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Original Research

Predicting the Efficiency of Inventory Management Using Artificial Neural Networks

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Abstract

The purpose of this study is to design a model to predict the efficiency of inventory management to help creditors and actual and potential investors and other stakeholders to avoid major losses in the capital market. For this reason, 137 companies listed on the Tehran Stock Exchange during the 10-years period 2012-2021 were examined. In this study, the predicting variables of institutional ownership, managerial ownership, corporate ownership, ownership concentration, board size, percentage of non-executive board members, and duality of CEO (Chief Executive Officer) role have been used. The efficiency of inventory management was predicted using a three-layer perceptron artificial neural network with the Backpropagation of Error algorithm. Finally, a network with the mean squared error of 0.360, 0.428, 0.261 and 0.353, respectively for training data, validation, test and total data and a coefficient of determination of more than 72%, as the best network Selected.

Keywords: Inventory management efficiency, Predictive variables, CEO, Artificial Neural Networks, Backpropagation of Error algorithm.

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Introduction

Commodity inventories have always been a major part of companies 'investments and resource expenditures and are very important in terms of amount and also have a significant impact on companies' profitability activities, therefore, commodity inventories are considered as one of the most important economic factors in the promotion and continuity of business units (Ji, Cheng, Lee, & Lin, 2012). In recent decades, the decision of business units to determine the optimal amount of inventories required for each financial period (inventory management), has become one of the most important financial and managerial decisions of business units (Setayesh & Kazemnezhad, 2010).

The goal of inventory management is to maximize shareholder wealth through the design and implementation of policies and strategies that reduce the cost of purchasing and maintaining goods. Inventories are not profitable in themselves and only generate revenue if they are sold, but by applying inventory management, which, in fact, maintains regular continuity in the coordination of production and sales activities and prevents operations from stopping due to lack of inventory. In a way, the process of profitability is achieved (Noravesh, Karami, & Vafi sani, 2009). (Bao & Bao, 2004) on the importance of inventory management believe that inventory management affects the performance of the company in various ways. They argue that companies can improve production planning by maintaining inventory, minimizing the cost of inventory shortages, and significantly reduce purchase costs through bulk purchases and speculation at transaction prices.

Due to the changes that have taken place in the inventory maintenance policies in commercial units in the last few decades, different opinions have been raised about the method of inventory management. Some researchers, such as the philosophy of timely production and information technology, believe that the maintenance of inventory in companies should be reduced, while others, such as growing demand for various products and the level of customer service, believe that more inventories should be maintained (Chen, Frank, & Wu, 2005).

On the other hand, the two main groups of corporate financiers are creditors and investors. Lenders are always looking to receive the principal and interest of their loans to the company and shareholders are looking to get their expected return on the company's activities and stock price changes due to the growing activity of the company (Etemadi, Noravesh, Azar, & Seraji, 2010). In such circumstances, the question that always arises is whether the inventory of goods as one of the most important economic factors in the promotion and continuity of the activities of organizations, is managed in the most efficient way possible? Do company managers manage inventory in the best possible way in order to meet the daily needs of the company, create value for shareholders and improve the organizational position? Is the inventory managed in such a way that creditors have a relative confidence in receiving the principal and interest of their loans and shareholders in obtaining their expected cash and price returns from the company's activities?

Therefore, the purpose of the present study is to design a model for predicting the efficiency of inventory management, in order to help financially sourcing companies

(especially creditors and actual and potential investors) and other stakeholders in sensible decisions and avoiding major losses in the capital market. One of the most practical methods in modeling and forecasting are artificial neural networks that have many applications in the fields of finance and accounting. These include forecasting companies' bankruptcy and financial helplessness and forecasting daily market returns. In this study, using a perceptron neural network, a three-layer model is presented to predict the efficiency of inventory management in companies listed on the Tehran Stock Exchange.

Literature Review

Inventory Management Efficiency

The inventory of goods in each business unit is one of the most important items of current assets of that business unit. Many experts consider inventory as a key tool to create value, flexibility and control in modern business units, so proper and effective inventory management at both corporate and macroeconomic levels seems important and necessary (Chikan, 2009).

Inventory management is a continuous process that on the one hand monitors and controls the orders and use of components that the company will use in the production of items, and on the other hand controls and monitors certain quantities of products for sale. The best policy in the field of inventory management is to optimize the level of orders and investment at the right time, and therefore Adapting and implementing an efficient strategy in inventory is a challenging task in any organization (Rajan & Francis, 2012).

Business units use different methods to manage inventory. The methods adopted have a significant impact on sales volume, profits and returns of business units. If inventory management is viewed solely as inventory, traditional models such as the economic order volume model can be offered. The economic order volume model is a valuable model that maximizes the company's revenue by minimizing inventory costs (Michalski, 2009). If inventory management is viewed as an internal system, the issue of material needs planning is considered as a product-oriented computer technology, with the aim of minimizing inventory and maintaining a delivery schedule (Lysons & Gillingham, 2003). Finally, if inventory management is viewed as an extra-organizational activity, the model of inventory management or control by the seller (the seller controls the level of inventory of customers and feels responsible in completing their inventory) and timely production, is proposed (Hojaji, Maaref doust, & Ebrahimi, 2009).

On the other hand, in a general view, corporate governance can be considered as including legal, cultural and institutional arrangements that determine the direction and movement of companies. Elements that are present in this scene are: shareholders and their ownership structure, board members and their combinations, company management led by the CEO, and other stakeholders who can influence the company's movement. (Setayesh & Kazemnezhad, 2010). According to (Bushman & Smith, 2001), regulatory mechanisms should be put in place to bridge the gap between ownership and management. One of the existing mechanisms to reduce agency problems and information asymmetry between managers and shareholders and consequently reduce problems in managing inventories and cash is the existence of an efficient board as one of the internal

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mechanisms of corporate governance. Therefore, the proper establishment of corporate governance mechanisms is a key step to promote accountability, optimal use of resources and effective management of inventory (Hashemi & Kamali, 2010).

Artificial Neural Networks

Artificial neural networks are trainable and analysis tool that attempts to mimic the patterns of information processing in the human brain. These networks are dynamical systems consisting of parallel processing units, or neurons which is a propensity to keep their experiential knowledge and making it available for use (Foruresh, 2005). Learning property of neural networks is important. The network as the learning systems has the potential to learn from past experience and environment and improve their behavior during the learning.

Improve learning network over time is measured based on the criteria for improvement; the goal is to model learning system (Menhaj, 2002). In Figure (1) is shown the components of a neuron.

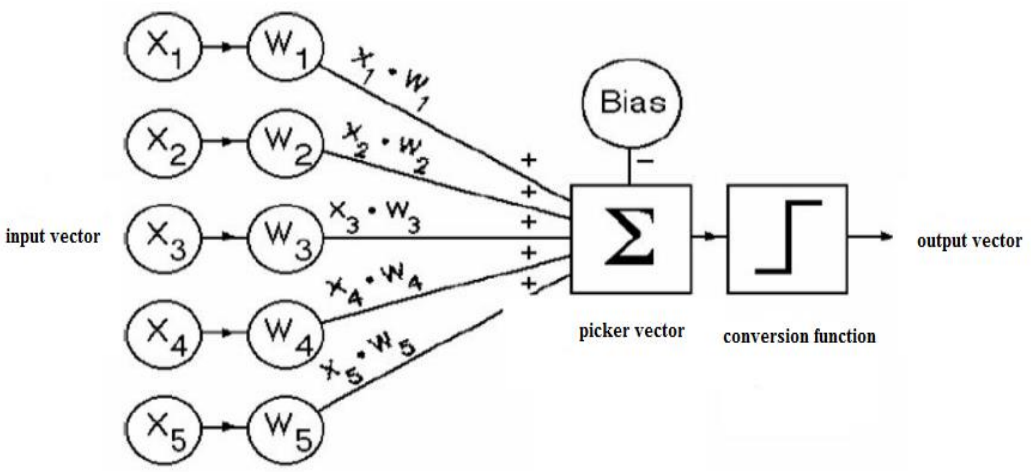

Figure 1. Components of a neuron.

In this model, the input vector x with the size xw + b enters into neurons. Then, it is under other action or process that is called as transfer function that provides neurons function. W parameter is called weight parameter. When a great neural network was created by putting together a large number of neurons, a network is available that is completely dependent on b and w amounts in addition to output function.

In such a large network, a large number of parameters w and b should be set by the network designer. The process of the work, in terms of neural networks, is known as the learning process. In fact, in a real test, after the presentation of the input vector, network is trained by measuring the output with the by selecting parameters w and b such that the desired output is achieved. Therefore, after such a network trained for a set of inputs to create the desired outputs, it can be used to solve the problems made by different compounds of inputs (Kordstani, Masomi, & Baghaei, 2013).

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Multi-Layer Perceptron Artificial Neural Network

Multi-layer perceptron artificial Neural Network is one of the strongest models of artificial Neural Network including input, hidden (center) and output layers. The structure of each of these layers is composed of a large number of neurons or nodes.

Figure (2) shows a multi-layer perceptron artificial Neural Network.

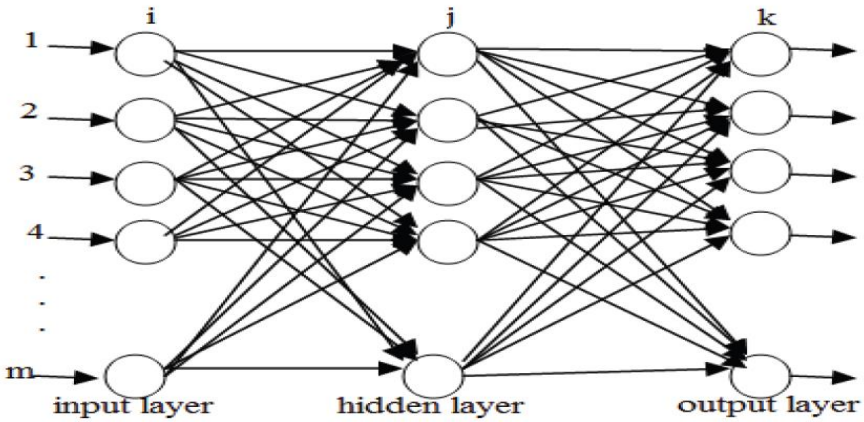

Figure 2. Multi-layer perceptron artificial Neural Network.

The number of neurons in the input and output layers tasked with only incoming and outgoing data depends on the number of input variables (training) and output variables of network. But, unlike the input and output layers, determine the number of neurons in the middle layer with the number of repeat cycles, are considered as the main problem in the design of artificial neural networks. Almost there is no proven formula for determining the optimal structure of network. This structure (the number of middle layers, number of neurons in the middle layers, the number of repeated cycles of learning) is determined experimentally. If the number of neurons in the middle layer and number of repeated cycles are selected underrepresented, the network will have the ability to adapt to the mapping.

On the other hand, high amount of these neurons and number of the repeated cycles, result in high fitness and lack of network generalizability, so that the network is experiencing a large increase in input becomes unstable. Thus, the low cycle of neurons should be used in the middle layer and are gradually used for the improvement of error, increases their number. Different methods are suggested solving this problem, the extent we can add to the number of neurons in the middle layer and the repeats cycle to avoid network with too fit, including early stopping rule using validation data (Roiger & Geatz, 2003).

According to early stopping rule, data is divided into three groups as training data, validation data, and test data. Training data is used for determining weights. Validation data are used when training, but they play no role in determining weights. Duty of validation data includes monitoring the generalization of network in line with network training. After offering all training data to network completely, using the weights,

validation data enters the network and the network amounts are calculated based on them. The calculated amounts are calculated by network for training data, and validation data are calculated by main amounts, and error amounts of training data and validation data. These errors are calculated again after each complete cycle of presenting the training data to the network.

Since a cycle, error of validation data increases. This means the network misses its generalization ability little by little, and keeps training data, without the ability to receive correct relationship between input and output data. Therefore, after presenting more validation error by network after consecutive times, the training process stops, and the weights of the least validation error are considered as the best result of the network training. If the error amount is not desired, it is essential to start a new training cycle. After the error on the training data and validation reached the desired level, test data that has not been used until this stage of the work, is used for final testing of network interoperability. This data group enters into the training network its optimal weight coefficients are calculated, their output is calculated, and finally are compared with main amounts. If you have a good amount of test data error, the job is finished.

"Movement technique" is another method that is helpful in network training, especially in cases where limited data is available. In this method, after network training of the obtained weights are used as the initial weights of the second round of training network, but in this new round of train, the place of training and validation data is changed. The previous validation data are used as training data and previous training data are used instead of the current validation data (Dezfoolian & Akbarpour, 2011).

Empirical Evidence

No research has been done on the subject and in general, research on inventory management efficiency has examined the relationship between inventory management efficiency and some variables (including some corporate governance mechanisms). However, in these studies, these variables have not been used directly to predict the efficiency of inventory management. Therefore, the following are some of the researches conducted in the field of inventory management efficiency and some corporate governance mechanisms.

(Tribo, 2007) examined the effect of ownership structure on investment in inventory. He concluded that institutional ownership reduces the company's liquidity needs and prevents over-investment, which in turn reduces inventory levels.

(Ameer, 2010) in a study examined the role of institutional investors in the management of cash and inventory of Asian companies. The results of his research showed that the increase in the stock portfolio of foreign banks (as a group of institutional investors) compared to the stock portfolio of domestic banks (as another group of institutional shareholders) led to more cash holdings and the inventory of goods becomes less.

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(Elsayed & Wahba, 2013) concluded in a study that in the presence of large (small) managerial ownership, dual CEO (non-dual) and large (small) board of directors, institutional ownership has a positive (negative) effect on inventory management.

(Ali & Shah, 2017) investigated the effect of corporate governance mechanisms on the efficiency of working capital management in Pakistani manufacturing companies. The results showed that the audit committee, the size of the board and the gender effect improved working capital.

(Nazemi, Momtazian, & Salehi nia, 2014) in a study examined the relationship between corporate governance mechanisms and inventory management efficiency. The results of their research indicated that there is a positive and significant relationship between corporate ownership, managerial ownership, institutional ownership and board size with the efficiency of inventory management. There is a negative and significant relationship between the duality of the role of the CEO and the percentage of non-executive board members with the efficiency of inventory management, but no significant relationship was found between the concentration of ownership and the efficiency of inventory management.

(Kengatharan & Sanoli Tissera, 2019) examined the effect of corporate governance factors on the efficiency of working capital management in Sri Lanka. Factors such as the structure of the board, the size of the board, the number of board meetings and the separation of the position of the chairman of the board from the CEO were tested. The results showed that the number of meetings of the board of directors and the separation of the position of the chairman of the board of directors from the managing director has a positive and significant relationship with the management of working capital.

(Ghayour, Heydary Farahany, & Shahi, 2022) in a study examined the effect of inventory management on financial distress with respect to the interactive role of management behavioral strains, namely overconfidence, myopia, and narcissism. Findings of their study showed that the increase of inventory management efficiency leads to decreased financial distress, and the behavioral strains do not have a significant effect on the change of such a relationship.

(Hashed & Shaik, 2022) examined the relationship between inventory management efficiency and financial performance in Saudi Arabian companies. The results showed that the management of inventory in Saudi Arabian firms is efficient. Further, the firm size is positively associated with ROA and Inventory Turnover Ratio (ITR). This shows a nexus between inventory management efficiency and firms' financial growth in Saudi Arabian companies.

Methodology

In this study, after the preparation of the data in Microsoft Excel and perform calculations for the required variables, three-layer Perceptron Neural Network was made for prediction of related party transactions. It has 8 neurons in the input layer and one neuron in the output layer, according to the number of input variables (training) and output.

The optimal number of neurons in the middle layer is achieved by trial and error, i.e. starting from the small number of neurons in the middle layer and then gradually increasing them and check the error changes, the optimum number is determined. To avoid overheating and improve network fit, the early stopping rule using data validation is used. For this purpose, according to this rule, the data is divided into three categories:

60% as training data, 20% as validation data, and 20% as data for network testing. Stopping rule is such that if validation error increases over 6 consecutive steps, even if the training data error is increasing, the training process is stopped. Criteria to measure network performance in the training process, is considered the mean squared error. Also, according to the surveys conducted, Tangent sigmoid transfer function was used in the middle layer, and linear transfer function was used in output layer.

Network training was done using Backpropagation of Error algorithm and Levenberg–Marquardt method. Because setting a linear efficient structure was difficult to predict the amount of related party transactions, and basically there is no knowledge of linear or non-linear relationship between the amount of related party transactions and the relevant variables (predictors), the ANN with specifications, is considered as the best tools to predict the efficiency of inventory management.

The Population and Sample

The study population consists of all companies listed on Tehran Stock Exchange during the period from 2012 to 2021. Taking into account the following restrictions for the companies, a sample (137 companies) was selected: 1- In terms of increased comparability, the fiscal period ended March. 2- Do not change the financial year during the period. 3- During the period under review, the trading symbol is not out of exchange. 4- The sample does not include financial intermediation companies, investments, leasing companies, banks and insurance companies; because the nature of the assets of these companies is different.

Research Variables

Inventory Management Efficiency

In the present study, inventory management efficiency has been used as an output for neural network training. According to the research of (Elsayed & Wahba, 2013), the efficiency of inventory management is obtained by using the ratio of the average inventory (the algebraic sum of the beginning inventory and ending inventory divided into two).

The Predictor Variables

In the theoretical foundations of inventory management efficiency, major research has examined the factors that significantly affect the efficiency of inventory management, but these variables have not been used directly to predict the efficiency of inventory management. Therefore, in this study, among the variables that has been studied in research on inventory management efficiency, based on the importance and computability

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in the Iranian business environment, the following seven variables as input variables, for neural network training, Used:

1) Institutional ownership: equal to the percentage of shares held by state-owned and public companies of the total capital stock, which includes insurance companies, financial institutions, banks, state-owned companies and other government components (Tsai & Gu, 2007).

2) Managerial Ownership: Indicates the percentage of shares held by family members of the Board of Directors.

3) Corporate Ownership: Equal to the percentage of shares held by Corporations of the total capital stock and includes a variety of Corporations (J, 2004)

4) Ownership Concentration: Absolute control of major shareholders over the management of the company is called ownership focus.

In this study, ownership concentration was measured using the Herfindahl-Hirschman index. The higher the index, the greater the concentration and presence of a small number of major shareholders in the ownership structure of the company, and vice versa. This is because some of the companies surveyed did not disclose less than 5% ownership in their financial statements. Therefore, due to the insignificance of percentages less than 5% and in order to homogenize the measurement method for all companies, a greater percentage of ownership and equal to 5% were included in the calculation of formulas. Herfindahl-Hirschman index is measured by the following formula:

$$HHI = \sum_{i=1}^{Nj} (SHARE_{i.j})^2$$

In this regard, $SHARE_{i.j}$ is the percentage of shares owned by shareholder i in company j.

5) Board size: Board size is the total number of board members of the company

6) Percentage of non-executive board members: This variable is obtained by dividing the number of non-executive board members by the total number of board members.

7) Dual role of CEO: This variable is a virtual variable, so that if the CEO is also the chairman of the board of directors, the value is one and otherwise the value is zero.

Research Findings

The purpose of this study is to predict the efficiency of inventory management among 137 companies listed on the Tehran Stock Exchange during 10 years. Therefore, a multilayer perceptron neural network was designed in MATLAB software and after several tests and changes in network parameters; the model structure with the lowest error was the structure (7-10-1) which was stopped using validation data. Therefore, the best

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neural network structure of the present study has 10 neurons in the middle layer. An overview of the neural network implemented by the software is shown in Figure (3).

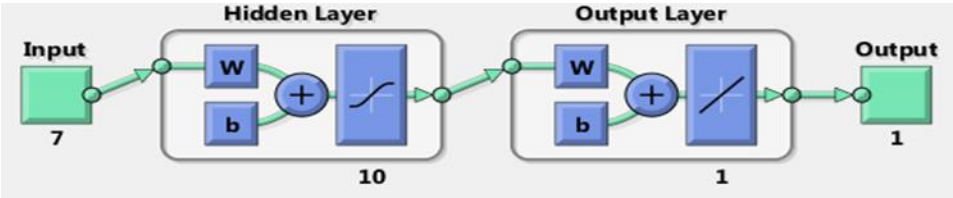

Figure 3. Neural network implemented by MATLAB software

In this study, the early stop method was used to prevent over-fitting of the network. According to the settings made in the network design process, if the validation data error increases by more than 6 consecutive steps, if even the training data error is decreasing, the training process will stop. The process of training the designed neural network, as shown in Figure (4), has stopped after 16 repetitions, because the validation data error has increased by 6 consecutive steps.

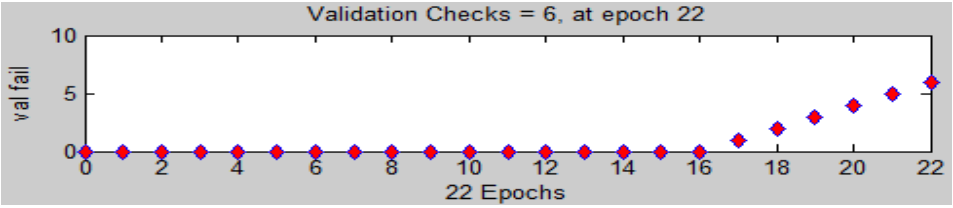

Figure 4. Investigation of validation data error in the training process

Figure (5) shows the curve of changes in the mean squared error in terms of the number of iteration cycles for the input data (predictor variables). This figure shows how the neural network training process proceeds from the input data. As can be seen, after 16 cycles of repetition, the designed artificial neural network reaches its best performance, meaning it causes the least squared error, so that if the network training continues, the training set error will start to increase and the network will start maintaining patterns. As shown in the figure, the best performance of the artificial neural network is designed at a point (16th iteration cycle) where the mean squared error for training data is .360, the mean squared error for validation data is .428, the mean squared error for test data is .261. And the mean squared error of the total data is .353. Also, according to Figure (6), it is clear that training data errors have almost the same behavior and characteristics as validation data errors. In addition, no over-fitting has occurred until step 16 (when the best performance for validation data occurs).

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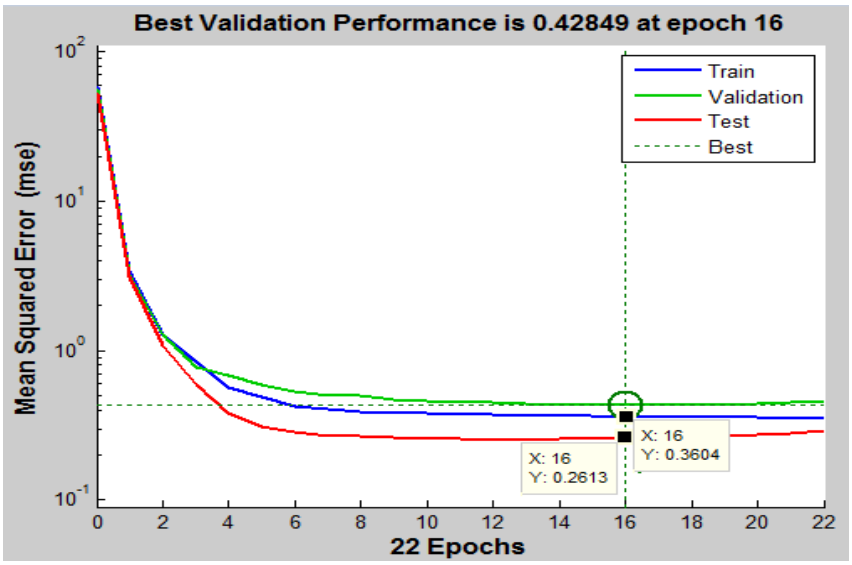

Figure 5. Curve of mean squared error versus number of replications performed in training, validation and test modes

Figure (6) shows the accuracy and use of the selected artificial neural network in modeling each of the training data, efficiency, test and total data set, to predict the efficiency of inventory management. If the output of the neural network is exactly equal to the actual values of the data, all points will be on the line Y = T. The more concentrated the data around the Y = T line, the better the identification of the data by the neural network. The Fit line is the regression line fitted to the data.

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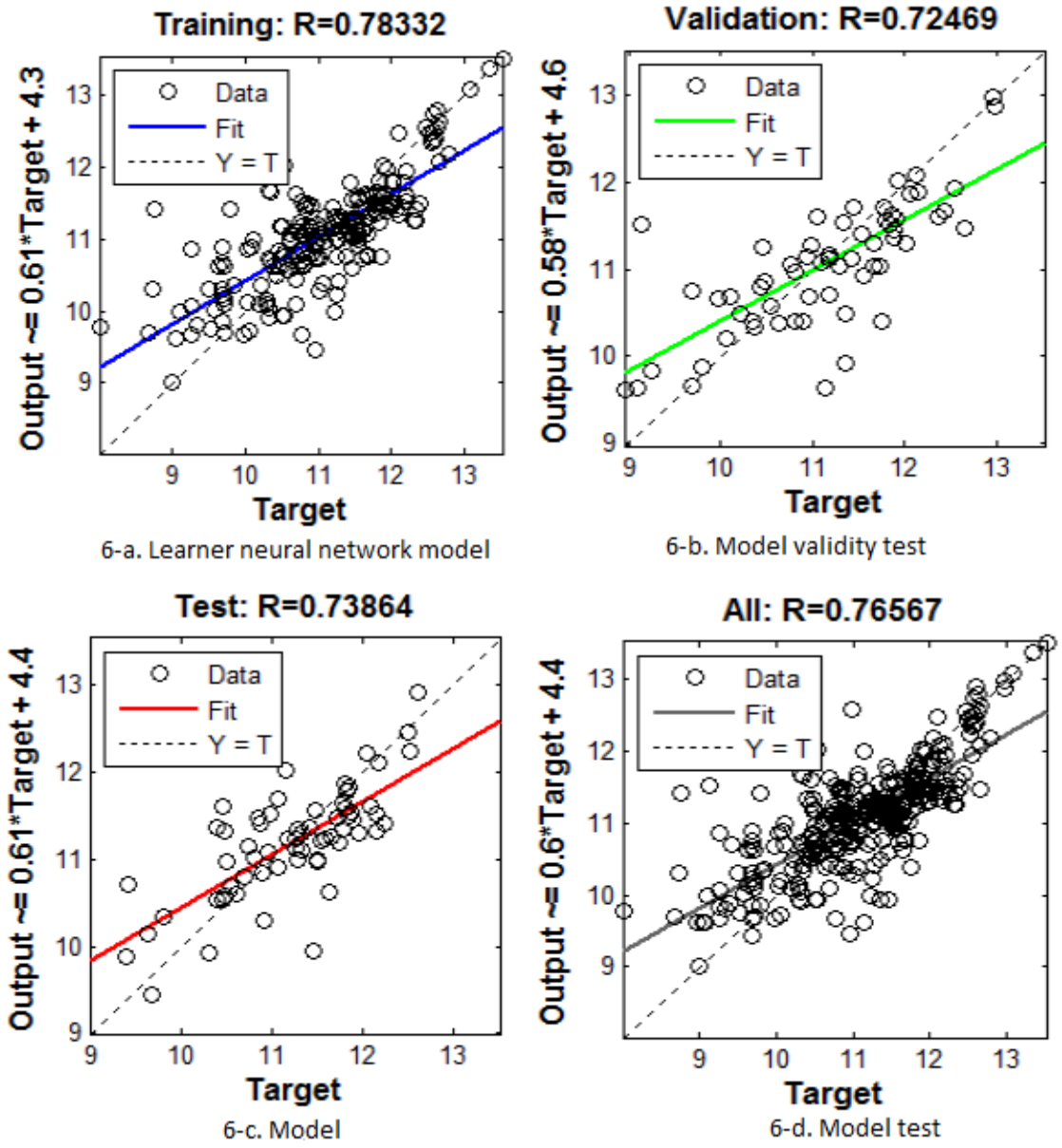

Figure 6. Evaluation of artificial neural network efficiency using regression analysis

Figure 6-a shows the general results of the training. This figure explains the model test using the training data. As can be seen, the model has a validity of %78 for validation, as shown in Figure 6-b, the model itself is validated again using validation and retest data with a coefficient of determination of 72%. Figure 6-c is a test of the model using the test data. This model with a coefficient of determination of 73% is also valid for test data. In Figure 6-d, where the model is tested using a set of data, a coefficient of determination of 76% confirms this validity.

Conclusion

Inventory management is a continuous process that on the one hand monitors and controls the orders and use of components that the company will use in the production of items, and on the other hand controls and monitors certain quantities of products for sale. Inventory management affects the company's performance in various ways. By maintaining inventory, companies can improve production planning, minimize the cost of inventory shortages, and significantly reduce purchasing costs through bulk purchases and bargaining at transaction prices.

In this regard, this study has predicted the efficiency of inventory management using artificial neural networks. The use of such forecasting models is useful to increase the accuracy of forecasts based on financial data. In this research, a multilayer perceptron neural network with the Backpropagation of Error algorithm has been used. Network parameters were determined after several tests. Finally, a network with the mean squared error 0.360, 0.428, 0.261 and 0.353 for training data, validation, test and total data respectively, and a coefficient of determination of more than 72%, as the best network for Predicting the efficiency of inventory management in companies listed on the Tehran Stock Exchange has been selected. Therefore, with neural network technology and predictor variables (institutional ownership, managerial ownership, corporate ownership, ownership focus, board size, percentage of non-executive board members, dual role of CEO), more than 72% of inventory management efficiency can be explained.

Practical Suggestions from the Research

1. In order to evaluate the risk and opportunities facing the business unit, creditors and potential and potential investors are recommended to estimate the efficiency of inventory management through artificial neural network technology and predictor variables of this research.

2. The board and non-executive members of the board as one of the pillars of corporate governance to understand the efficiency of inventory management is recommended to use the technique of artificial neural networks and predictor variables of this study.

The Securities and Exchange Commission, as a Supervisor, is recommended to use artificial neural network technology and predictor variables in order to reduce financial crises in companies and help promote and sustain the activities of business units.

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