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APPLICATION OF ARTIFICIAL NEURAL NETWORK SUPPORTING THE PROCESS OF PORTFOLIO MANAGEMENT IN TERMS OF TIME INVESTMENT ON THE WARSAW STOCK EXCHANGE

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Abstract: The paper presents the use of artificial neural networks as a tool expert, which supports decision-making for the quarterly period investing on the stock exchange. The authors also proposed a set of 12 features of the economy and the stock market, which has a universal character so that the approach presented in the publication of this configuration data can be useful for any chosen market. Tests were carried out on the basis of actual data from WSE (GPW in Warsaw) and the Polish economy.

Keywords: artificial intelligence, stock exchange, features, investment

INTRODUCTION

The period of globalization with the gradual removal of barriers to the cash flows should contribute generally to the increase in the volume of financial transactions in the world. The practice has become so until 2007, since the collapse of Lehman Brothers started a new period for the capital markets in which we can distinguish two trends. Firstly, the value of financial transactions in the world is about 30% lower than in the strong development of the capital markets, it is in the years between 2006-2007 [Report Life after Lehman 2013, p.6]. Secondly, it has negatively impacted on the equity markets of countries belonging to the "emerging

markets". One such a country is Poland[1]. Practice shows that due to the globalization, the analysis should take into account not only indigenous capital markets but also foreign markets, due to their interdependencies [Murphy 2004, p. 236]. Therefore, financial institutions desiring to raise cash customers for their efficient investment in shares, must effectively choose a stock exchange with an international portfolio diversification.

In this light, the problems which are still under discussion is the method of selecting the securities exchanges and the duration of the investment on the selected exchange. Due to the current state of stock exchanges of the countries belonging to the emerging markets, it is the second focus of the presented problems. Artificial neural networks can be used as a tool for supporting the decision on stock market investments for a specific period of consideration. Therefore, the further part of the publication is dedicated to discuss it. The purpose of this article is to propose a support tool to the decision to invest in the selected stock exchange on the emerging markets on the example of the Stock Exchange in Warsaw. Artificial neural networks are many times used in economic research, but for a specific purpose, which is a choosing the best investment period in shares listed on the stock market, applying this tool has not been met by the authors yet.

It should be added that in the article we used a set of empirical data and artificial neural networks as a modeling tool. Experiments were performed using quarterly data because too short investment period with a given currency may be too less effective due to transaction costs.

GENERAL PRESENTATION OF THE STOCK EXCHANGE IN WARSAW (ON 06.30.2014)

Warsaw Stock Exchange in SA (abbreviated WSE) is a relatively young creation, because it was founded on 12 April 1991 and from 16 April 1991 it began to take its trading sessions. It should also be recalled that the first session of the shares recorded only five companies [gpw.pl]. The main task is to organize characterized exchange trading in financial instruments in order to ensure that the concentration in one place and time, offers buyers and sellers an adequate determination of the course and fulfillment. Currently, Polish stock market faces the challenge as the value of transactions made on it and its capitalization classify it as a small one, especially compared with the stock exchanges of countries with mature economies [Halicki 2013, pp.164-165]. Data characterizing the WSE, which are relevant from the perspective of the analysis are presented in the Table 1.

[1] Despite strong economic growth, Poland is still perceived as a country of emerging market. This is confirmed by the fact that renowned MSCI Emerging Markets Index includes more than 800 shares from 23 countries of this type, including the shares of the Poland.

Table 1. The basic data relating to the Warsaw Stock Exchange (end of June 2014)

Features of WSE	**Values of Features of WSE**
Market capitalization	EUR 148,283.44 mln
Number of listed companies	897
Number of listed bonds	481
Number of listed ETFs	3
Value of Equity Trading of the stocks in period between January - June 2014	EUR 25,743.8 mln

Source: own studies based on FESE - Federation of European Securities Exchanges, (http://www.fese.eu/en/)

ARTIFICIAL NEURAL NETWORKS IN THE CONTEXT OF DETERMINING THE DECISION TO INVEST IN THE SELECTED STOCK EXCHANGE (AN EXAMPLE OF WSE)

Artificial neural networks can be considered as a tool to assist decision-term investments on the selected stock exchange and the aim of this article is to propose a tool for determining the investment decisions for the quarterly period on the example of the Stock Exchange in Warsaw from the perspective of maximizing the return on investment in shares. The neural network is formed by a large number of elements [Tadeusiewicz 1993, p.13], called neurons, in order to process information, which can also be described as a binary element [Arbib 2003, p. 7]. Neurons are connected together in a network with specific weights that are modified in the course of the learning process. It can be divided into 3 types. The first one is defined as a "supervised" learning with a teacher [Ghosh-Dastidar, Adeli 2009, pp.1419-1431]. This method is available as a pair consisting of a learning input vector and the desired response vector. It is assumed then that we know in advance how the network will behave and is known for correct answers to some vectors of the input space. The second was called learning without the supervision [Acciani and other 2003, pp. 427-436] (unsupervised learning), that is, without a teacher, for which there is no information available (either from the teacher or critic) describing the correctness of answers provided by the network. The network still has inputs and outputs, but there is no feedback from the environment. Learning with a critic or reinforcement [Noel, Pandian 2014, pp. 444-451] (reinforcement learning) is the third kind, and does not assume the existence of a teacher, and the only critic who does not give a specific answer, but evaluates its correctness.

The use of artificial neural networks in the context of determining the decision to invest in a given period on the selected stock exchange can be seen as a method based on computer pattern recognition (called. Pattern recognition) based on neural networks. In the case of the analysis period to invest on the stock exchange, the objects are those periods. This solution also requires the assignment

of objects to specific characteristics. Ultimately, during the learning process, artificial neural networks should recognize the different situations of economic and stock market, which will provide the basis for a decision to assign them to the appropriate class. However, the application of the proposed scheme of conduct, it is necessary to determine the specific characteristics of these periods. The basic difficulty in the application of this tool lies in the fact that it is not easy to determine the team universal features that are an essential factor in the process of its use. This is evidenced by the fact that in the literature on portfolio management there can not be found a universal set of properties, that is possible to be used by each managing portfolios, giving under analysis the holding period for the selected stock exchange in the world. With this in mind, and limiting the considerations to shares, it is worth suggesting the 12 universal traits for the described periods (along with the features of countries where there is a stock exchange), which can be a learning data for artificial neural networks. A set of these data should allow to generate a 3-class decision. The first would include the period during which you should not invest in stocks (based on suggestions by the expert, the pattern in this case is "-1"), and the second - in which you should invest (the pattern is "1"). While the third would include a decision on the period in which you can continue to invest, but rather not to increase the portfolio (the pattern is "0"). This division is made on the basis of the suggestions of an expert. It is easy to show that the division of classes is due to the separate periods in order to evaluate their attractiveness from the perspective of obtaining a high return on investment in equities. At the same time we should take into account the fact that the placement of cash for short periods of time in the shares of the exchange could become unprofitable because of transaction costs and low liquidity of certain shares. The article shows only the best quarter of investing in stock market, except for the aspect of the choice of financial instrument, therefore the research does not concern individual shares. Key assumptions concerning their empirical study are as follows:

- A single period of the investment on the Warsaw Stock Exchange is 3 months and tested quarterly periods from 02 Jan. 2001 to 30 June 2014 (the number was 54). It was assumed, therefore, that the attractiveness of the period is examined from the perspective of 3 months. On the basis of the characteristics of the individual periods, their attractiveness was rated(in the form of expert's suggestions) and there was assigned the value of the standard, amounting to "-1", "0" and "1". This will allow the study of artificial neural networks to evaluate future 3-month periods based on the expected value characteristics. This means that after 3 months, you can decide to continue investing or enlarging the portfolio or sell stocks.
- The research process used "supervised" learning where after learning network based on actual data, an experiment was conducted for 20 hypothetical periods predictable and the possible values of the features, but that may be ambiguously evaluated by an expert.

- Experiments were performed using a variety of network configurations, wherein: the number of entries was always 12 and a multiple of the learning experience was constantly changed, the number of neurons in the hidden layer was between 4 and 20. Finally a network architecture comprised of the hidden layer, which consisted of the 6 neurons and the output layer (thus it was two layer feed forward neural network), wherein the transfer function in the hidden layer was sigmoid function (TANSIG), and in the output layer – linear function (PURELINE), multiple learning was 50.
- The network was trained by Back Propagation Method, according to the algorithm of L-M (Levenberg-Marquardt), and the goal of learning was to obtain the smallest value of the sum of squares of the difference between the output of the network and the value of the pattern constructed by an expert.

The precise nature of the proposed universal set of 12 features is presented in tabular form (the 6 traits relates to the stock exchanges, and the state, and other 6 features is the change in the value of the former). It should be noted that as the value of a change becomes greater, it becomes the better - except for a change in the risk index because its growth is evaluated negatively.

Table 2. Set of features quarters of investing in WSE (related to the stock segment)

Name of the features	**The indicator used to calculate the value of feature**	**Essence in relation to the returns on investment in shares**
Polish economic growth (in relation quarter to quarter) and its change in % compared to the previous quarter.	Growth of GDP	Real processes in the economy interact (sometimes with delay) with stock's price
The quarterly growth rate of the main index WIG 20 and the change in % compared to the previous quarter.	WIG20 index	The index will enable a synthetic presentation of the situation on the stock market.
Risk WIG20 quarterly and its change in % compared to the previous quarter.	The standard deviation of the rate of return index based on the last five quarterly periods.	The higher is the standard deviation, the greater is the risk.
The growth rate of the stock exchange capitalization in% - relation of quarter from the previous quarter and the change in% compared to the previous quarter .	The total value of stock market capitalization of all companies is the capitalization of the stock exchange.	The growth rate of market capitalization reflects directly the increase in prices of all shares listed on the stock exchange.
The rate of increase in the value of trading in shares-quarter relation to the same quarter of the previous year (a database	Turnover in terms of value is calculated as the product of the course and the	When the marketing of the instrument is higher than the other, we can say that the liquidity of the instrument is

Name of the features	The indicator used to calculate the value of feature	Essence in relation to the returns on investment in shares
with only the cumulative value) and its change in% compared to the previous quarter.	number of sold and purchased instruments (counted twice).	higher. As the trade in shares grows, we can expect a growing interest in the stock market, which affects the share's price.
The increase in the number of listed companies and its change compared to the previous quarter.	The increase in the number of new companies listed on the Stock Exchange during the quarter.	A growing number of companies shows a positive trend in the stock market because it reflects the expectations of issuers.

Source: own study

The presented set of features aimed to reflect generally the situation on the stock market in the period of 3 months. All the features were calculated on the basis of reputable databases OECD[2], FESE[3] and Stooq[4]. The expert's suggestion became a standard, which was used for artificial neural networks to learn. Almost all the features are expressed in "%", only the last 2 take the values of natural numbers, positive or negative. Sample time along with the actual data is presented in Table 3.

Table 3. Examples of the actual data values of 12 features in a second quarter of 2014. (that is on 06.30.2014)

Name of the features	Value of the feature	Change of feature value
Polish economic growth	1.06%	0.0%
The rate of return of the main index WIG 20	-2.18%	-4.74%
The risk of WIG20	4.48%	-1.46%
The growth rate of market capitalization of the Stock Exchange	-2.26%	-4.29%
The rate of increase in the value of trading in shares	-3.99%	-11.30%
The increase in the number of listed companies	5	8
Expert suggestion	Z (pattern value)	-1

Source: own study

[2] OECD (http://stats.oecd.org/index.aspx?queryid=350) [Accessed 29 August 2014]
[3] FESE, (http://www.fese.eu/en/)[Accessed 29 August 2014]
[4] Stooq, (http://stooq.pl/)[Accessed 29 August 2014]

USING ARTIFICIAL NEURAL NETWORKS TO DETERMINE THE QUARTERLY INVESTMENT DECISION ON THE SELECTED STOCK EXCHANGE (THE EXAMPLE OF WSE)

Implementation of empirical research required to carry out a multi-stage cycle simulation running in the MATLAB software environment. On the basis, the network has been taught using actual data. The aim was to obtain simulation results consistent with the suggestions of an expert to be able to undertake investment decisions in the future. It should be noted that in the study, there were tested variants of a neural network architecture with hidden layer neurons and receptors, where the input amount was always 12, and one neuron in the output layer. In addition, the number of epochs was set in the range (50-2000). The network generated results in the form of numbers from about -1 to 1. As it is known, the initialization of the neural network implemented by a random selection of the initial weights and biases generated different starting points in the learning process, hence each learning process was associated with not identical end results. However, in the initial learning phase, the neural network did not establish the weights properly because its answers were different from the expert's indications. Therefore, there was proposed an innovative approach of multiple learning of artificial neural network in the way that the result of each learning (that is, the distribution of weights and biases - input threshold) was the beginning of the next learning. The number of these repetitions (iterations) were matched experimentally and the smallest number was 50, after which the distribution of weights and biases provide the correct response network. Most interesting elements of the experiments in the learning process are presented in the form of table (table number 4).

To improve the quality of the results, the outcome of the experiments is presented in a quantitative form. The values are calculated based on the arithmetic mean of the three results for the learning network. In Table 4, the "C" is the sum of the squares of the difference between the output of an artificial neural network and the value of the pattern (the recommendation of an expert). The lower is the value of "C", the result generated by the network is improved, and the ratio "D" is the number of indications (data network) which differ from the experts' not less than 0.99. The lower is the ratio "D", the better is the result of the network and „n" is the number of the examined period.

In addition, in experiments there were also used modifications of startup data, using multipliers for some input. There was used:

a – multiplier, which is multiplied by the value of two features (each of the studied period) that is growth and change in the value of the growth.

b – multiplier, which is multiplied by the value of two features (each of the studied period) that is the increase in the number of listed companies and the change in the value of the growth.

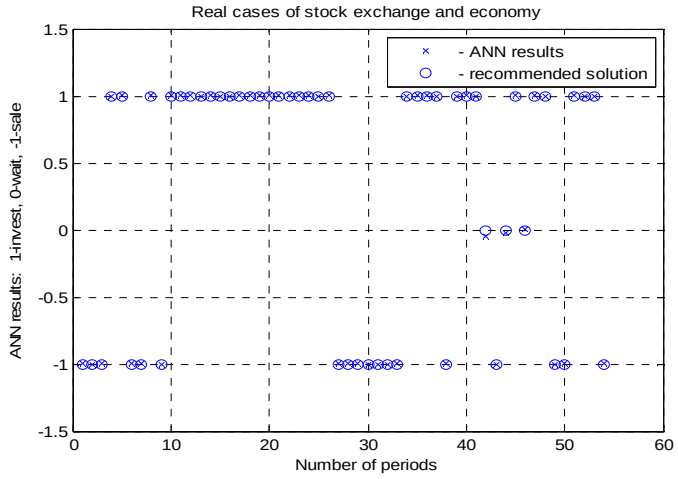
Table 4. Selected information about the experiments of the learning process.

No.	Description of the experiment	Type of data	The averaged result	Comment
1	Standard learning networks without multipliers	The real (n=54)	C=17.36 D=5	This approach does not guarantee satisfactory results generated by the network.
		The hypothetical (n=20)	C=11.59 D=4.33	
2	Multiple learning network without the use of multipliers	The real (n=54)	C=0.44 D=0	The indicated method proved to be moderately satisfactory, however, did not yet expert network tool.
		The hypothetical (n=20)	C=4.53 D=2	
3	Multiple learning network of multipliers for parameter data (a=10, b=3)	The real (n=54)	C=0.00 D=0	This method proved to be the best. In relation to the actual data, the network recognizes perfectly expert suggestions, reaching 100% efficiency (Fig. 1). For the hypothetical data results are also good.
		The hypothetical (n=20)	C=3.16 D=2.33	

Source: own study

In the summary of empirical study, a standard network training without multipliers does not always result in satisfactory end results, but multiple network learning multipliers proved to be the best method (which is presented in Figure 1, in which the OX axis is the number of the examined period, while the axis OY - Values the network results in a marked "O" and the suggestions of the expert - in the form of "X").

Figure 1. Answer of network with data multipliers based on the real values



Source: own study on the basis of the result of MATLAB

Figure 1 presents the results of simulation Option 3 in Table 2, which visually can be considered satisfactory (in all cases the position of the "O" and "X" is almost identical).

CONCLUSIONS

The aim of the publication is to present the research of artificial neural networks as an expert tool, supporting the decision to invest cash in the shares of the selected stock exchange on the basis of the knowledge obtained from the history of the quarterly observation periods. To solve the research problem, which is to determine the investment decision, it was first offered a universal set of 12 features of the economy and the stock exchanges on which the artificial neural network (implemented in MATLAB) could be subjected to the learning process. In the process of learning, the artificial neural network was configured in a variety of ways.The best results were obtained for the two layer feed forward neural network when:

- the network consists of one hidden layer composing of 6 neurons, and the output layer, where the transfer function in the hidden layer was "TANSIG", and in the output layer - "PURELINE",
- the network was trained by Back Propagation method, according to the algorithm of L-M (Levenberg-Marquardt).

Such realized net, unfortunately not always generates results similar to expert's forecasts. Therefore, further modifications were proposed in both data and learning process, and in particular the use of:

- multipliers that increase the value of the first 2 and last 2 features (in the case of WSE there were used numbers 10 and 3),
- multiple learning neural network (it equaled 50).

It should be emphasized that the effective maneuver enhancing the quality of the results was the introduction of multipliers "a" and "b" and the use of multiple learning. Finally, there were obtained satisfactory research results, whose main characteristic was that the artificial neural network obtains results consistent with expert's suggestions based on real data. On this basis, it is reasonable to conclude that the artificial neural network can be regarded as an expert system, supporting decisions for the quarterly investing period on the stock exchange. Furthermore, it appears that the proposed set of 12 features has such a universal character that the presented way to configure the network with this set of data can be useful in any chosen market. Therefore, the presented approach in this article and supplemented in other prognostic tools for the value of features in future 3 month periods can be a comprehensive expert system for portfolio management process of shares listed on various stock exchanges.

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