ordinary regression in research in various sciences, fuzzy regression is used due to reasons such as inaccuracy and uncertainty in the observations of variables, a small number of data, problems related to the definition of the appropriate distribution function, and ambiguity in the relationship between dependent and independent variables. In fuzzy regression, the concept of fuzzy numbers and fuzzy relations is used, which is based on fuzzy sets. The fuzzy set theory was introduced by Lotfi Askarzadeh in 1965 (see [14,15]). Since its introduction, this theory has expanded and deepened a lot and has found various applications in different fields. Fuzzy regression can be used to fit both fuzzy and precise data in a regression model, while ordinary regression can only fit precise data. A review of previous studies divides fuzzy regression approaches into three categories. The first fuzzy regression approach is based on uncertainty minimization as the optimality criterion. The second approach uses the least squared error as the appropriate criterion. And the third approach can be described as interval regression analysis. Fuzzy regression has many differences compared to ordinary regression, which mainly comes from its foundations. Two of the most important differences are:

1) The diagnostic statistics that determine the appropriateness of the model in ordinary regression are not relevant in fuzzy regression because fuzzy regression is based on the Possibility Theory, while the foundation of ordinary regression is the probability theory that follows the randomness rule.
2) The heteroscedasticity and the collinearity phenomenon, which exist in ordinary regression due to the randomness of data, are not relevant in fuzzy regression.

2 Theoretical foundations and research background

The fuzzy linear regression, first introduced by Tanaka et al in 1982 (see [12]), is a type of regression that is used to establish a functional relationship between the dependent variable and independent variables in a fuzzy environment.
In the fuzzy linear regression model, fuzzy membership functions are used instead of probability distribution functions to describe the behavior of parameters. Fuzzy linear regression is generally divided into three types:

1) Relationships between the variables (regression model coefficients) are assumed to be fuzzy.
2) Observations in the dependent variable and independent variables are imprecise and fuzzy.
3) Both relationships between variables and observations are considered fuzzy.

Fuzzy regression model is used to model vague and ambiguous systems and imprecise phenomena. This type of regression is widely used in various sciences, including management and accounting (See [9]). In this study, linear regression with fuzzy coefficients is used, which assumes that the observations and variables are accurate and there is ambiguity in the regression formula and coefficients.
As mentioned by Bisrier et al. [4], fuzzy numbers are determined by membership functions that can be triangular, trapezoidal, Gaussian, or a combination of them. For the simplicity of the work, we consider the membership functions of the fuzzy set in the following triangular form:

$$\mu_{\tilde{A}}(x) = \begin{cases} 1 - \frac{c-x}{l_A}, & c - l_A \leq xc, \\ 1 - \frac{x-c}{r_A}, & c \leq x \leq c + r_A, \\ 0, & \text{otherwise}, \end{cases}$$

where $\mu_{\tilde{A}}(x)$ is the membership function of the triangular fuzzy number $\tilde{A} = (c, l_A, r_A)$ with the center c (which is a real number) and the width of the right and left are indicated by a sign r_A and l_A, respectively. In the case of $l_A = r_A$, the fuzzy number is called a symmetric triangular fuzzy number (see [6, 8, 11, 13]).
Suppose that Y is the dependent variable and $X_1, X_2, \ldots, X_k$ are independent variables. Now consider the following n observations:

$$\begin{aligned} Y &= (Y_1, Y_2, \ldots, Y_n)^t \\ X_j &= (x_{1j}, x_{2j}, \ldots, x_{nj})^t \quad j = 1, 2, \ldots, k \end{aligned} \tag{1}$$

In this case, when only the coefficients of the regression model are fuzzy, the fuzzy regression equation is represented by the equation (2)

$$\widetilde{Y_i} = \widetilde{A_0} + \widetilde{A_1} x_{i1} + \widetilde{A_2} x_{i2} + \cdots + \widetilde{A_k} x_{ik} \qquad i = 1, \ldots, n. \tag{2}$$

where, $x_i = (1, x_{i1}, \ldots, x_{ik})$ is a real input vector of independent variables and $(\tilde{A}_0,\ \tilde{A}_1, \ldots, \tilde{A}_k)$ are fuzzy coefficients (see [9]). The goal is to estimate

the parameters of model (2) $\left(\tilde{A}_0,\ \tilde{A}_1, \ldots, \tilde{A}_k\right)$, so that the model provides the best fit for the data (1). We use the triangular membership function to calculate the above parameters (see [8]).
Let c_j and s_j be the center and width of the fuzzy coefficients $\tilde{A}_j$ for $j = 0, 1, 2, \ldots, k$, respectively, so equation (2) can be written as follows:

$$\widetilde{Y}_i = (c_0, s_0) + (c_1, s_1)\, x_{i1} + (c_2, s_2)\, x_{i2} + \cdots + (c_k, s_k)\, x_{ik}, \quad i = 1, 2, \ldots, n.$$

As a result, for $i = 1, 2, \ldots, n$, we have

$$\widetilde{Y}_i = (c_0 + c_1 x_{i1} + c_2 x_{i2} + \cdots + c_k x_{ik}, s_0 + s_1 |x_{i1}| + s_2 |x_{i2}| + \cdots + s_k |x_{ik}|)$$

For a given h, the presence of fuzzy regression can depend on the solutions of a linear programming problem as follows:

$$\text{Minimize} Z = \sum_{i=1}^{n} \left(s_0 + \sum_{j=1}^{k} s_j |x_{ij}| \right)$$

Subject to

$$c_0 + \sum_{j=1}^{k} c_j x_{ij} + (1-h) \left[s_0 + \sum_{j=1}^{k} s_j |x_{ij}| \right] \geq Y_i$$

$$c_0 + \sum_{j=1}^{k} c_j x_{ij} - (1-h) \left[s_0 + \sum_{j=1}^{k} s_j |x_{ij}| \right] \leq Y_i \quad i = 1, 2, \ldots, n$$

$$s_j \geq 0 \qquad j = 0, 1, 2, \ldots, k.$$

The details of achieving this linear programming problem are described by Savick, Chung, Berry-Stolzle, et al., Changa and Ayyub, and Tanaka et al. ([3,5,7,10,12]).

In financial research, the fuzzy regression method with appropriate fuzzy width is able to cover price fluctuations and protect the decision maker from forecasting error and its cost. This method is a low-cost method and it is very useful for data that is small in number. Furthermore it takes less time than other methods and a better estimate is obtained. For this reason, it has been considered in recent years in accounting, economics, management and medical sciences. An example of this type of research has been done by Artikis and Papanastasopoulos, Ammar Shafi and Saifullah Rusiman, Hoglund and Chung (see [1,2,7,9]).

One of the basic concepts in the capital market is the concept of profit, stability and quality of profit. Accounting profit is an indication that changes the beliefs and behavior of investors and is a suitable indicator for stock returns and predicting future cash flows. Also, as a digit valuable in the set of financial statements, as a criterion for evaluating the company's performance and making rational decisions, which expresses the characteristics of the company's future profits. On the other hand, profit stability also means maintaining the profitability of the company over time. That is, in fact, they consider the sustainability of profit to be equal to the quality of profit. It should be noted that the importance of sustainable profit lies in its repetition. In this study, fuzzy linear regression is using the effect of cash and accrued profit components on its stability, the effect of profit stability on cash and equity, as well as the stability of hidden profits in stock prices are investigated.

3 Research methodology

The statistical population of this research includes all the companies admitted to the Tehran Stock Exchange, which were actively present during the period of 1390-1394. The sampling carried out among the four industries in the Tehran Stock Exchange: automobile and parts manufacturing, pharmaceuticals, basic metals, and ceramic tiles. These companies were investigated because of their importance among industries and also because of their available data. We sampled these industries and selected a few companies, and again due to the high accuracy of the work, the sampling of the annual performance companies was also done. Sample member companies must have the following characteristics:

1. To be present in the Tehran Stock Exchange during the research years.
2. The end of their financial year is the end of the solar year and they have not changed their financial year during the aforementioned period.
3. If during the research period, their symbol is stopped, the period of suspension should not exceed 6 months. Finally, for 35 years, companies have been selected as a sample.

In every research, independent and dependent variables along with the model used to estimate the relationship between them play a fundamental role. The variables, the models, and the hypothesis in this research are as follows.

a. Dependent variables

1) $NI_{i,t+1}$ is the profit efficiency variable of the company in the $(t+1)$th period, which is calculated by the following formula:

$$NI_{i,t+1} = ACC_{i,t+1} + FCF_{i,t+1}, \tag{3}$$

where ACC refers to the change in operating assets and FCF refers to operating cash flow. To calculate the change in operating assets, this formula is used:

$$\begin{aligned}\text{ACC}= &(\text{Total current operating assets- Total current debt})\\ &+(\text{ Total noncurrent operating assets- Total long term debt})\end{aligned}$$

2) $RET_{i,t+1}$ is the stock price return in the $(t+1)$th period, which is calculated by the ratio of the stock price in the next period to the stock price in the current period, minus one.

b. Independent variables

1) Profit performance (NI): includes net profits at the end of the financial period.
2) Free cash flow (FCF): includes the company's free cash flow If Cash includes cash and short-term investments of the company, $DIST_D$ is the ratio of changes in total liabilities to changes in total assets and $DIST_E$ includes the ratio of the total equity of ordinary and preferred capital and minority capital to the total assets, which is reduced by the profit efficiency, then the sum of these values is considered as the company's free cash flow.

c. Research model

According to the definition of variables, model (4) is used for the first hypothesis

$$NI_{i,t+1} = \alpha_0 + \alpha_1 \left(NI_{i,t} - FCF_{i,t}\right) + \alpha_2 FCF_{i,t} + \varepsilon_{i,t}. \tag{4}$$

In this model, α_1 measures the stability of accrual component dividend and α_2 stability of dividend cash components of profit. With a little calculation, the above model can be written as model (5)

$$NI_{i,t+1} = \alpha_0 + \alpha_1 NI_{i,t} + (\alpha_2 - \alpha_1) FCF_{i,t} + \varepsilon_{i,t}. \tag{5}$$

In model (5), $\alpha_2 - \alpha_1 > 0$ will confirm the first hypothesis. Model (6) is used to test the second hypothesis.

$$NI_{i,t+1} = \alpha_0 + \alpha_1 NI_{i,t} + \alpha_2 CASH_{i,t} + \alpha_3 (DIST_D)_{i,t} + \alpha_4 (DIST_E)_{i,t} + \varepsilon_{i,t}. \tag{6}$$

In model (6), if condition (7) is satisfied, the second hypothesis will be confirmed.

$$\alpha_4 > \alpha_3 \ , \qquad \alpha_4 > \alpha_2 \ , \quad \alpha_4 > 0. \tag{7}$$

Model (8) is also used for the third hypothesis. In model (7), if $\alpha_2 > 0$, the third hypothesis is confirmed.

$$RET_{i,t} = \alpha_0 + \alpha_1 NI_{i,t} + \alpha_2 FCF_{i,t} + \varepsilon_{i,t}. \tag{8}$$

d. Hypothesis

The following assumptions have been considered based on the assumptions of Artikis and Papanastasopoulos (2016) and the fuzzy linear regression method has been used to evaluate them.
H1: Cash components of profit have more sustainability than accrual components.
H2: Greater profit stability (which is caused by the cash components of profit) has a greater impact on the amount of cash and equity.
H3: Earnings expectations embedded in stock prices fully reflect the sustainability of earnings related to the cash components of earnings.

4 Research findings

With the help of SPSS software, the descriptive statistics indices including mean, median, mode, maximum, minimum, standard deviation, skewness, standard error of skewness, kurtosis and standard error of kurtosis were calculated and displayed in Table 1.

Table 1 descriptive statistics

descriptive statistics	NI	RET	FCF	$DISI_E$	CASH	$DIST_D$
mean	-0.157798	0.405789	0.418759	-0.353440	0.038091	0.604963
median	-0.520735	-0.047322	0.454211	-0.709016	0.032684	0.556283
mode	0.0000	-1.0000	0.000	-5.6456	0.0008	0.0891
Standard deviation	2.1529709	1.4762982	2.3662858	2.1504243	0.0320771	0.268224
skewness	2.374	2.665	-1.459	2.442	1.892	0.684
standard error of skewness	0.297	0.297	0.297	0.297	0.297	0.297
kurtosis	9.527	7.376	6.636	9.804	4.612	0.791
standard error of skewness	0.586	0.586	0.586	0.586	0.586	0.586
minimum	-5.5371	-1.0000	-9.1823	-5.6456	0.0008	0.0891
maximum	9.0514	6.6018	6.3079	8.9558	0.1625	1.3330

A simple inspection reveals that the distribution of CASH, FCF, NI, and RET are not normal. Therefore, we use linear fuzzy regression that does not need this assumption.

Test of the first hypothesis

For the simplicity of calculations and use of GAMS software, change the variables $NI_{i,t+1}$, $NI_{i,t}$ and $FCF_{i,t}$ to y, x_1 and x_2 respectively. Therefore, the fuzzy linear regression model (9) is obtained.

$$y = (c_0, s_0) + (c_1, s_1)\, x_1 + (c_2, s_2)\ \ x_2. \tag{9}$$

Our goal in model (8) is to find the coefficients c_0, c_1, c_2 along with s_0, s_1 and s_2. In this way $\alpha_0 = (c_0, s_0)$, $\alpha_1 = (c_1, s_1)$ and $\alpha_2 = (c_2, s_2)$ are calculated. Then, by using the methods of converting fuzzy numbers into crisp numbers, we convert these coefficients into real coefficients. We must find the coefficients s_i, c_i $(i = 0, 1, 2)$ by solving a linear programming problem including the following objective function (10):

$$\text{Minimize } Z_1 = \sum_{j=1}^{m} (s_0 + s_1 |x_{1j}|) + s_2 |x_{2j}| \,. \tag{10}$$

m is the number of years that the company is in the sample and x_{ij} means the j(th) observation of the i(th) variable. The constraints of the linear programming for each year-company are as follows:

$$\begin{cases} y_j \geq c_0 + c_1 x_{1j} + c_2 x_{2j} - (1-h)\,(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|)\,, & j = 1, \ldots, m \\ y_j \leq c_0 + c_1 x_{1j} + c_2 x_{2j} + (1-h)(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|), & j = 1, \ldots, m \\ \ c_i \geq 0\ ,\ \ s_i \geq 0 & i = 0, 1, 2 \end{cases}$$

Using a selected sample of 35 companies, we will have a linear programming problem with seven constraints along with non-negative constraints.

The objective function in testing the first hypothesis with linear fuzzy regression is minimize $Z_1 = s_0 + 110.7047\ s_1 + 63.13\ s_2$. After entering the data in GAMS software, and after solving the problem, we will have the optimal solution as follows:

$$\tilde{y} = (0, 9.5445) + (0, 0)\,(NI - FCF) + (1.0252, 0)\,FCF,$$

where the value of the optimal objective function is 9.5445. Now, using the center of gravity method, we convert the fuzzy coefficients into real coefficients through the use of a definite integral.

$$\alpha_0 = 0, \quad \alpha_1 = 0, \qquad\qquad \alpha_2 = 1.0252.$$

Assuming $h = 0.1$ and converting the optimal solution to real numbers, $\alpha_2 - \alpha_1 > 0$ is obtained. So the first hypothesis is confirmed.

Test of the second hypothesis

As before and for simplicity, change the variables $NI_{i,t+1}$, $NI_{i,t}$, $CASH_{i,t}$, $(DIST_D)_{i,t}$ and $(DIST_E)_{i,t}$ to y, x_1, x_2, x_3, and x_4, respectively. In this way, the fuzzy linear regression model (11) is obtained.

$$y = (c_0, s_0) + (c_1, s_1)\, x_1 + (c_2, s_2)\ \ x_2 + (c_3, s_3)\ \ x_3 + (c_4, s_4)\ \ x_4. \tag{11}$$

To find the coefficients, it is necessary to solve the following linear programming problem:

$$\text{Minimize}\quad Z_2 = \sum_{j=1}^{35} \left(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}| + s_3 |x_{3j}| + s_4 |x_{4j}|\right)$$

$$\text{Subject to}\begin{cases} y_i \geq c_0 + c_1 x_{1j} + c_2 x_{2j} + c_3 x_{3j} + c_4 x_{4j} \\ \quad - (1-h)\left(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}| + s_3 |x_{3j}| + s_4 |x_{4j}|\ \right) \\ \\ y_i \leq c_0 + c_1 x_{1j} + c_2 x_{2j} + c_3 x_{3j} + c_4 x_{4j} \\ \quad + (1-h)\left(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}| + s_3 |x_{3j}| + s_4 |x_{4j}|\right) \end{cases}$$

$$j = 1, 2, 3, \ldots, 35$$

$$s_j \geq 0, \qquad j = 0, 1, 2, 3, 4$$

Using the observations related to the sample including 35 years-companies, and considering $h = 0.1$, the objective function of the above linear programming problem to find the coefficients of the fuzzy linear regression model for the second hypothesis becomes as follows:

$$Z_2 = s_0 + \ 65.9271\ s_1 + 1.4272\ s_2 + 20.8468\ s_3 + 67.7522\ s_4.$$

In the optimal solution, after converting the fuzzy numbers to real numbers, we will have:

$$\alpha_0 = 0.18169, \quad \alpha_1 = 0, \quad \alpha_2 = 0, \quad \alpha_3 = 0.5107, \quad \alpha_4 = 0.$$

Therefore, due to the fact that condition (7) is not satisfied, the second hypothesis is not confirmed.

Test of the third hypothesis

To reject or confirm the third hypothesis, like the previous two hypotheses, and for simplicity, change the variables $RET_{i,t}$, $NI_{i,t}$ and $FCF_{i,t}$ to y, x_1 and x_2 respectively. In this case, to find the fuzzy linear regression coefficients in (12), we will have the following programming problem

$$y = (c_0, s_0) + (c_1, s_1)\, x_1 + (c_2, s_2)\ \ x_2\ . \tag{12}$$

$$\text{Minimize}\quad Z_3 = \sum_{j=1}^{35} \left(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|\right)$$

$$\text{s.t.}\begin{cases} y_i \geq c_0 + c_1 x_{1j} + c_2 x_{2j} - (1-h)\left(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|\ \right) \\ y_i \leq c_0 + c_1 x_{1j} + c_2 x_{2j} + (1-h)\left(s_0 + s_1 |x_{1j}| + s_2 |x_{2j}|\right) \end{cases}$$

$$j = 1, 2, 3, \ldots, 35$$

$$s_j \geq 0 \qquad j = 0, 1, 2$$

Now by considering the observations related to the statistical sample and assuming $h = 0.1$, the objective function will be summarized as follows:

$$Z_3 = 65.9291\ s_1 + 63.13\ s_2.$$

In the optimal solution and after converting the fuzzy numbers to real numbers, we will have:

$$\alpha_0 = 2.67759,\ \alpha_1 = 0.0334,\ \alpha_2 = 0.$$

As a result, because the FCF coefficient in the optimal solution is equal to zero, then the third hypothesis is not confirmed.

5 Conclusion

The hypotheses of the study by Artikis and Papanastasopoulos [2] were investigated with ordinary linear regression. In this study, the same hypotheses have been tested by considering fuzzy linear regression and a selected sample of companies admitted to the Tehran Stock Exchange. The results of the tests in our study are consistent with the results of the literature for the first hypothesis, but for the second and third hypotheses, the results are different. In this research study, the profitability of the company and its return on an accrual basis, using fuzzy linear regression - about the relationships between the variables (fuzzy regression model coefficients) - with three hypotheses about the stability of profit, the cash component of profit and stock price have been investigated. After data analysis, which was done using a sample of four selected industries, automobiles and parts manufacturing, pharmaceuticals, basic metals, and ceramic tiles from the Tehran Stock Exchange in 2011-2016, the result of the research confirms the first hypothesis ”Cash components of profit have more sustainability than accrual components”. But the second hypothesis ”Greater profit stability (which is caused by the cash components of profit) has a greater impact on the amount of cash and equity” and also the third hypothesis ”Earnings expectations embedded in stock prices fully reflect the sustainability of earnings related to the cash components of earnings” have not been confirmed. The suggestion for researchers who are interested in using the fuzzy linear regression method in financial research is to conduct this research in different economic conditions affected by changes in inflation and exchange rate for countries in a specific region such as the Persian Gulf countries in a period of ten years.

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