Using Fuzzy Regression and Neural Network to Predict Organizational Performance

Liang-Hung Lin[1]

[1]Department of International Business, National Kaohsiung University of Applied Sciences

415 Chien Kung Road, Kaohsiung 807, Taiwan, ROC.

Abstract

As everyone knows, multiple regression analysis is an important approach to prediction studies. However, regression model has some limitations and constraints in the real world practices. This study applied fuzzy regression using neural network (FRNN) to predict organizational performance, and the findings indicate that the accuracy rate analysis supported FRNN to be a better method to predict nonlinear variables.

1. Introduction

In both manufacturing and service sectors, new approaches to innovation management have become prime drivers of various industries. As product life cycles condense and substitutive product offerings expand, product innovation becomes increasingly outstanding for establishing sustainable competitive advantage. Thus, no matter scholars, managers, shareholders, and investors desire to know and to predict organizational performance on innovation and corporate profit rate. They are really critical indexes to forecast the firms' profits and developments. As everyone knows, multiple regression analysis is an important approach to prediction studies. However, regression model has some limitations and constraints in the real world practices and applications. For example, nonconstancy of error variance, presence of outliers, nonindependence of error terms, and nonnormality of error terms present four common constraints of multiple regression models [1]. Moreover, data scale and nonlinear relationships show two other limitations of traditional linear model for data analyses. Applying fuzzy theory and neural network, this study wishes to improve the prediction performance on organizational innovativeness.

2. Determinants of Performance

This study adopted two criteria to measure organizational performance: profit rate and organizational innovation. The former measures firms' capability to exist; and the later measures firms' capability to grow and develop. The definition and classification of innovation vary among the various studies. Scholars asserted that innovation involves invention and commercialization. Other studies considered that innovations include new products, services or production processes introduced by firms. From the perspective of management, they described innovation as the creation of value from knowledge or information. Recently from an organizational perspective, innovation has been defined as the adoption of an internally generated or purchased device, system, policy, program, process, product or service that is new to the adopting organization [2].

In research on determinants of organizational performance, professionalism and administrator education has been found as individual factors of innovation in various industries. The studies on organizational innovation also examines organizational age, size and quality as factors of organizational level. In the environmental influences, competition and financial distress are the major environmental variable to affect technological and administrative innovation [3]. Thus, dependent variables in this study consists of product innovation and process innovation, whereas determinants of innovation include professionalism, training, age, size, quality, process management, and competition

3. Methods

3.1. Fuzzy regression

Traditional regression theory considers error as a concept of probability, whereas fuzzy regression theory see errors as a possibility [4,5]. Thus, the linear fuzzy regression model can be expressed as:

$$Y_j = A_1 x_{1j} + A_2 x_{2j} + \ldots + A_n x_{nj} = \mathbf{A} x_j \qquad (1)$$

Or,

$$\mathbf{Y} = \mathbf{AX} = (\mathbf{aX}, \mathbf{c}|\mathbf{X}|) \qquad (2)$$

Where

$\mathbf{a} = [a_1, a_2, \ldots, a_n]$ and $\mathbf{c} = [c_1, c_2, \ldots, c_n]$

The regression coefficient $A_i = (a_i, c_i)$ is a triangular fuzzy number with its center= a_i and spread = c_i. Thus for a sample point with center = y_j and spread = d_j, the seeking of boundaries is a problem of linear programming:

$$\text{Min} \sum_{j=1}^{m} \mathbf{c}\,|\mathbf{x}_j|$$

$$\begin{aligned} s.t. \quad & y_j + d_j \le \mathbf{a}\mathbf{x}_j + \mathbf{c}\,|\mathbf{x}_j| \qquad (3) \\ & y_j - d_j \ge \mathbf{a}\mathbf{x}_j - \mathbf{c}\,|\mathbf{x}_j| \\ & (j = 1,2,\ldots,m),\ c \ge 0 \end{aligned}$$

The upper boundary of this model is $ax_j + c\,|x_j|$, whereas lower boundary is $ax_j - c\,|x_j|$ and center is ax_j. Moreover, y_j and d_j is the center and spread of jth sample.

3.2. Fuzzy regression using neural network (FRNN)

In order to solve the problem of non-linear relationships, Scholars [6] developed technique of Fuzzy regression using neural network (FRNN) using the theories of fuzzy regression and back-propagation neural network. The major concepts of FRNN are:

$(\mathbf{x}_p, \mathbf{y}_p)$ indicates the pth sample, $\mathbf{x}_p = [x_{p1}, x_{p2}, \ldots, x_{pn}]$ indicates input vector of this sample. $\mathbf{y}_p = [y_{p1}, y_{p2}, \ldots, y_{pk}]$ is the output vector of this sample, so the prediction model can be expressed as

$$Y(\mathbf{x}_p) = A_0 + A_1 x_{p1} + \ldots + A_n x_{pn} \qquad (4)$$

Where Ai is a fuzzy number and

$$\mathbf{y}_p = f(\mathbf{x}_p) \qquad (5)$$

Thus, $\mathbf{y}_p$ cab be estimated by a three-layer back-propagation neural network:

- Input layer: $o_{pi} = x_{pi}$, $i = 1,2,\ldots,n$. (6)
- Hidden layer: $o_{pj} = f(net_{pj})$, $j = 1,2,\ldots,n'$,

$$net_{pj} = \sum_{i=1}^{n} w_{ji} o_{pi} - \theta_j, \quad j = 1,2,\ldots,n'. \qquad (7)$$

- Output layer: $o_p = f(net_p)$

$$net_p = \sum_{i=1}^{n'} w_j o_{pj} - \theta \qquad (8)$$

- Error function: Min $E=\sum_{p=1}^{m} E_p$

$$=\sum_{p=1}^{m}\frac{1}{2}\omega_p[y_p-g^*(x_p)]^2 \qquad (9)$$

Where E is error and $g^*(x_p)$ is upper boundary of prediction and

$$\omega_p=\begin{cases}1 & if \quad y_p > g^*(x_p)\\ \omega & if \quad y_p \le g^*(x_p)\end{cases} \qquad (10)$$

The FRNN can be shown as Figs 1 and 2.

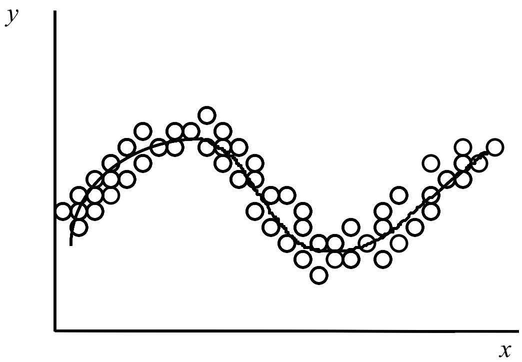

Fig. 1. Result of back-propagation neural network

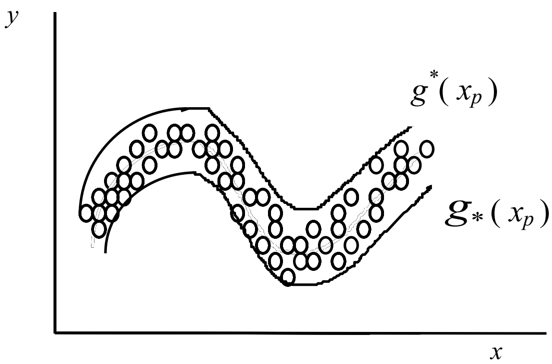

Fig. 2. The result of FRNN

3.3. Sample collection process

We tested our model with a large sample of the computer industry in Taiwan. Data is obtained from questionnaires mailed to the all opened or over-the-counter computer companies around Taiwan. Some firms' fundamental data are collected from the Securities and Futures Commission, Ministry of Finance, Taiwan, Republic of China. For the sake of participant blindness, the purpose of this survey was unknown to the respondents to prevent from biasing the actual innovativeness intentionally. A follow-up procedure was undertaken after the questionnaires mailed. Computer industry covers the computer manufacturing companies, the electronic companies, and the semiconductor companies. Over 300 questionnaires were delivered to the firms and 56 questionnaires were retrieved during the survey period. Taking off the invalid respondents and obvious outliers by statistical checking, this sample was consisted of 52 participated companies. The measures of product and process innovations adopted the similar criteria addressed by Koufteros et al. (2002).

3.4. Measures

Dependent variables (organizational performance):

- Organizational innovation: The number of patents issued by a firm. Data were obtain from USPTO (United States Patent and Trade Office) and IPO (Intellectual Property Office, ROC).
- Corporate profit rate: return after tax/ income

Independent variables (determinants of organizational performance). Data was obtained from questionnaires mailed to the all opened or over-the-counter computer companies around Taiwan. Independent variables include 8 major determinants of organizational performance:

- Organizational culture to innovate.
- Product line development.
- Price of product
- Guanxi with other firms
- Employee wage
- Environmental management and forecast ability for top managers
- Leadership of top management
- Environmental protection ability for the firm.

4. Results

Adopting multiple regression analyses to predict organizational innovation and profit rate, we found that product line development, employee wage, and environmental management and forecast ability for top managers are three significant determinants for profit rate (with F = 1.59, p = 0.174, R-sq = 0.31); culture to innovate, product line development, and guanxi with other firms are significant determinants for innovation (with F = 1.69, p = 0.16, R-sq = 0.32). However, the linear regression results do not work well. So we applied FRNN to predict organizational performance. The results are shown in Table 1. Please note that accuracy rate for prediction means that the testing sample was include in the 95% prediction interval. 52 samples was divided into training sample (37) and testing sample (15).

This study indicates that the accuracy rate for both dependent variable supported FRNN to be a better method to predict nonlinear variables. However, only traditional linear regression can indicate which independent variable to be significant in the model. Analyzing two methods at the same time seems to provide complete information for managers.

	Profit rate		Innovation	
Methods	Statistic	FRNN	Statistic	FRNN
Accuracy	53%	60%	47%	67%

Table 1. Summary report for the results of linear regression (Statistic) and FRNN

5. References

[1] J. Neter, M. Kutner, C. Nachtsheim, and W, Wasserman, *Applied Linear Regression Models.* New York: McGraw-Hill, 1999.

[2] F. Damanpour, "Organizational innovation: a meta-analysis of effects of determinants and moderators," *Academy of Management Journal*, Vol. 34(3), pp. 555–590, 1991.

[3] T.M. Amabile, M.R. Conti, H. Coon, J. Lazenby, and M. Herron, "Assessing the work environment for creativity", *Academy of Management Journal*, Vol. 39(5), pp. 1154-1184, 1996

[4] J. Watada, and Y. Yabuuchi, "Fuzzy Robust Regression Analysis," *IEEE International Engineering Management Conference*,1994.

[5] J. Sanchez, and A. Gomez, "Estimating a Fuzzy Term Structure of Interest Rate Using Fuzzy Regression," *European Journal of Operational Research*, Vol. 154, pp. 154-174, 2004.

[6] H. Ishibuchi, and H. Tanaka.,"Fuzzy Regression Analysis Using Neural Networks," *Fuzzy Sets and Systems*, pp.257-265, 1992