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Research Article

MODELLING AND FORECASTING GOLD PRICE USING GMDH NEURAL NETWORK

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ABSTRACT
Forecasting the price of gold and its changes as an economic event has long been within the interest area of investors and financial analysts. This study aims to make gold -price forecast modelling using GMDH neural network and Multilayer Perceptron neural network (MLP), as well as determination of top model using performance evaluation criteria. Necessary data of the research was collected through Internet from Central Bank website (www.cbi.ir) and in particular from Novin Rah Avard [modern approach] software from 1386 [2007] till1391 [2012]. In this research, weekly means of eight effective indexes on gold price were selected for the mentioned interval. Good and acceptable results of performance evaluation criteria obtained from GMDH neural network indicate high capability of this network for identification of ruling patterns on data as well as unique characteristics of fast convergence, high accuracy, and approximation ability of strong function of the network confirming suitability of GMDH neural network for prediction of gold price.

Keywords: *Gold Price, Modelling, MLP Neural Network, GMDH Neural Network*

INTRODUCTION
Human beings are creatures who are naturally looking for decoding surrounding phenomena of past in order to be able to forecast the behaviour of such phenomena and to react to possible future events by creating the possibility for forecasting. Logical mind of human has always been avoiding the illusion and inability, in all aspects of life, in describing phenomena and making efforts to determine their dimensions (Ghadiri, 2009).

It is obvious that the issue is more apparent in economic fields. Whether human beings are considered economically wise creatures or not, their efforts to respond complexities, issues, and ambiguities of economic fields cannot be forgotten. On the other hand, the main feature of markets nowadays is changing and transformation and we are witnessing modern improvements and innovations in human communities. Various factors including modern production technologies, using robots, advent of complex telecommunication networks, inventions, and industrial discoveries, expansion of operation, organizations` duties, administrative structures, and a thousand other important factors have expanded and twisted national economy. Furthermore, highly dynamic nature and constant changes in capital market have made researchers and economists to think about the best methods for future predictions and appropriate decision –making. This has something to do with the fact that the more a phenomenon is dynamic and farther from static condition, the more difficult the forecast will be.

From the past onward, gold has received a considerable amount of attention in the markets. This attention has made researchers, investors, and activists in the capital markets to look for invent and use new forecasting methods in order to achieve better results.

Accurate forecast of gold price helps forecast of conditions and trends` requirement in the future. This work provides useful information for investors to take necessary and essential measures to prevent dangers, to reduce dangers which are leading to financial damages or even bankruptcy. To predict or forecast the future price of gold, forecast model uses factors with major and considerable effect on determination of gold prices. Various methods have been developed and implemented for gold-price forecast (Corti and Holliday, 2010).

Research Importance and Objectives

When standard regressions were not able to make it in the form of multiplication as a result of complexity of the calculations and linear dependence problem, Ivankhnenkov came up with the idea of a technique to create a high-degree polynomials named Group Method Of Data Handling, GMDH algorithm. This method is ideal for complex systems with unclear structures that analysts are enthusiastic to comprehend the relationship among input and output variables with high degree. Ivankhnenkov`s algorithm is a heuristic method extracting the knowledge from the nature of data and it is not, like regression analyses, based on a fixed theoretical foundation. The chief problem in modeling complex systems such as economic and social affairs and affairs in which behavioral and structural procedure of data is not clear is the prejudgment of researchers about the model structure. Since the given system might be vast and complex, initial assumptions of modeling might ideally be some ambiguous guesses (Callen *et al.,* 1996). Therefore, obtained results in these conditions have ambiguous and mostly qualitative nature. However, in suggested method of Ivankhnenkov, the researcher recommends some models for analysis and forecast complexities without assuming the internal performance way of system. The main idea of this algorithm is designing an optimum complex model based on only the data and information and no theoretical background from data performance way is done by the researcher. It is forecasted, in stock market, that there are complex relationships between financial and profit proportion of each share. Since complete and comprehensive theoretical perception does not exist in terms of these relationships and interactions between mentioned variables, using smart neural network for modeling these relationships is a useful approach (Ivankhnenkov, 1968).In this research, GMDH neural network is used to forecast the gold price and then its performance is compared with MLP neural network.

Research Background

Lin (2010) studied the prediction of gold price using ARIMA and GARCH models. Their research studied the duration of 1971 till 2010 using monthly data for forecasting gold price. He applied Box-Jenkins research method for making ARIMA models. In this research, 1971-to-2008 data is initially used for the estimation of ARIMA model. Estimation result shows that harmonic mean with p and q (ARIMA (1,1)) is an appropriate model for gold price. Then, this model was used for forecasting the interval from 2009 to 2010. Moreover, the results revealed that GARCH model with p and q (1, 1) is a suitable model for forecasting gold price (Lin, 2010).

Dooley and Lenihan (2005) studied time –series models for predicting metal prices. In this research, two models including ARIMA and interrupted future prices for forecasting metal prices were used. The results of the research showed that the former can predict better in comparison the latter (Dooley and Lenihan, 2005).

Ivakhbneko and Muller (1996) studied the latest GMDH neural network findings in forecasting stock market forecast and analysis (Ivakhbneko and Muller, 1996).

Goleusov and Kondrasheva (1987) have shown the capability of GMDH in extraction of sufficient information about mutual dependency of financial indexes of countries with ruling economic systems (Goleusov and Kondrasheva, 1987).

Domestic Researches

Mash`ashai (2011) in his M.S. thesis, studied forecast modeling of profit of each share using neural networks and genetic algorithms. In this thesis, forecast of profit for each case is studied by MLP neural network and rule-extraction technique from neural networks using genetic algorithms. Research results reveal that rule-extraction technique enjoys less forecast error in comparison with MLP network and integrity between actual data and forecasted data by this network is higher than MLP. Thus, forecast accuracy of rule-extraction technique is higher than MLP network (Mash`ashai, 2011).

Abrishami *et al.,* (2009), in their research entitled "pattern making and forecasting the economic growth of Iran by GMDH neural network "concluded that efficiency of GMDH algorithm is far better than ARIMA model for forecasting economic growth considering the comparison of error criteria in obtained optimum pattern from GMDH neural network with ARIMA time series. GMDH neural network shows a better performance compared to regression methods (Abrishami *et al.*, 2009).

Abrishami *et al.*, (2008) in a research entitled modeling and forecasting petrol price using GMDH neural network concluded that GMDH neural network enjoys high capability for modeling complex procedures and forecasting non-linear dynamic paths. To this end, this approach can be applied for forecasting international prices as well as energy consumption management inside the country (Abrishami *et al.*, 2008).

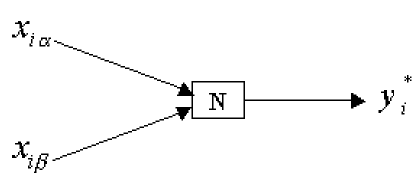
Afsar (2005), in his M.S. thesis entitled forecast of stock price using fuzzy neural networks and mixed method, studied the forecast of stock price. This thesis tried to study forecast modeling of stock price using three scenarios including classic methods, artificial intelligence, and mixture. Results obtained by Afsar were the fact that fuzzy neural networks are more capable in comparison with artificial neural networks (Afsar, 2005).

Furthermore, he concluded that time-series forecasts, using mixed neural network pattern, can reduce estimation error of stock price in comparison with single model. Another result of this research is that artificial -intelligence methods show better results in comparison with classic methods.

Sarfaraz and Afsar (2005) studied the effective factors on gold price and presented a forecast model using fuzzy neural networks and regression. Their results showed that fuzzy neural networks enjoy higher capability compared to regression ones to forecast gold price. Since fuzzy neural network systems do not require accurate and definite data as well as big data sample, it can provide a good forecast of gold price and ensure that this method is able to provide more suitable forecast in comparison with classic methods (Sarfaraz and Afsar, 2005).

GMDH Neural Network

GMDH neural network is auto-organized and one-way network made up of a considerable number of layers and each layer contains many neurons (Anastasakis and Mort, 2001). All neurons enjoy similar structures in that they have two inputs and one output. Based on figure (1), each single neuron, enjoying five weights and one bias, provides processing operation between input and output data.



$$y_{ik}^{*} = N(x_{i\alpha}, x_{i\beta}) = b^{k} + w_1^{k} x_{i\alpha} + w_2^{k} x_{i\beta} + w_3^{k} x_{i\alpha}^{2} + w_4^{k} x_{i\beta}^{2} + w_5^{k} x_{i\alpha} x_{i\beta}$$

Where

$(i = 1,2,3,....,N)$ N is number of input and output data

$(K = 1,2,3,...,C_m^2)$, $\alpha, \beta \in \{1,2,3,...m\}$ m is the number of previous layer

Weights were calculated by minimum error squares and then clear and fixed values are replaced in each neuron. The top quality feature of this kind of network is that neurons of previous step or previous layer are the agents of new neuron production for the number of $C_m^2 = \frac{m(m-1)}{2}$ some produced neurons will necessarily be omitted in order to avoid network divergence.

Neurons which stay for expansion and development of the network might be omitted to create network – convergence form and lack of their link with last-layer neurons. These layers are normally called inactive neurons. Selection and omission criteria of neurons in one layer is Percentage of the sum of squares error, (r_j^2) , between actual output values, (y_i) ,and jth output neuron.

$$r_j^2 = \frac{\sum_{i=1}^{N} (y_i - y_{ij}^*)^2}{\sum_{i=1}^{N} y_i^2}$$ Equation (2)

Where

$j \in \{ 1,2,3,..., C_m^2 \}$, m is number of selected neurons in previous layer (Noori *et al.*, 2010).

The map between input and output variables by this kind of neural network is created and it is in the form of Olterabeh non-linear function as following: (Ivankhnenko and Muller, 1995).

Equation (3):

$$\hat{y} = a_0 + \sum_{i=1}^{m} a_i x_i + \sum_{i=1}^{m}\sum_{j=1}^{m} a_{ij} x_i x_j + \sum_{i=1}^{m}\sum_{j=1}^{m}\sum_{k=1}^{m} a_{ijk} x_i x_j x_k + ...$$

Structure which is considered for neurons is a summarized quadratic two-variable.

Equation (4)

$$y_i = f(x_{ip}, x_{iq}) = a_0 + a_1 x_{ip} + a_2 x_{iq} + a_3 x_{ip} x_{iq} + a_4 x_{ip}^2 + a_5 x_{iq}^2$$

The function f is equipped with six x factor estimating $\{(x_{ip}, x_{iq}), i = 1,2,..., N\}$ system and optimal output of $\{(y_i), i = 1,2,..., N\}$ for all dependent two-variable samples (Atashkari *et al.*, 2007).

The function f is planned according to minimum error squares.

Equation (5)

$$Min \sum_{k=1}^{N} \left[(f(x_{ki}, x_{kj}) - y_i)^2 \right]$$

To this end, we solve simultaneous equations which have six x factor and total number of N equations.

Equation (6):

$$\begin{cases} a_0 + a_1 x_{1p} + a_2 x_{1q} + a_3 x_{1p} x_{1q} + a_4 x_{1p}^2 + a_5 x_{1q}^2 = y_1 \\ a_0 + a_1 x_{2p} + a_2 x_{2q} + a_3 x_{2p} x_{2q} + a_4 x_{2p}^2 + a_5 x_{2q}^2 = y_2 \\ \vdots \\ a_0 + a_1 x_{Np} + a_2 x_{Nq} + a_3 x_{Np} x_{Nq} + a_4 x_{Np}^2 + a_5 x_{Nq}^2 = y_N \end{cases}$$

Above simultaneous equations can be shown in the form of matrix as following:

Equation (7): Aa = Y

Where

$$\mathbf{A} = \begin{bmatrix} 1 & x_{1p} & x_{2q} & x_{1p}x_{1q} & x_{1p}^2 & x_{1q}^2 \\ 1 & x_{2p} & x_{2q} & x_{2p}x_{2q} & x_{2p}^2 & x_{2q}^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{NP} & x_{Nq} & x_{Np}x_{Nq} & x_{Np}^2 & x_{Nq}^2 \end{bmatrix}$$

$$\mathbf{a} = \{a_0, a_1, a_2, a_3, a_4, a_5\}^T$$

$$\mathbf{Y} = \{y_1, y_2, y_3, ... y_N\}$$

To solve this equation, non-squared inverse matrix of A needs to be calculated.

Multi-Layer Perceptron Network (MLP)

After revival of neural network in 1980s, Multi-Layer Perceptron network was introduced as one of the most efficient networks to solve non-linear unsolvable questions. This network enjoys a high capability in terms of forecasting economic and financial variables.

Important characteristics of Multi-Layer Perceptron network are as following:

1. It enjoys at least one intermediate layer.

2. It uses non-linear activating and differentiable functions in intermediate layer.
3. Learning algorithm has been designed in a way that it carries error from output layer to previous layers.
4. Error correction has been started from the last layer and then previous layers are corrected.
5. Links in this network enjoy a high degree.

The chief cause of success for this network must be looked in the type of learning algorithm of this network. The algorithm used in this network is back propagation algorithm of error. This algorithm is always looking for minimizing error squares. This is completely similar to estimation of regression coefficients using OLS method in statistics and econometrics. Therefore, each neural network follows an error function as following :

Error function in MLP network:

$$\varepsilon_{(t)} = \frac{1}{2}e^2 \quad (8)$$

Where e is indicating observed error value.

While designing a network, parameters of network structure, type of training algorithm, learning rate, number of network layers, number of neurons in each layer, and number of repetitions for each pattern during training need to be considered (Aazami, 2009).

Training can be classified in terms of training and learning rule. Training type in MLP network is training by supervision. Although learning rule is learning after publication of augmented Delta rule.

Delta rule is as following:

$$w_{(t+1)} = w_t + \Delta w_t \quad (9)$$

$$\Delta w_t = \eta e_k p_{kj} \quad (10)$$

$$e_k = d_k - a_k \quad (11)$$

d_k = optimal output value

a_k = Obtained output value

η = learning rate (adjustment parameter of learning speed of network)

w_t = related weight

p_{kj} = Input to neuron k and output from neuron j

The proof of this rule is by most pungent fall method indicating that the lowest point of error can be reached by continuous movements against gradient vector. This claim can be confirmed by Taylor series (Hakin, 1999). In this method, weights are balanced by the first derivative (gradient) of error between the optimal and actual output and error output and actual weight, considering the weight values. The goal of this method is to reduce error f unction and reach minimum absolute value.

$$w_{(t+1)} = w_t + \Delta w_t \quad (12)$$

$$\Delta w_t = \eta e_k p_{kj}^{l-1} f'(v_j^l) \quad (13)$$

$$v_j^l(t) = \sum_{j=0}^{n} w_{kj}(t) p_{kj}^{t-1}(t) \quad (14)$$

$$e_k f'(v_j^l) = \delta_j^l \quad (15)$$

Where

p_{kj}^{l-1} = input to k neuron and output from j neuron in the layer previous to last

= local derivation vector in the last layer

δ_j^l

Learning process and calculations in neurons and hidden layers is as following using input-output equation:

$$y_p^{(k)} = sgm_p^{(k)}\left[W_{ip}^{(k-1)}.y_i^{(k-1)} - \beta_i^k\right]; \quad (16)$$

$$\left(p = 1,2,...,N_k; k = 1,2,...,M\right)$$

Where $W_{ip}^{(k-1)}$ is the link weight between ith neuron in the layer (k-1) and pth neuron in kth layer; $y_p^{(k)}$ is output of pth neuron in kth layer; and $sgm_p^{(k)}$ is sigmoid activating function of pth neuron in the layer kth. Furthermore, sigmoid activating function is as following:

$$sgm(x) = \frac{1}{1+\exp(-x)} \quad (17)$$

The structure of MLP network containing three layers with four inputs, one hidden layer and one output is shown in figure (1).

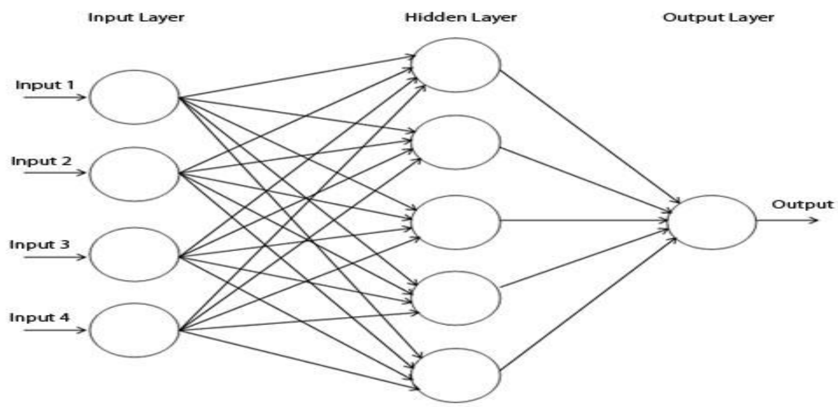


Figure 1: MLP structure

In order to train MLP network and achieve optimal prediction, the network need to be trained and taught under various parameters which have the same characteristics of the network. In other words, network will provide different weights by changing these parameters. At last, the final weight with the lowest error is introduced as final weight and parameters which lead to achieve this weight as network parameters and characteristics. These parameters are as following:

➢ ***Numbers of Network Layers***

Using a single-layer network is not able to forecast well for solving non-linear complex issues (because activation function is linear). In fact, all neural networks with more than one layer partially use activating non-linear functions. Using activating non-linear functions leads to update of neural network ability to model non-linear questions and provide optimal responses. This feature happens with non-linear, differentiable, activating, and continuous function in that there are non-linear functions in intermediate layers. It is noteworthy that excessive increase of neural-network layers (more than three layers) is not recommended at all.

➢ ***Numbers of Neurons of Each Layer***

The next issue is determining the number of neurons of intermediate and output layers. If the aim of using neural networks is forecast, one neuron must exist in output layer. Whereas in contrast, if it is used for classification or identification of pattern, some neurons can be used in output layer. A substantial number of methods have been presented to determine the number of neurons in intermediate layers in which no one is general. Although, the best method to determine the number of neurons is trial and error method. Increasing the number of neurons in hidden layer from a small amount to a big one, first, error sum reduces then it increases again after reaching a certain size of neurons. The best network size can be chosen by this method.

- ***Learning Rate***

Learning rate is one of determining parameters of learning momentum in neural networks and it plays an effective role in network-learning efficiency. This rate is chosen between 0 and 1. Generally, learning rate of neural networks is randomly chosen by trial and error. However, it is normally considered between 0.1 and 0.3 for most practical usages. Higher learning rate lead to faster network learning but when input data diversity is high, network will memorize instead of learning and the network efficiency will fall.

- ***Number of Repetition***

Learning algorithms change output weights after calculation of each output category which means update it. This algorithm needs repetition process to achieve the weights. Number of repetitions for each learning process is also obtained through trial and error. The optimum point of repetition number is a point where the network enjoys the best learning.

- ***Network Momentum***

Momentum parameter is used to increase the convergence speed of the network. If the network momentum is selected too high, it can increase the possibility of getting away from the goal leading to instability of the network. Lower momentum coefficient usually shows better performance for optimum learning of the network.

Research Variables

Since forecast is done through learning and training in neural networks on input variables (independent), input variables are one of important issues for modeling using neural networks. To this end, eight input variables or model independent were taken into account by collecting internal and external resources using library method and studying research literature as in table (1).

Table 1: Input variables (independent) in the research

No.	Variable	Abbreviation
1	Silver price	s
2	US Dollar index	$
3	Oil price	o
4	Inflation rate	INF
5	Interest rate	Int
6	Stock index	TEPIX
7	Euro	E
8	International price of gold	G

To measure the effectiveness of mentioned variables in various patterns, MATLAB software was designed to minimize the modeling and forecast error (Chen and Xu, 2006). Thus, this research is applied one in terms of goal and it is descriptive as well. Its pattern is quasi-experimental using post-test approach.

Research Statistical Population

Since this research studies the forecast of gold price, an initial collection of data is required in that all were factors which had close link with gold price. Library research was used to collect theoretical principles and research literature. Moreover, necessary information and data for the research was collected through Central Bank website (www.cbi.ir), office of economic investigations of Islamic Republic of Iran Central Bank, and in particular Novin Rah Avard software from 1386[2007] till 1391[2012].

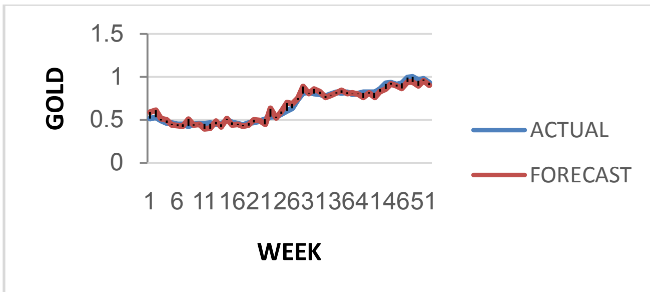
In this research, weekly mean of effective indexes on gold price in the mentioned course were selected. Then, data were fallen in to two categories including training data and experimental data in order to implement learning activity in non-linear models. To this end, learning was done on training data including means of 260 weeks of 1386-1390 [2007-2011] and then they were tested using experimental data from 52 selected weeks in 2012 in order to determine the forecast accuracy and gold-price forecast is done. Thus, in this research, GMDH neural network was used to predict gold price and then its performance is compared with that of MLP neural network. It is noteworthy that data analysis was done using MATLAB software.

Data Analysis

According to mentioned topics, results obtained from information analysis are presented. After identification of appropriate models (GMDH, MLP), based on observations, values of model estimation ($\hat{y}$) and finally indexes of dispersion were calculated according to test data. It is noteworthy that results of gold- price prediction for experiment data have only been provided.

Prediction by GMDH Neural Network

In the following graph, estimation value of ($\hat{y}$) is shown and parameters of final network structure leading to optimum error are listed in table (2).



Graph 1: Actual and output data of GMDH model

Transfer function in output layer	Transfer function in hidden layer	Number of neurons in hidden layer	Number of hidden layers
Volterra	Volterra	20	3

To study the forecast accuracy of network, evaluation performance method was used. The results are listed in table 3.

Table 3: Dispersion indexes of test data according to GMDH model

DATA TEST	GMDH	MAE	0/028	RMSE	0/038	MSE	0/0015	R^2	0/98

Prediction by MLP Network

Forecast by MLP network is in a way that training and learning actions on network is selected where the best output weight with the lowest error is concluded. Thus, data preparation for learning by the network is one of the most important tasks of working with neural network. To this end, data, according to what was mentioned, were normalized between 0 and 1 and were available for the network. On the other hand, data were fallen in to two categories in order to assess the output weight in that learning was initially done on experimental data and then final output weight were tested on training data in order to evaluate the accuracy of network forecast.

Of all data used in this research, data for the year 1391[2012] were considered as experimental data and the rest were used for network training. During learning process, the amount of learning is always assessed by objective functions and finally a network is accepted that enjoys the lowest error. To achieve the best prediction error in MLP network, data training must be done by various parameters in order to reach optimum error. To this end in this research, we reached the acceptable error by training of more than a hundred patterns. The following steps need to be taken in order to achieve the best MLP network structure to predict gold price:

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Determining the Number of Neurons in Hidden Layers

Determining the number of neurons in intermediate layers (hidden) is not an easy task and trial and error must be done to improve the general performance. Generally, the power of network in identifying existing complexities in training data increases by increased number of neurons in hidden layers but this fact might decrease the capability of network generalization. In fact, if the number of neurons in intermediate layers is too excessive, network memorizes instead of learning. In this research, the network with 20 neurons in hidden layer reached the minimum error level by doing trial and error.

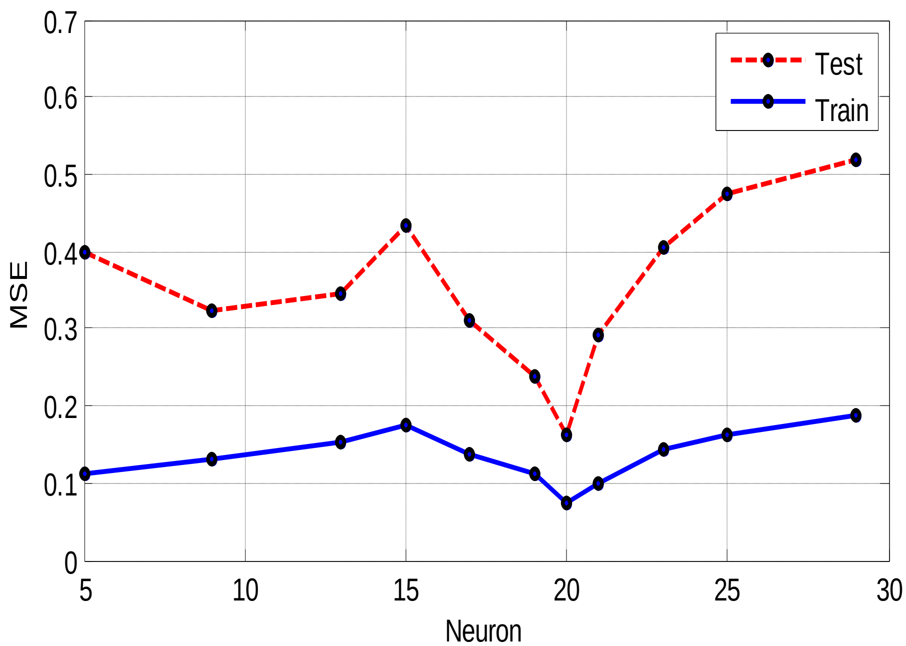


Figure 2: Total error of MLP network compared to the number of neurons in hidden layer

Optimum Determination of Number of Repetition in the Network

Determination of repetition number for network learning is obtained through trial and error. In this research, an acceptable error level was obtained by 17 repetition cycles. In graph 2, total error of MLP network is shown in comparison with the number of repetition.

Optimum Determination of Network Learning Rate

This parameter was determined through error and trial and we reached learning rate of 25 per cent of features for one forecast network.

Optimum Determination of Network Momentum

After studying various momentums for the network, finally, momentum level of 0.15 was selected as one of network parameters leading to reach acceptable forecast error for gold price.

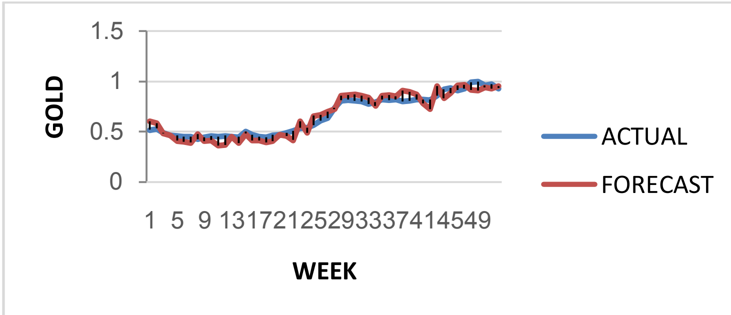
Parameters of final network structure leading to optimum error are shown in table (4).

Table 4: Parameters of final network structure of MLP

Activating function	Learning rate	No. of neurons in hidden layer	Repetition Number	Network Momentum
Non-linear Sigmoid	0.25	20	17	.015

Data Agreement

Data agreement of actual and output data of the network is shown in the following picture:



Graph 3: Graph for actual and output data of MLP neural model

To study the forecast accuracy of the network, performance evaluation methods were used in that the results are in table (5).

Table 5: Results of performance evaluation of MLP neural network

DATA TEST	MLP	MAE	0/052	RMSE	0/067	MSE	0/004	R^2	0/88

The results indicate that GMDH neural network has better performance in all four performance evaluation criteria in comparison with MLP network.

Performance Comparison of Prediction Models

The general goal of this research is to provide an appropriate model for forecast of gold price and its effective indexes. According to results of past researches confirming the superiority of non-linear models for gold-price prediction, GMDH neural network and MLP neural network have been used. Eight fundamental variables were taken into account as input variables of network. The results of this research reconfirming the non-linear model superiority for gold-price forecast shows that GMDH neural network has better performance for gold-price forecast rather than past. Table (6) compares the evaluation results of performance for these two models.

Table 6: Performance comparison of GMDH and MLP network

PEC (Performance evaluation criteria)	MAE	RMSE	MSE	R^2
GMDH	0/028	0/038	0/0015	0/98
MLP	0/052	0/067	0/004	/88

To reach better training of network and achieving reasonable results, data were fallen in to two training and experimental categories although decision criteria for prediction accuracy of two models are experimental data for gold-price forecast. Among four performances –evaluation criteria, three criteria including MSE, RMSE, and MAE are related to standard error mean. The lower they are, the less error the network had done the forecast. Consequently, the efficiency of model will be higher and determination –coefficient criteria (R^2) study the correlation between actual and predicted data. The value of (R^2) is between 0 and 1 and the value of one explains complete agreement. In conclusion, the more (R^2) is closer to one, it will be more optimal.

Research Conclusion

In this research, forecast of one of important and effective variables on investors` decision making, price gold, was studied.

To this end, non-linear methods were selected for forecast based on market feature. We tried to predict the price of gold by GMDH neural network and MLP neural network. Necessary data was collected from Central Bank Web Site and Novin Rahavard software from 1386[2007] till 1391[2012] by weekly means. To achieve reasonable results and better training of the network, samples were divided in to two categories including training and experimental ones. Generally, obtained results from the research are as following:

1. One of important and general results of this research is that effective variables for gold-price forecast have non-linear relationship with gold price and non-linear models have had optimal performance for its forecast. This finding confirms the research result of Abarbanell and Boushi (1997) and all researches afterward.
2. Good and acceptable results of performance evaluation criteria obtained from GMDH neural network indicate high capability of this network for identification of ruling patterns on data as well as unique characteristics of fast convergence, high accuracy, and approximation ability of strong function of the network confirming suitability of GMDH neural network for prediction of gold price.
3. As it is obvious, some indexes are effective factors on gold-price forecast: silver price, oil price, US dollar index, Stock price index, banking interest rate, inflation rate, and international price of gold.
4. As it is clear from results, GMDH neural network has better performance in comparison with MLP network in terms of four assessing criteria. In terms of MSE, RMSE, and MAE criteria, GMDH enjoys lower error means compared to MLP network. On the other hand, calculated determination coefficient value indicated high correlation between actual and predicted data by two models. But this correlation is noticeable in GMDH neural results in that 98 per cent of correlation between actual and predicted data by GMDH neural network is defined and interpreted while it is 88 percent for MLP.

Finally, researchers are recommended:

1. Considering the indexes of this research as effective factors on decision making, investors are suggested to use these models for gold-price forecast in order to invest in gold market.
2. Investors can use these models to forecast stock profit of companies.
3. Investors can use GMDH model for ranking various effective financial ratios on companies` EPS.
4. Using GMDH model, companies can be ranked by various effective ratios and its degree on stock-profit forecast.

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