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Research Paper

Investigating the Market Efficiency in Tehran Stock Exchange through Artificial Intelligence

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ABSTRACT

This study aimed to assess the level of efficiency in the Iranian capital market, a domain where optimal resource allocation and micro and macro investments hold pivotal significance. The primary role of the capital market is to facilitate the circulation of capital and the efficient allocation of resources. The central inquiry in this context pertains to whether there exists a consistent pattern for determining stock prices. The question of market efficiency gains particular importance since understanding the factors influencing stock prices is critical in the stock market. It prompts the examination of whether there is a discernible regular pattern for stock price determination. Consequently, this study undertook an investigation into the efficiency of the capital market in Iran. To conduct this analysis, the researchers utilized daily data from the total index of the Tehran Stock Exchange spanning the years 2008-2017. The test methodology employed artificial neural networks and time series training tests. The results of the tests unveiled weak efficiency in the Tehran Stock Exchange. Importantly, this inefficiency remained relatively unchanged compared to the initial period studied. In other words, within the Tehran Stock Market, it is feasible to make predictions about returns through the application of artificial intelligence.

1 Introduction

The concept of efficient markets is well documented in the finance literature. The theory states that past asset price movements cannot be used to predict future asset price movements [5]. One of the most important features of financial markets is the efficiency of the markets. An efficient securities market is a place where the price of the securities traded in this market, at any time, can accurately reflect all the data that has become known to everyone about the securities. After the efficient-market hypothesis was presented and later on expanded by Fama in the 1960s, the usefulness of accounting data was questioned. The efficient-market hypothesis states that past data is reflected in the price and the market does not react to past information (historical cost) in a strong and semi-strong efficient mode. The main task of this market is to flow capital and allocate resources efficiently and optimally. Is there a regular

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pattern for determining the stock price? In general, in an efficient market, prices are a good indicator of resource allocation. Additionally, in this market, natural and legal persons can make many investment decisions and make the best choice among the securities offered by companies. If in a market the price of securities is a full reflection of all data available at any time, that market can be called efficient [9]. The investors' goal in buying stocks and investing in companies is to make a profit. Hence, most investors try to make more profit than others and above the market average.

However, market efficiency theory states that in order to obtain additional returns, no investor has access to more data than others. According to capital market theory, prices always reflect available data, and stocks are always traded based on their real and fair value, and it is impossible for an investor to buy a stock at a price below its real value or sell it at a price higher than its real value. Thus, it is impossible to earn a profit higher than the average market profit, and the only way to earn a higher profit is to buy high-risk stocks [1]. In this paper, we test the weak form hypothesis of market efficiency for the Tehran Stock Exchange(TSE) by examining whether total index follow a random walk. The findings from our research has implications for investors because if the TSE is not efficient and price movements are independently and identically distributed random variables, some investors can exploit the inefficiency in this market by gaining abnormal rates of returns as opposed to just earning normal rates of return. This may be beneficial to investors that engage in alternative trading strategies in the futures market by correctly predicting future price movements. Accordingly, this study intends to investigate the data efficiency of the capital market using artificial intelligence, and given that this research is about an emerging market like the Iranian capital market, it can be useful for researchers in other countries. Moreover, since this research is carried out with recent data from the Iranian capital market until 2017, it is different from the previous studies.

2 Theoretical Foundations and Literature Review

2.1 Efficient-Market Theory

The stock exchange market's main role is to attract savings and direct liquidity in the economy towards its optimal directions so that it leads to the optimal allocation of scarce financial resources [5]. However, this depends on the efficiency of the financial markets. According to "market efficiency", prices are affected by stock and market data. Thus, considering this theory, no investor has an advantage over the others in terms of dividend forecasting because no investor has data asymmetry and does not have access to data more than the other investors. In financial accounting, securities market efficiency has important applications [10]. Efficiency means that the content of the disclosed information (rather than the form of disclosure) is influenced by market, i.e., the market values the content of the disclosed information. In efficient market theory, accounting is significant because it competes with other sources of information such as news media, views, and comments of financial analysts, and even market prices. By means of informing investors, accounting can survive only if it provides information, compared to other sources, that is effective, reliable, timely, and cost-effective.

An efficient market is the one, in which the price of securities equals the value of the investment and market prices reflect a complete and immediate set of information. In this kind of market, investors expect to earn a normal return on their investment. For example, in an inefficient market, it is not possible for an investor to make abnormal returns (except by chance) through historical prices. Similarly, in a semi-strong efficient market, it is unlikely that an asset generates abnormal returns using existing general information (except by chance). Finally, in a highly efficient market, the investor cannot (except by chance) dominate the market and achieve greater returns than market returns. In this notion, an efficient market is a semi-strong market because in the United States there are strict laws that prevent the use of internal information (private information) to buy and sell securities. Therefore, due to limitations in using all the information needed to analyze market prices, the stock market is always considered as a semi-strong market.

Samuelson and Mendelburt [5] presented a logical theory of the efficient market theory, based on which if the market is competitive and the normal trading profit is zero, unexpected price changes in markets with uncertainty should act as an independent random change. They argued that unexpected price changes represent new information. Since new information is the result of new conditions, it contains information that cannot be deduced from previous information. Therefore, new information must be independent over time. Accordingly, if the unexpected normal profit is zero, the unexpected change in the price of the securities should be independent over time. This theory in economics was developed independently by Muth [19]. The efficient market theory has had a significant impact on macroeconomic analysis. The efficient market hypothesis has been further tested in the social sciences. One of the most important experimental steps in this field is the creation of data generated by the Center for Research in Security Prices (CRSP) by Meryl Lynch at the University of Chicago. The center has maintained detailed information on the latest monthly prices, dividends, and capital changes for all shares on the New York Stock Exchange since 1926 and the daily prices of all shares on the US-New York Stock Exchange since 1926 based on computer files. Experimental studies based on these information and the efficient market theory show that using these data available, it is not possible to make more profit than normal profit because this information has already been used.

2.2 Degrees of Information Efficiency in the Market

According to Fama’s research, market information efficiency is divided into three groups as follows [15]

2.2.1 Strong Efficiency

This type of efficiency theory is the most extreme use, according to which all information in a market, whether private or public, is effective in stock prices. Even the information of the internal staff of companies and the market does not give an advantage to one investor over another. Accepting an efficient market theory in its purest form may be difficult, but there are three categories to this theory that indicate the extent to which this theory can be applied to the market. In a fully efficient information market, securities prices are strongly influenced by market information, and investors cannot make unusual profits using information. In this market, the price of securities equals the intrinsic value. If some information is not fully reflected in the stock price, then the market is not fully functional.

2.2.2 Semi-Strong Efficiency

According to this type of market efficiency theory, all general information is effective in determining stock prices and neither fundamental analysis nor technical analysis is effective in gaining an advantage over other investments.

2.2.3 Weak Efficiency

Fama described weak efficiency as follows, "In this type of efficiency, all previous stock truths affect its current price.” Therefore, technical analysis cannot be used to predict the future stock price [5]. In weak efficiency, some of the available information is from previous periods and their impact is reflected in securities' price. In a semi-strong market, all known and available information quickly affects prices. This market also includes the weak form of the efficient market. In a strong market, stock prices are completely influenced by information, both general and non-general information. In this market, no investor can benefit more than the normal rate of return at one point in a certain time. This market also includes a weak and semi-strong efficiency [3].

3 Experimental Background

Quantitative evaluation of market efficiency first entered the literature of financial economics in the 1960s, and in his well-known article, Fama compiled, compared, and categorized market efficiency study methods [5]. Lee used the variance ratio test to test whether the weekly stock returns of the United States and ten industrialized countries namely Australia, Belgium, Canada, France, Italy, Japan, the Netherlands, Switzerland, the United Kingdom, and Germany followed the random walk hypothesis for 1967-1988. In his studies, he found that the random walk model is still a good description for the weekly return series for most of these countries [10]. Lee et al. Estimated market performance using the daily stock market prices of Shanghai and Shenzhen, using the generalized Dickey-Fuller unit root test and the cointegration tests from May 21, 1992 to December 18, 1995. The results of the Engle-Granger two-step method, as well as Johansen's cointegration test and the causality test indicated that the Chinese stock market is inefficient in general [11]. A relatively comprehensive study was conducted by Liu et al. to examine the stock market efficiency in Hong Kong, Singapore, South Korea, and Taiwan with respect to their respective macroeconomic and fiscal macroeconomic policies. The study used quarterly data for total stock prices, money supply, and budget deficit (surplus).
The results of their research showed that none of the stock markets of these four small Asian tigers (Hong Kong, Singapore, South Korea, and Taiwan) are effective in relation to both monetary and fiscal policy information. There are short-term stock market inefficiencies in these four countries. Using Phillips-Perron (PP) unit root tests and Johansen's cointegration test, Chan et al. tested the weak efficiency and efficient market theory for eighteen international stock markets. These markets included Australia, Belgium, Canada, Denmark, Finland, France, Germany, the Netherlands, India, Italy, Japan, Norway, Pakistan, Spain, Sweden, Switzerland, the United Kingdom and the United States. Chan et al. concluded that all stock markets individually had a weak efficiency, and only a small number of stock markets had evidence of co-integration with markets [2]. Gronewold tested both weak and semi-strong efficiency using daily data for 1975-1992 for the Australian and New Zealand stock markets. Weak efficiency was tested using Dickey-Fuller, and Phillips-Perron (PP) unit root tests, variance ratio, and autocorrelation tests, and semi-strong efficiency was tested using both co-integration and Granger causality tests. The results of unit root tests showed that both indices were nonstationary and indicated weak efficiency [6]. Using daily data on the value of the Ukrainian stock market index for 2000-2005, Adelia Batrushina examined market efficiency at various levels (weak, semi-strong, and strong) based on the Efficient Market Hypothesis (EMH). The study used statistical models such as the Irwin method and cointegrating regression Durbin Watson (CRDW) test.
They concluded that the increase in the stock index was accidental only in 2001, and ultimately the Ukrainian stock market had weak efficiency. Jinhu Jeung examined the efficiency of the Korean capital market in terms of fiscal and monetary policies. In other words, in his study, he experimentally examined the efficiency of Korean stocks in terms of macroeconomic information. In order to test the semi-strong market efficiency, this study used monthly data for 1982-2000 and full information maximum likelihood (FIML). The findings of the study were consistent with the efficient market hypothesis for

monetary policy, but the outcome was unclear for fiscal policy [8]. Raksha Gobna and Parikshit Bashu tested the weak efficiency in a random walk theory in two major securities markets in India for 1991-2006. In the study, they used the augmented Dickey-Fuller test (ADF), Phillips-Perron (PP) unit root test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests, as well as LOMAK variance ratio test. The test results showed that the markets did not have weak efficiency [7]. Fadaeinejad (1994) examined the weak and semi-strong efficiency of the Tehran Stock Exchange in two forms using the weekly stock prices of 50 companies listed on the stock exchange for 1989-1993. In his study, for weak efficiency, he used parametric and nonparametric methods of the autocorrelation of time series of successive changes to test stock price turnover, and for semi-strong efficiency, he used a market model and measuring abnormal returns regardless of beta. The results of the study showed the inefficiency of the capital market in the Tehran Stock Exchange at both weak and semi-strong levels for the period under study. Namazi examined the weak and efficiency of the Tehran Stock Exchange using daily and weekly price data of 40 companies listed on the stock exchange for 1989-1994. In his study, he used sequential correlation coefficient methods, normality tests, and filter rule.

The results showed the inefficiency of the Tehran Stock Exchange. In their study, Yaghoubnejad and Shirazi evaluated the efficiency level of information in the Iranian capital market according to the investors' reaction to the information included in the financial statements with regard to the main role of the stock exchange, attracting wandering resources in society and directing them to value-added activities, stated that this is subject to the efficiency of capital markets. According to Yaghoubnejad and Shirazi, in order to achieve the mentioned goals, it is necessary for the capital market to have allocative, operational, and information efficiencies. In order to test this hypothesis, the correlation of price changes, as an indicator of investors' reaction to the information included in the basic financial statements including earnings per share, cash earnings per share, company value, return on investment and return on equity over a six-year period using the data of 102 companies listed on the Tehran Stock Exchange were tested. The results showed that the correlation among the independent variables with changes in stock value was not significant in all years studied and the correlation among the variables did not improve over time. Using the monthly data of the total stock index for 1998-2007, Saeed Rasekhi and Amir Khanalipour examined the information efficiency hypothesis in the Tehran stock market [16]. This was tested with the hypothesis of non-significance of ARMA model coefficients. The return term coefficient in the first interval was significantly opposite to zero, and this finding indicated information inefficiency in the Tehran Stock Exchange. Shams and Soleimani Ashrafi investigated the relationship between price fluctuations and information asymmetry in the periods prior to the announcement of earnings on the Tehran Stock Exchange [18].

Their results showed a significant relationship between price fluctuations and information asymmetry and the value of transactions and information asymmetry. In fact, increased fluctuation limit can increase market efficiency and information symmetry. In their study, Nazifi et al examined the stock return trend using Markov-switching autoregressive (MSAR) model. The results of their research showed that the fluctuations of the financial index of the Tehran Stock Exchange can be better described using the Markov switching model rather than simple models. Using Markov model, they divided the stock return fluctuations into two high-fluctuation and low-fluctuation regimes, and the results showed that in the Tehran Stock Exchange, the duration spent in the high-fluctuation regime is longer than the low-fluctuation regime.

4 Methodology

Based on the research subject, this applied research is based on information about stock returns (total

stock index) in Tehran Stock Exchange, and the results can be analysed for a wide range including managers of financial institutions, monetary policymakers, financial analysts, investors, stock exchanges and researchers. Moreover, considering that past information was used for analysis, this research is a post-event study. The research is an analytical-mathematical study. Using artificial neural network, this study examined the efficiency of Tehran capital market. The statistical population included all companies listed on the Tehran Stock Exchange because in analysing the data, the total index was used, which was the result of the daily stock prices of all listed companies. The study covered a 10-year period from 2008 to 2017. In this study, total available data was used for sampling, which was the very total index. The purpose was to investigate the information efficiency of the capital market and to provide a method for evaluating the efficiency with artificial neural network (NN) models.
The approach used in the present study provides an indicator for assessing the degree of market inefficiency and the timing and speed with regard to efficiency. Given that the research examined an emerging market like Iran's capital market, it can be useful for researchers in other countries. Since this research was carried out with recent information from the Iranian capital market until 2017, it is different from previous studies. Given the above, the main question of this research is whether the Iranian stock market has weak efficiency? In this regard, the second research question was that according to the characteristics of the market and also the research objectives and in order to answer the research question, the following hypothesis was proposed:

4.1 Research Hypothesis

According to the examined data from the total index of Tehran Stock Exchange, there was a weak efficiency in the Tehran Stock Exchange.

4.2 Research Model

In order to evaluate the efficiency of the market, its weak level was evaluated. The weak form of the efficient market hypothesis requires that there is no opportunity for profit based on past changes in asset prices. This implies that an efficient market must be an unpredictable market. Therefore, the total index was used as a basis for testing the research hypothesis. The variable used in this study was the total daily index for 2008-2017. In order to analyse and test the hypothesis, the Levenberg-Marquardt back-propagation algorithm in the artificial neural network and MATLAB have been used. The weak form of the efficiency hypothesis requires that there be no chance of profitability based on past changes in asset prices. This implies that an efficient market must be an unpredictable market. This is often tested through the following simple regression:

$$r_t = \beta_0 + \sum_{i=1}^{\rho} \beta_i r_{t-1} + e_t \quad (1)$$

Where r is the rate of return on assets and the weak form of efficiency makes $\beta_i = 0$ i> 0. This hypothesis is often tested by estimating such equations using the OLS or GMM methods. With regard to the Tehran stock market (as well as other emerging markets), this approach is not very logical because it effectively tests the performance throughout the market formation period and is hardly acceptable that such markets have been fully efficient markets from the beginning. As a result, primary inefficiency of market formation periods causes a bias in the results of estimation and testing, and indicates that due to inefficiency in the past, there is still a chance of profit. Therefore, there should be a way to model this variable structure for the estimation process. Then, there must be a standard or test for stock market efficiency in order to assess the possibility of profitability opportunities. There should also be a standard to measure the timing of market movement toward efficiency so that one can explain the speed at which markets become more efficient. This method can only be achieved by developing a new version of the above equation that allows using unstable parameters over time. First, the above equation can be reformulated as follows:

$$r_t = \beta_{0t} + \sum_{i=1}^{\rho} \beta_{it} r_{t-i} + e_t \tag{2}$$

In this equation, the parameters have a time index and can change over time. The second feature of conventional financial time series models is that the error process often does not have a complete set of normal, identical, and independent distribution (NIID). In order to solve the heterogeneity in the variance of the error process and also to consider the sequential correlation, coding and artificial neural network, which estimates using in-network learning system, were used.

4.3. Artificial Neural Network

In computer science, artificial neural networks (ANN) are computational models inspired by animals'central nervous systems that are capable of machine learning and pattern recognition. ANN is a nonparametric approach, and it does not consider any assumption about the functional form between inputs and outputs [4]. The original idea of using neural networks as a tool for prediction dates back to 1964. In his dissertation, Hu used an adaptive linear network to predict the weather. It should be noted that due to the lack of training algorithms for multilayer networks at the time, studies related to forecasting topics were conducted restrictively. Finally, in 1986 the backpropagation algorithm (BP) was introduced by Rumelhart et al. Werbos first applied the backpropagation algorithm to neural networks and showed that networks trained using the backpropagation algorithm performed better than traditional statistical methods such as regression and ARIMA. One of the first successful applications of neural networks in prediction problems was a study conducted by Lapedes and Farber in 1988. Using two time series derived from logic mapping and the Glass-McKee equation, they designed the feedforward neural network through which they were able to simulate and predict dynamic nonlinear systems with appropriate accuracy. A neural network can be defined as follows:

An adaptive system that includes some simple processing elements and is modelled on the brain's neural network. The processing elements, which are actually neurons, come together to complete a processing direction. These processing elements are usually arranged in layers with regular pages so that there are complete or random connections among the layers. Artificial neural networks (ANNs) try to form very simple neural systems that are created by simulating natural and real samples. Kohonen divided the structure of neural networks into three categories based on physiology and how they are modelled: feedforward, feedback, and self-organizing networks.

Artificial neural networks have features that make them superior in some applications such as pattern separation, robotics, and learning control. These features are as follows:

1. Ability to learn Learning ability is the ability to adjust network parameters (weights) over time as the network environment changes and the network experiences new conditions so that if the network is trained for a specific situation and a small change occurs in environmental conditions (input data to the network), the network could be efficient in new conditions with brief training.

2. Data dispersion: It can be stated that there is no one-to-one relationship between inputs and

weights, and in fact, each weight is related to all inputs and not to a specific and unique neuron. In other words, each neuron in the network is affected by the total activity of the other neurons.

3. Generalizability: After being trained with the basic examples, the network can produce a suitable output for an untrained input. This output is obtained based on the generalization mechanism. In other words, the network learns the function, learns the algorithm, or acquires a suitable analytical relation for points in space.

4. Parallel processing: When neurons are aligned and respond to the inputs of that alignment simultaneously, the processing speed is accelerated.

5. Resistance: In a neural network, although each neuron operates independently, the overall output of the network is the result of the local behaviours of multiple neurons. This feature avoids local errors from the final output.

The following can be the summary of the application of neural networks.

1. Classification, identification, and pattern recognition: A variety of static and dynamic neural networks have been used to classify and identify patterns. For instance, to identify Latin, Arabic, Persian, etc. characters.

2. Signal processing: In this regard, one can mention the use of neural networks in speech and image processing, machine vision, coding, and image compression.

3. Predicting time series: Neural networks have been widely used to predict time series, particularly where time series are complex and do not provide the conditions for the application of classical techniques.

4. Modelling and control: In adaptive systems, particularly when the process is very complex, neural networks provide a suitable solution, and generally, first, the system controller is identified and then designed.

5. Optimization: This is used in resource allocation and distribution management systems as well as in financial and banking systems. In particular, multilayer neural networks (1MLP) with backpropagation algorithms are widely used for optimization.

6. Financial, insurance, security, and stock market subjects, and entertainment equipment: Neural networks are used as advisors in capital allocation, financial analysis, currency price forecasting, stock price forecasting, insurance policy evaluation, and creating animation for entertainment equipment.
The artificial neural network model can be used as a test to find dynamic nonlinear processes, including chaotic processes in data. Artificial neural network models are flexible nonlinear models that can estimate and predict complex nonlinear time series with acceptable accuracy. Neural network models consist of three layers: input, middle, and output.

4.4 Using Artificial Neural Networks to Predict Time Series

There are two types of data on which a neural network can be trained: time series data and classification data [17]. McCulloch and Pitts showed that neural network is capable to be expressed in a mathematical algorithm and provided the first artificial neural networks. Neural networks provide a selforganizing method based on mathematical algorithm to resolve problems. Neural networks have several applications such as echology, prediction, classification and clustering [14]. Today, artificial neural networks are used in a variety of real-world issues. The most well-known applications of neural networks include approximation of functions, data classification and clustering, data storage and review, optimization of constrained problems, path tracking, and so on. One of the most important applications of artificial neural networks is that they can be used as a powerful tool for predicting time series. There are several approaches to using neural networks for prediction problems, of which multilayer feedforward neural networks (MLF -NN) are the two most widely used. In general, the forecast model for time series issues is generally as follows:

$$x_t = F(x_{t-1}, x_{t-2}, \ldots, x_{t-k}) \tag{3}$$

Where x_t is dependent variables and $x_{t-1}, x_{t-2}, \ldots, x_{t-k}$ independent variables. Neural networks can be trained to predict one or more independent variables, although the accuracy of the prediction is highly dependent on the appropriate network training. In this research, in using the neural model, the data were divided into three parts: 1. Training data 2. Validation data 3. Test data. Thus, 70% of the data was used for training and 15% for model validation. In the end, the remaining 15% of the data was used to test the obtained model.

Training data: This data is injected into the model during training and the model gradually adapts to the data and reduces its error.

Validation data: This data is used to measure the generalization of the model and to complete and finalize the training.

Test data: This data does is not involved in the training process of the model, but is used to measure the efficiency and performance of the model after training.

In order to perform neural network tests, as shown in the figure 1, MATLAB and neural network time series and coding were used.

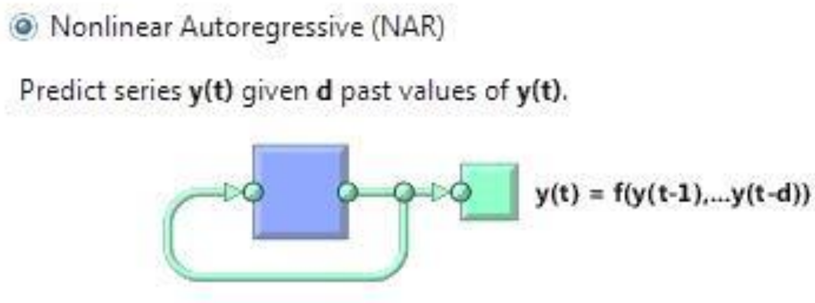

Fig. 1: Regressive Neural Network

The network also uses the Levenberg-Marquardt backpropagation algorithm. Finally, using MSE and R scales, the predictive power of the index was analysed using artificial intelligence, which indicates the efficiency or inefficiency in the market. Mean squared error (MSE) is the difference between the outputs and the goals, and the lower the value, the better. A zero value means that there is no error, and regression value is to express and measure the correlation between outputs and targets. If regression is one, it means a completely closed relationship, and if regression is zero, it implies a random and non-closed relationship. Therefore, in this study, the market efficiency was evaluated through the artificial neural networks and training and testing the daily data of the total index by year breakdown and comparisons.

5 Research Findings

5.1 Descriptive Statistics

Descriptive and inferential statistics were used to analyse the collected data. Given that time series data was used to test hypotheses, descriptive statistics of research data including data about mean, median, minimum, maximum, and standard deviation of the data is shown in table 1.

Table 1: Descriptive Statistics of Research Variables

Statistical indices	**TEPIX**	**Price index**
	TEPIX	Price index
Number of observations	2244	2244
Mean	48808	22388
Median	47690	22271
Minimum	7955	7776
Maximum	99522	44924
Standard deviation	28512.18	9036.12
Skewness	0.023	0.114
Kurtosis	1.414	2.110
Jarque-Bera	235.029	78.911
p-Value	0.000	0.000

The figure 2 shows the diagram of the total index and price.

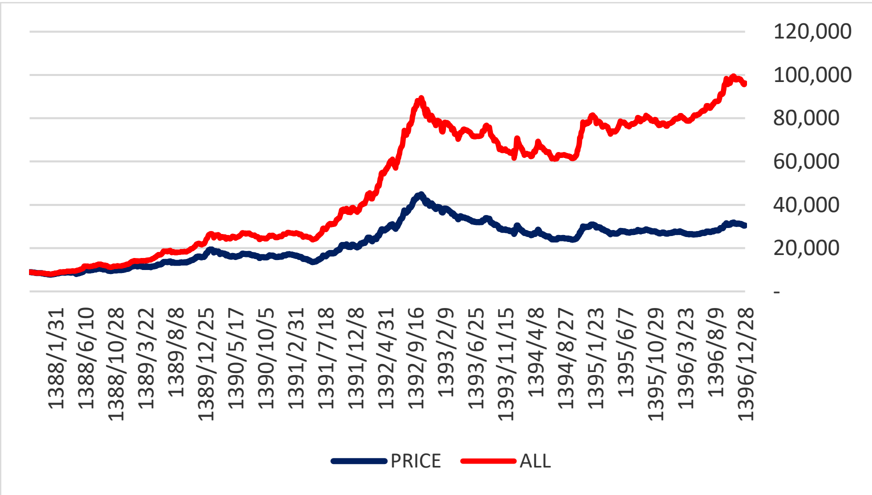

Fig.2: Growth Trend of the Total Index and Stock Price Index of Tehran Stock Exchange

5.2 Reliability (Stationary) of Data

In time series and combined analysis, it is assumed that the time series is reliable (stationary). Different tests are used to investigate such a mode. Thus, Dickey-Fuller test was used for the reliability test for the variable studied in the models whose results are shown in Table 2.

Table 2: Reliability Tests Research Rariables (Generalized Dickey-Fuller test)

Variable	**Description**	**Statistical values**		**Test result**
Symbol		**Fisher statis-tics**	**p-Value**	
TEPIX	TEPIX	134.54	0.000	Confirmed
Price index	Price index	104.57	0.037	Confirmed

As seen in the Table above, the p-value for all variables was less than 5%; therefore, the variables were stationary during the research period, and the model can be estimated for all observations. Both the total index and the price index do not have a lack of long-term memory in terms of performing GARCH models. In addition, due to the lack of a unit root, the nonstationary efficiency of the total index of the stock price index was rejected, which implies that there were stable moments for returns.

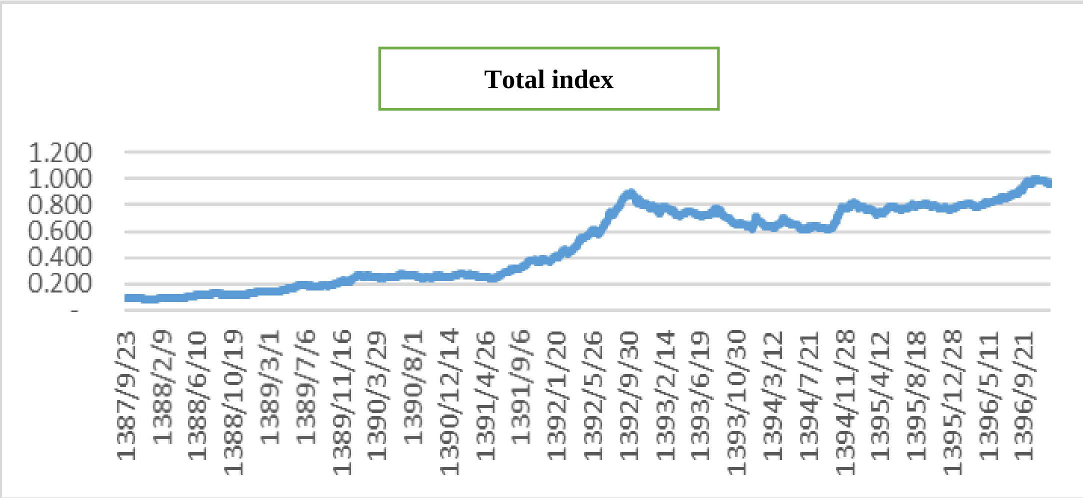

Fig. 3: Correlation of the Total Index Over Time

Table 2 shows $\beta_1 t$ estimates during the study period for the Tehran Stock Market Index at a 95% confidence level. In order to analyse and interpret the trend of changes in the stock market efficiency in the Tehran Stock Market, it is necessary to have an overview of the events affecting the stock market during the studied period.

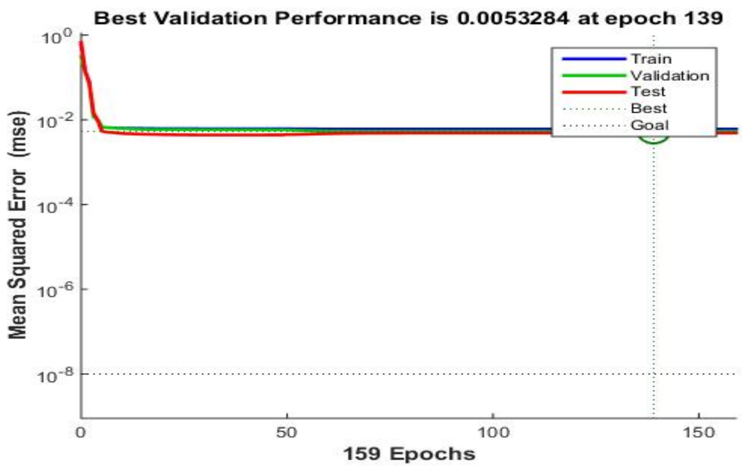

Fig. 4: The Curve of Mean Squared Error for 2017

5.3 Results from The Artificial Neural Network Model

In order to perform neural network tests using coding in MATLAB, first, the number of return periods in the time series was defined as 5, 10, and 15. Then, the number of latent layers and neurons to perform the training process was determined. The results of the training, testing, validation process and related tables and reports by year are presented in the appendix. For instance, the output of the neural network learning system for 2017 for the results obtained for the evaluated years as Fig. 4. According to the curve of the mean squared error, it can be stated that training and validation were well done, and at the same time, the test data also matched the error level of 0.005, which was a good value. In fact, the accuracy of the model in estimating the data was high. Additionally, according to the regression curves in Figure 5, data matching in the training phase was more than test data.

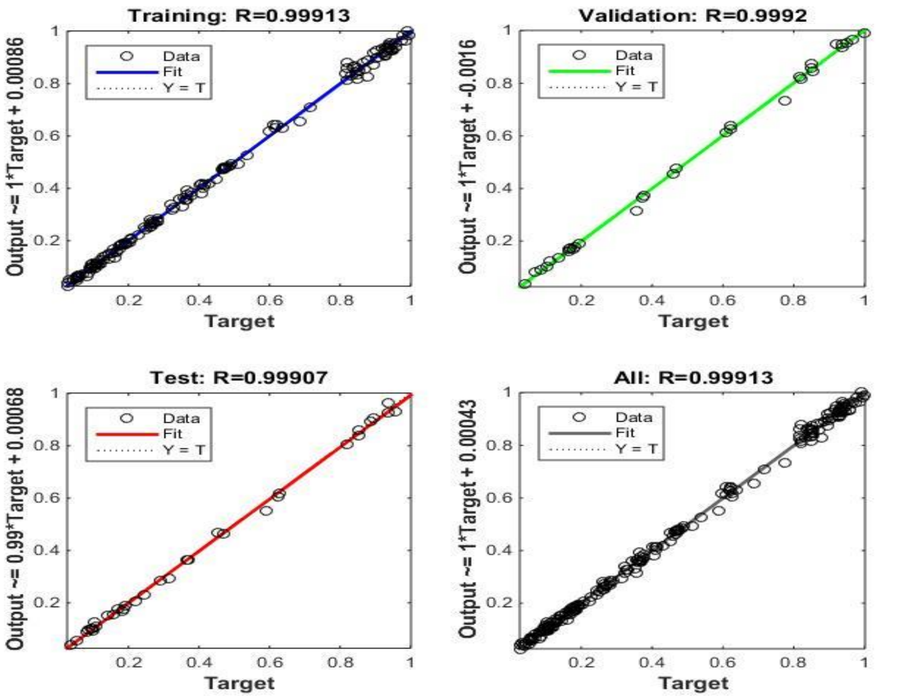

Fig. 5: Data Matching in the Regression Curve for 2017

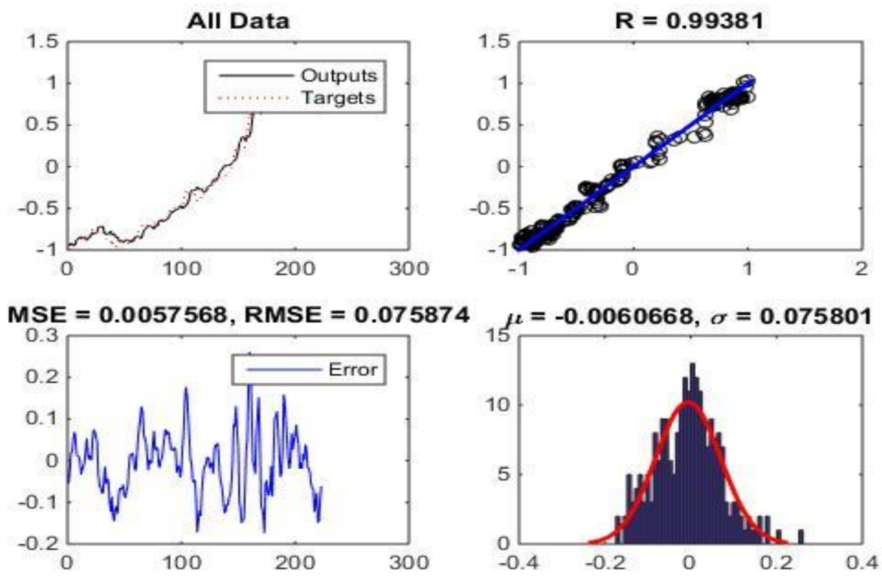

Fig. 6: The Sum of the resulting Graphs for 2017

As shown in Table 3, and according to the above explanations, in all years the MSE was close to zero, which indicates the high accuracy of the forecast in all the above years. In addition, regression values were close to one in all years, which indicates the intensity of serial data dependence.

Table 3: Summary of Results Obtained from the Artificial Neural Network for 2008-2017

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
MSE	0.02293	0.0075	0.0046	0.08000	0.0070	0.0040	0.01700	0.01000	0.0320	0.0057
RMSE	0.015143	0.0800	0.0600	0.02900	0.0800	0.0600	0.13000	0.10000	0.1700	0.0750
REG	0.968	0.989	0.992	0.80	0.9992	0.990	0.960	0.980	0.900	0.990

6 Discussion and Conclusion

Market efficiency is the main foundation of a conventional financial economy and a basic condition for the optimal allocation of financial resources in a capital market and the basic foundation of a conventional financial economy. In recent decades, extensive studies on market efficiency have led economists to develop an understanding of an efficient market, and as a result, the methods of examining the subject and its implications have undergone serious changes. Paying attention to the position and key role of the capital market is extremely important. The capital market, which is the market of supply and demand of financial resources, can play its vital role well when the process of supply and demand of its financial resources is optimally allocated. The main prerequisite for optimal allocation of resources in the capital market is efficiency in its function. The difference between effective and efficient capital markets and inefficient markets is due to the data and the degree of transparency and access to it.
The more data related to the capital market (comprehensively, coherently, and influentially on market activity), the greater the influence of the capital market on economic growth and development. This study examined and evaluated the efficiency of the capital market using time series models in the artificial neural network for 2008-2017. The test results indicated the ability to predict (inefficiency) in stock returns on the Tehran Stock Exchange using an artificial neural network. This conclusion can have many reasons. One of the most important reasons for predictability (inefficiency) in the Tehran stock market is low liquidity and lack of timely disclosure of market information. Therefore, when the market size and trading volume increase, it is expected that the predictability of returns will decrease and the market will become more efficient. In general, in the Tehran Stock Market, the overall performance of the market in most of the study period was predictable. During the research period, the Tehran Stock Exchange was inefficient. This inefficiency did not change much since the beginning of the period, and as a result, it is possible to predict returns and earn abnormal returns and over zero profit in this market. The results of this study were consistent with the findings of Yaghoubnejad and Shirazi; Rasekhi and Khanalipour; Nourbakhsh et al. and Mohammadi et al.

References

[1] Ebrahimi, S. O., haji shahroodi, D., *Evaluating capital market efficiency by measuring the desire to return to the average of the top indices of the Tehran Stock Exchange*, Third International Conference on Economics, Management, Accounting with Value Creation Approach, Shiraz, 2017, coi: MAVC03_009.

[2] Chan, K. C., Gup, B. E., and Pan, M. P., *International Stock Market Efficiency and Integration: A Study of Eighteen Nations*, Journal of Business Finance and Accounting, 1997, **24**(6), P.803-813. Doi: 10.1111/1468-

5957.00134

[3] Daniali, M., Mansoori, H., *Investigating the efficiency of Tehran Stock Exchange at a weak level and prioritizing the factors affecting it*, Quarterly Journal of Economic Research (Islamic-Iranian approach), 2013, P. 71-96

[4] Doaei, M., Davarpanah, S. H., *ANN-DEA Approach of Corporate Diversification and Efficiency in Bursa Malaysia,* The Journal of Advances in Mathematical Finance and Aplicaton, 2017, **2**(1), P.9-20. Doi:10.22034/amfa.2017.529058

[5] Fama, E.F., *Efficient Capital Markets: A Review of Theory and Empirical Work*, Journal of Finance, 1970, **15** (2), P.383-417. Doi: 10.1111/j.1540-6261.1970.tb00518.x

[6] Gronewold, N., *Share Market Efficiency: Tests Using Daily Data for Australia and New Zealand*, Applied Financial Economics,1997, **7**, P.645-657. Doi: 10.1080/758533856

[7] Gobna, R., P. K. Basu., *Weak Form Efficiency in Indian Stock Market*, International Business and Economics Research Journal,2007, **6**(3), P.57-64. Doi: 10.19030/iber.v6i3.3353

[8] Jeong, J., *Foreign Currency Crisis and Semi-Strong Efficiency of the Korean Stock Market*, School of Business Administration Kyungnam University Korea, 2004.

[9] Izadikhah, M., Farzipoor Saen, R., Ahmadi, K. and Shamsi, M., *How to use fuzzy screening system and data envelopment analysis for clustering sustainable suppliers? A case study in Iran*, Journal of Enterprise Information Management, *2021, 34(1), P. 199-229. Doi: 10.1108/JEIM-09-2019-0262*

[10] Khajavi, SH., Ghasemi, M., *Efficient market theory and behavioral finance*, Financial Research Quarterly, 2006.

[11] Lee, U., *Do Stock Prices Follow Random Walk? Some International Evidence*, International Review of Economics and Finance, 1992, **1**(4), P.315-327.Doi: 10.1016/1059-0560(92)90020-D

[12] Lee, U., *Stock Market and Macroeconomic Policies: New Evidence from Pacific Basin Countries*, Multinational Finance Journal, 1997, **1**(4), P.289-273.Doi: 10.17578/1-4-2

[13] Khoshroo, A., Izadikhah, M., Emrouznejad, A., *Total factor energy productivity considering undesirable pollutant outputs: A new double frontier based malmquist productivity index*, Energy, 2022, 258, doi: 10.1016/j.energy.2022.124819.

[14] Mobarek, A., K. Keasey., *Weak-form Market Efficiency of An Emerging Market: Evidence from Dhaka Stock Market of Bangladesh*, 2000, Leeds University Business School.

[15] Namazi, M., Shooshtarin Z., *The Investigation of the Efficiency of Iran's Stock Exchange*, Financial Research Journal, 1995, **2**(7) - Serial Number 7,Summer

[16] Niknafs, J., Keramati, M. A., *Estimating Efficiency of Bank Branches by Dynamic Network Data Envelopment Analysis and Artificial Neural Network,* The Journal of Advances in Mathematical Finance and Aplicaton, 2020, **5**(3), P.377-390. Doi: 10.22034/amfa.2019.1585957.1192

[17] Rahnama Roodposhti, F., Salehi, A., *Schools and theories of finance and accounting*, Second Edition, Tehran, Islamic Azad University, 2011, Central Tehran Branch Publications

[18] Rasekhi, S., Khanalipoor, A., *Experimental analysis of stock market fluctuations and information efficiency (Case study of Tehran Stock Exchange)*, Iranian Economic Research, 2010, **13**(40), P.29-57

[19] Saberi, M., Rostami, M. R, *Forecasting the Profitability in the Firms Listed in Tehran StockExchange Using Data Envelopment Analysis and Artificial Neural Network,* The Journal of Advances in Mathematical Finance and Aplicaton, 2016, **1**(2), P.95-104.Doi: 10.22034/ amfa.2016.527823

[20] Shams, SH., Soleymani, Ashrafi, M., *Investigating the relationship between price fluctuations and information asymmetry in companies listed on the Tehran Stock Exchange*, Journal of Experimental Accounting Research, 2014, **3**(1). Doi: 10.22051/JERA.2013.569

[21] William Poole, E. S., Phelps and Martin N. B,, *Rational Expectations in the Macro Model*, Brookings Papers on Economic Activity, 1976, **2** , P. 463-514. Doi: 10.2307/2534381