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ARTIFICIAL NEURAL NETWORK SUPPORTING THE PROCESS OF INVESTING ON THE FOREIGN STOCK EXCHANGES

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Abstract: The publication presents the use of artificial neural networks as a tool expert that supports the process of decision-making for the quarterly period to invest in selected stock exchanges. It proposes a set of 10 features of exchanges, which is of enough universal character that the approach presented in the publication may be useful for any chosen stock exchange. The conducted study was based on actual data.

Keywords: artificial intelligence, process of portfolio management, stock exchanges features, investments

INTRODUCTION

Globalization, mostly associated with the economic sphere, significantly affects the process of managing a portfolio of financial instruments. It follows clearly and unequivocally that this process must take into account the international diversification. It should be noted that in the globalization conditions, financial integration does not always have a positive effect on economies, as strong shock to the financial system interfere with the flow of capital [Kalemli-Ozcan et al. 2013], which in turn reduces the profitability of investments in the stock markets. As a result, investors who wish to use the international diversification of the portfolio, should take into account the fact that inadequate time to invest in foreign stock exchange, whose index at the time of the investment can increase their volatility, can be considered as a major factor influencing negatively the achieved rate of return.

All this suggests that international diversification, despite the numerous advantages presented in the literature, cannot be regarded as a part of the portfolio

management process, which in all conditions increases the return on investment. As it is widely known, the investments on foreign exchanges are also connected with the purchase of foreign currencies, however detailed analytical studies show that the currency risk is an important component of the overall investment risk [Menkhoff et al. 2012]. The purpose of this article is to present the artificial neural networks (ANN) as a tool to support international diversification of the portfolio of financial instruments during the period for a medium-term investing. Artificial neural networks in this area, according to the authors, were not yet used. It should be added that the article is based on actual data and empirical literature as well as surveys and considerations of their own.

GENERAL PRESENTATION OF THE SELECTED STOCK EXCHANGES (ON 06.30.2015)

For research purposes, we selected seven foreign stock exchanges, namely: NYSE Euronext, NASDAQ OMX, Japan Exchange Group - Tokyo, Hong Kong Exchanges Deutsche Börse, NYSE Euronext (Europe), SIX Swiss Exchange. Stock exchanges were selected for this reason that it is they who are most often subject to analyzes, published by the most reputable financial portals[1], suggesting the most interest investors in the world. It is for this reason that we carry out a study of the use of designated stock exchanges. The reason is that investors around the world tend to be interested in investing on them. While the exchanges are so large (due to the transactions made on them and their capitalization, especially in comparison with the stock exchanges of countries with developing economies) that studies based on them may become a base for such a configuration tool to support (artificial network neural), which will be useful for analyzes other than those selected exchanges, including Polish, thereby stimulating international portfolio diversification. The data characterizing the selected stock exchange, relevant to the analysis, are presented in a Table 1.

Table 1. The basic data relating to the selected stock exchanges (end of June 2014)

Stock exchange	Capitalization (USD millions)	The share of the stock market capitalization of all stock exchanges (members of WFE)
NYSE Euronext	19 237 429.6	28.03%
NASDAQ OMX	7 243 276.1	10.55%
Japan Exchange Group-Tokyo	4 944 150.2	7.2%
Hong Kong Exchanges	3 751 454.3	5.47%
Deutsche Börse	1 752 563.7	2.55%
NYSE Euronext (Europe)	3 414 827.8	4.98%
SIX Swiss Exchange	1 545 786.2	2.25%

Source: own studies based on WFE - World Federation of Exchanges , (http://www.world-exchanges.org/)

[1] That follows from the observation of the authors.

ARTIFICIAL NEURAL NETWORKS IN THE CONTEXT OF SUPPORTING THE DECISION TO INVEST IN THE SELECTED STOCK EXCHANGES

Considerations conducted in this publication were restricted to shares due to investor interest, as these financial instruments are most purchased among all listed on the stock exchanges that are members of WFE[2] [WFE 2015]. Despite the fact that carried out research, devoted to the analysis of artificial neural networks in the context of promoting investment decisions in the stock market, should take into account the fact that there are many other tools that perform this function[3], but they do not support the process of international portfolio diversification. What's more, they do not include the definition of an optimal period of investment from the perspective of medium and long term investments. Technical analysis can be included to some of them, which is a form of investor support, especially for weekly investment horizon [Menkhoff 2010]. In the long-term investment horizon, investors use more greately the fundamental analysis, also for forecasting [Lui, Mole 1998].

Another tool that allows even to determine the shares of selected assets, is to analyze the portfolio, which is largely based on the values of rates of return and risk levels measured by standard deviation. Such an assumption can be regarded as hindering the decision support. Firstly, in practice of creating portfolios, investors pay attention not only to their return and risk [Lynch 2001], which can be calculated by different methods. Secondly, the standard deviation is not a monotone measure, mainly because of that, it cannot be considered to be appropriate for risk measurement [Foster, Hart 2009]. As part of portfolio analysis there are most frequently used techniques for constructing portfolios: the Markowitz method [Markowitz 1952], the method takes into account borrowing and lending at the risk-free rate [Elton, Gruber 1995] and the method based on Lagrange function [Francis 2000]. Given that the portfolio analysis is useful for weighting of assets in the portfolio, it is a tool willingly used by institutional and individual investors. Econometric models that have not received attention, also play an important role in portfolio management, but their deep analysis is beyond the scope of the publication. As it was mentioned, these methods do not help greatly in determining optimal investment period and do not support the process of international diversification, so as a conclusion of this part of the work there comes out the necessity to present the use of artificial neural networks in these areas.

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[2] World Federation of Exchanges is an organization bringing together the most advanced exchanges in the world (http://www.world-exchanges.org/).

[3] Giving an overview of the characteristics abstracted tools to support investors in the publication of efficient market hypothesis.

The design of artificial neural networks, which are formed by neurons, as well as their ability to learn, shows conclusively the usefulness of international portfolio diversification and to determine the optimal time to invest. As you know, the main problem of investment funds is the lack of reliable information on future prices and trends of investment assets. For this reason, neural networks are used for many years for the purpose of forecasting in the financial markets [Azoff 1994]. In addition, it is also used successfully to generate a transaction strategies [Morajda Domaradzki 2005].

Returning to the substance of the discussion, it is worth noting that in this publication its purpose can also be formulated as the attempt to use artificial neural network in the context of the support of international portfolio diversification from the perspective of determining optimal investment horizon with a view to maximizing the rate of return on long-term investment in equities. Because of the possibility of determining the learning network to a type of research study defined as teaching "supervised" (Supervised) with the teacher. It is often used when configuring the network in order to make predictions [Pokharel, Deardon 2014]. All these considerations can be defined in such a way that the themes and issues of international diversification investment period is not treated separately, but as one area for the simplification of research. This approach is mainly caused by the fact that in the analysis of investment period on selected stock exchanges, the object becomes concrete exchange during the period. This allows you to assign the appropriate characteristics, because as the desired end result, the artificial neural networks should recognize different situations in stock exchange, which will provide the basis for a decision to assign them to the appropriate class. With this in mind, a set of features in the presented concept plays an important role, but literature does not specify the team. Therefore, restricting the study to the segment of shares proposed 10 universal characteristics of these exchanges given periods. Their values will generate 3 classes decisions. The first would cover the period during which you should not invest in stocks on the selected stock exchange (based on expert suggestions, the value pattern in this case is "-1"). The second class of the pattern equal to "1" would be ascribed to the period in which you should invest, while the third and final would determine a decision regarding the period during which you can continue an already made investment, but rather, without enlarging the portfolio value (value pattern is in this case " 0 "). It can also be added that the division is compiled on the basis of proposals of their own, however it comes as a result of the stems of cut-tested to assess their attractiveness from the perspective of obtaining a high return on investment in shares traded on various exchanges. The study takes into account the fact that the international short-term investments could become unviable if only because of transaction costs and the costs of buying and selling foreign currencies. For this reason, the publication was quarter as the minimum holding period on stock exchanges in shares, without analysis of concrete shares. Key assumptions concerning their empirical study are as follows:

- A single period of the investment in selected markets is 3 months, however for the network learning there have been studied quarterly periods from 07.01.2003 to 12.31.2014 (the number of periods was 46, while the size of the training set - 322 as a single period falls 7 exchanges) . It assumes also that the attractiveness of each period are examined from the perspective of 3 months. On the basis of the characteristics of each period they rated their attractiveness at the suggestion of the expert by assigning the value of the standard, which is "-1", "0" and "1". Such a concept has allowed the science of artificial neural network in order 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 shares.
- To assess the effectiveness of network learning, there was prepared a testing set for 7 stock exchanges, which included two quarterly periods from 01.02.2015 to 06.30.2015. This means that the size of this set was 14.
- In the research process there was applied the "supervised" learning and experiments were carried out using a variety of network configurations, wherein: the number of inputs always was 10 and the multiple learning has been amended (learning network was continued to a predetermined accuracy).
- The study finally adopted the following network architecture: two hidden layers (the penultimate layer composed of two neuron, the second hidden layer - with six neurons) and the output layer - one neuron. Transfer function in the hidden layer was tansig nonlinear function, and the output layer – linear.
- The network was trained by Back Propagation, according to Levenberg-Marquardt algorithm, and the purpose of learning was to obtain the smallest value of the sum of the squares of the difference between the output of the network, and the value of the pattern constructed by an expert. Multiple of learning in studies provide established network quality.

The precise nature of the proposed universal set of 10 features is presented in tabular form (whereas 5 features are related to a stock exchange, and other 5 features are the change in the value of the former). It should be added that the higher amount of change (growth), the better is the stock exchange estimated during the period.

Table 2. Set of features quarters of investing in the selected stock exchange (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
The increase in the number of listed companies and its change in % compared to the previous quarter.	The increase in the number of new companies listed on the stock exchanges during the quarter.	A growing number of companies shows a positive trend on the stock markets.
The quarterly growth rate of the index of the largest companies and its change in % compared to the previous quarter .	Indices of the largest companies in selected stock exchange (according to the assumptions WFE)	The index of the largest companies is a barometer of the economy.
The quarterly growth rate of the main index and its change in % compared to the previous quarter.	Main indexes of selected stock exchanges (according to the assumptions WFE).	The main index is a synthetic indicator of the stock market situation.
The growth rate of stock market capitalization in % - report quarterly to the previous quarter, and its change in %.	The sum of the stock market capitalization of all the companies creates the capitalization of selected exchanges.	The growth rate reflects a market capitalization directly increase the prices of all shares listed on the stock exchanges.
The rate of increase in the value of trading in shares-relational quarter to the same quarter of the previous year and its change in% compared to the previous quarter.	Turnover in terms of value obtained by multiplying the exchange rate and the number of shares bought and sold.	The growing trade in equities means increasing the liquidity of these financial instruments.

Source: own study

The presented set of features is aimed to reflect in a general way the situation on the stock market during the 3 month period. All of the features are calculated on the basis of well-known database WFE. Suggestion of expert became a standard, which had used artificial neural networks to learn. As you can see, all the features are expressed in "%". Sample time along with the actual data are presented in Table 3.

Table 3. Examples of the actual data values of 10 features in a fourth quarter of 2014. (that is on 12.31.2014) belonging to a learning set for the German Stock Exchange (Deutsche Börse)

Name of the features	Value of the feature	Change of feature value
Number of listed companies	-3.18%	-1.75%
Blue chip index performance	3.50%	7.14%
Broad stock index performance	4.14%	8.32%
Domestic market capitalization	1.30%	12.66%
Value of share trading	-0.05%	0.93%
Expert suggestion	Z (pattern value)	1

Source: own study

USING ARTIFICIAL NEURAL NETWORKS TO DETERMINE THE QUARTERLY INVESTMENT DECISION ON THE SELECTED STOCK EXCHANGES

Simulation studies were performed in MATLAB software environment for obtaining simulation results according to the suggestions of an expert. In its initial phase of research, the neural network did not receive satisfactory results (did not establish the correct weights), so they changed the learning process in such a way that the outcome of every learning became the beginning of the next. Number of repetitions is chosen experimentally, until the quality of the network was no worse than a predetermined (the results of specific experiments quantified with key elements of the study are shown in Table 4). In addition, in the experiments there were also used modifications of startup to improve the learning process, using multipliers for certain data input. There were used the following multipliers:

a – multiplier, which multiplied the value of first set of two features.

b – multiplier, which multiplied the value of second set of two features.

c – multiplier, which multiplied the value of third set of two features.

d – multiplier, which multiplied the value of fourth set of two features.

e - multiplier, which multiplied the value of fifth set of two features.

To improve the quality of the results, the outcome of the experiments is presented in a quantitative form (see Table 4).

Table 4. Selected information regarding experimentation of ANN (the values shown are calculated on the basis of the average of three learning outcomes of network)

Description of the experiment	Type of data	The averaged result	Comment
Standard lear-ning networks without multipliers	The training set (n=322)	F=1.12 G=0	Learning of network was not effective (big value of F).
	The test set (n=14)	F=9.65 G=0.33	

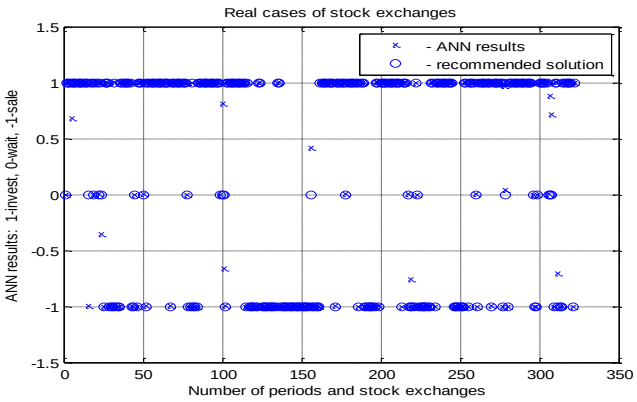
Description of the experiment	Type of data	The averaged result	Comment
Multiple learning network without the use of multipliers	The training set (n=322)	F=0.76 G=0	Network activity has become more efficient, but it cannot be considered as a tool expert.
	The test set (n=14)	F=4.52 G=0	
Multiple learn-ing network of multipliers for parameter data (a=0.9; b=1.5; c=1.8; d=0.9; e=0.25)	The training set (n=322)	F=0.58 G=0	This method proved to be the best. The network was taught, as compared to the data training set, a network of well-recogni-zed expert suggestions (Fig. 1).
	The test set (n=14)	F=4.24 G=0	

"F" is the sum of the squares of the difference between the output of ANN and the value of the pattern, "G" is the number of indications (data network) which differ from the experts' not less than 0.99, „n" is the number of the examined periods and stock exchanges.

Source: own study

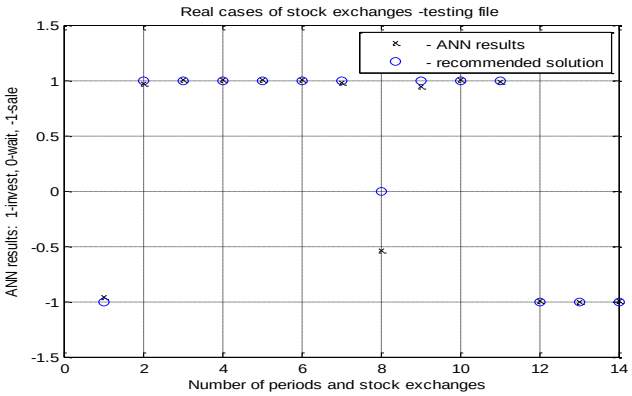
It is easy to observe that the standard learning network without the use of multipliers was not effective. Therefore a repeated learning network of multipliers chosen by trial and error, which made it possible to learn the network (this is presented in Chart 1, in which the OX axis is the number of periods studied, and the axis OY - value, whereby the network results were determined in the form of "O" and suggestions expert - in the form of an "X").

Figure 1. An example network response for multiple learning from multipliers data on actual values in the training set



Source: own preparation

Figure 2. Results of network with multipliers data on actual values in the set testing



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

Figure 1 shows the results of simulation of option 3 in Table 4 for a training set, which visually can be considered as satisfactory (in almost all cases the position "O" and "X" is almost identical). In contrast, Figure 2 shows the results of tests carried out on the basis of a set of testing, checking utility network. A network set up under option 3 made it possible to obtain satisfactory results (this is also illustrated by the position "O" and "X").

CONCLUSIONS

To solve the problem of the research, there was proposed in the first place a universal set of 10 features, based on artificial neural network which may have undergone a process of learning by analyzing data of 7 foreign stock exchanges. The learning process was most effective when:

- network composed of two hidden layers, which included 6 and two neurons, and the output layer (one neuron), the transfer function in the hidden layer was "tansig" and in the output layer - "PURELINE",
- the network was trained by Back Propagation, according to Levenberg-Marquardt algorithm,
- multipliers used the changing values of the characteristics in the same way for each of the seven exchanges,
- network was learnt until the network performance was satisfactory.

In summary, the authors obtained satisfactory results of the research, as an artificial neural network obtained results consistent with expert suggestions based on actual data training set. In this way, the network generated the correct results also for a testing set , therefore it could be considered as an expert system, supporting making decision for the quarterly period to invest in various stock exchanges. Furthermore, it appears that the proposed set of 10 features has enough

universal character that the presented way configuration of the network together with this set of data can be useful in any chosen market. Therefore, the approach outlined in this article, supplemented with modified Prognostics (artificial neural network with data multipliers), concerning the values of the characteristics in future 3 monthly periods for various stock exchanges, can provide a comprehensive expert system for portfolio management process shares, listed on various stock exchanges.

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