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DETERMINANTS OF THE INDEX OF PRICES AND QUOTATIONS ON THE MEXICAN STOCK EXCHANGE: SENSITIVITY ANALYSIS BASED ON ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

This study applies a neural network (NN) methodology to determine the relative variable impact between variables, established by financial theory, as determinants of Index of Prices and Quotations (IPC) on the Mexican Stock Exchange. A NN model is proposed because these variables have nonlinear and nonparametric behavior. NN models are most appropriate and efficient than conventional linear models in these situations. The architecture used to implement the network was Multilayer Perceptron (MLP) with a hidden layer. The following variables were used in the input layer: Index Dow Jones Industrial Average (DJIA), Consumer Price Index (CPI), International Reserves (RI), Yields on Treasury Certificates (CETES), Monetary Aggregate (M1), and Exchange Rate (TC). The algorithms applied to assess variable contribution were Connection Weights Approach and Garson's Algorithm. Then, a comparative analysis of the results of each algorithm was performed. We conclude the variable International Reserves has the greatest impact. Moreover, results allow quantifying the impact of each proposed variable on the IPC of the Mexican Stock Exchange. This study adds to research that demonstrates the efficiency of artificial neural networks for the simulation and provides a methodology to determine relative importance of financial economic variables.

JEL: E31, C45

KEYWORDS: Financial Economic Variables, Mexican Stock Exchange, Artificial Neural Network, Sensitivity Analysis

INTRODUCTION

In most cases, the relationship between financial economic variables are highly complex and display a non-linear behavior. Such is the case of variables that impact the stock market. The market works as an intermediary between debt instruments and actions, increasing the efficiency of funding because of the competition between various sources. It is a means to make long-term investments and for companies to obtain financing to carry out their investment projects. It is of interest identify the origin of variations in yield and the discount rate expected. An efficient method for modeling price indices is artificial neural networks. In this methodology the models are not parametric. This provides an advantage because the input variables should not meet normality or linearity criteria. An artificial neural network (ANN) mimics the structure and behavior of the brain to find a solution to different problems. Its objective is to find the functional relationship between input and output elements by using a set of mathematical algorithms that specify nonlinear relationships between data sets. They are usually used as tools for predicting trends, and to classify and determine the level of association between data sets. (Haykin, S., 1999).

Several studies indicate that neural networks fail to adequately simulate fluctuations in the levels of stock prices over time. But still, one needs further research to know to what extent each of the variables impact performance of the Index of Prices and Quotations. This study presents an evaluation of two methods of sensitivity analysis, Connection Weights Approach and Garson's Algorithm, applied to variables determining the Index of Prices and Quotations of the Mexican Stock Exchange. These synaptic weights are obtained as output of from an artificial neural network. Comparison of association rates obtained with each of these methods is performed. The remainder of the paper proceeds as follows. In the literature review section, we present the related literature about neural networks applied on financial Economic variables and studies to try to determine factors that affect the behavior of the Index of Prices and Quotations on the Mexican Stock Exchange. The data and methodology section describes the data and defines the variables. It also describe the algorithms used to get the results. In results and discussion section, we show the sensitivity analysis and discussions. The paper closes with some concluding comments.

LITERATURE REVIEW

This section summarizes the main findings of studies that try to determine factors affecting behavior of the Index of Prices and Quotations on the Mexican Stock Exchange. We describe variables used in studies that use artificial neural networks in financial economics. We also refer to studies that try to prove the superiority of artificial neural networks over other methods of modeling. These are the main studies that have been completed in Mexico. Arellano (1993), using the cointegration technique developed by Engle and Granger, found that movements of the DJIA have a direct impact on the Index of Prices and Quotations. For this reason he concludes that influence of US stock market movements have on the Mexican Stock is of great importance. Ibarrarán & Troncoso (1998) applied techniques on unit roots and cointegration to determine Granger causality on exchange rate and market indices. They conclude the exchange market is directly related to the stock market. Guzmán, Leyva & Cárdenas (2007) infer by an econometric evaluation, that the Index of Prices and Quotations on the Mexican Stock Exchange is directly explained by market value, exchange rate, and Yields on Treasury Certificates (CETES).

In the international sphere, the following are some of the most relevant studies. Fama and French (1989) conclude that market value and rates of interest have high explanatory power on the expected value of performance. Fernández-Serrano & Sosvilla-Rivero (2003) examines the linkages between US and Latin American stock markets using cointegration techniques and found a long-run relationship for the Dow Jones (DJ) index. Jawadi, Arouri, & Nguyen (2010) used multivariate cointegration tools to show that Argentina and Mexico's markets have a short-term financial dependence on the US Market. On the other hand, Kutty (2010) examined the relationship between stock prices and exchange rates in Mexico and used Granger causality to show that stock prices lead exchange rates in the short run, and there is no long run relationship between these two variables.

The recent increment in papers that use artificial neural networks to model financial economic variables has proven that neural networks have powerful pattern classification and prediction capabilities. Parisi & Guerrero (2003) analyzed the predictive ability of neural network models to predict changes in stock indexes. They conclude that neural network models outperform autoregressive integrated moving average (ARIMA) models. Gonzalez, de Faria & Albuquerque (2009) performed a predictive study of the principal index of the Brazilian stock market through artificial neural networks and the adaptive exponential smoothing method, respectively. The goal is to compare the forecasting performance of both methods on this market index, and in particular, to evaluate the accuracy of both methods to predict the sign of the market returns. They conclude that both methods produce similar results regarding the prediction of index returns. On the contrary, neural networks outperform the adaptive exponential smoothing method in forecasting market movements. They find relative hit rates similar those in other developed markets. Shachmurove (2010) used artificial neural networks to examine dynamic interrelations among major world stock markets, concluding that Multilayer Perceptron models with logistic activation functions were better able to foresee daily stock returns than traditional forecasting models, in terms of lower mean squared errors.

METHODOLOGY

From existing studies, the following variables were selected as inputs for the model: 1.) Index Dow Jones Industrial Average (DJIA), 2.) Consumer Price Index (CPI), 3.) International Reserves (RI), 4.) Yields on Treasury Certificates (CETES), 5.) Monetary Aggregate M1, and 6.) Exchange Rate (TC). The database was built with monthly values of variables mentioned from January 2000 to May 2015. To develop the model, nonlinear architecture known as neural network Multilayer Perceptron is used. This architecture came from the evolution of Simple Perceptron. This methodology can only classify linearly separable sets. Its main advantage is that it allows network training to be performed in hidden layers, i.e., layers that do not directly connect the inputs and the outputs.

Architectural alternatives were tested on the MATLAB platform, to find the optimum number of neurons in the hidden layer. By comparing the goodness of fit of each architecture through the correlation coefficient, we determined the most efficient architecture is one of ten neurons in the hidden layer. Therefore, the optimal architecture is, seven neurons in the input layer, one per input variable, ten neurons in the hidden layer, and one neuron in the output layer, the output variable, in this case the Index of Prices and Quotations. The network achieves minimized error within the first ten iterations, stopping its training where the validation reaches the slightest error. There are three stages in the development of neural network models: training, validation and testing. Table 1 shows the results for each stage. Results show the model has a global setting of 0.99595.

Table 1: Goodness of Fit

Stage	Goodness of fit
Training	0.99704
Validation	0.99262
Test	0.99551
Global	0.99595

This table shows the goodness of fit of each stage of the neural network model.

Garson's Algorithm

Garson proposed a method of partitioning neural network weights to determine the relative importance of each input variable in the network. This algorithm, as shown by Equation 1, calculates the relative contribution of each variable by the product of the weights obtained from the input layer to the hidden, and the weights of the hidden layer to the output (Garson, 1998). The next formulas represent calculation of variable importance for predictor variable X (where X = 1 to 7) using the weights connecting each of the input neurons Z (where Z = 1 to 7) to each of the hidden neurons Y (where Y = A to J) to the single output neuron. (Olden, Joy & Death 2004)

$$\mathrm{Input}_{\mathrm{X}} = \sum_{\mathrm{Y=A}}^{\mathrm{J}} \frac{|\mathrm{Hidden}_{\mathrm{XY}}|}{\sum_{Z=7}^{7} |Hidden_{ZY}|} \quad (1)$$

Connection Weights Approach

Garson's algorithm, as shown in Equation 2 uses absolutes values of the connection weights, so it does not provide information on the effect of input variables directly or inversely related to the output. Olden et al. (2004) presented a connection weights approach in which the actual values of input-hidden and output-hidden weights are taken. This method sums the products across all the hidden neurons (Olden & Jackson, 2002).

$$\text{Input}_X = \sum_{Y=A}^{J} \text{Hidden}_{XY} \quad (2)$$

RESULTS AND DISCUSSIONS

Values of synaptic weights are summarized in Table 2. Each weight represents the intensity of signal transfer between one neuron and another.

Table 2: Synaptic Weights

Input/Hidden	A	B	C	D	E	F	G	H	I	J
RI	2.97	-0.03	-0.46	-0.04	-0.73	0.17	-0.09	0.07	0.07	0.38
M1	-0.42	-0.10	0.47	-0.02	0.86	0.09	0.00	-0.56	0.16	0.37
DJIA	-0.59	0.08	-0.15	-0.03	0.29	-0.12	-0.07	0.11	0.43	-0.41
TC	0.89	0.15	-0.31	0.02	-0.82	0.06	0.34	-0.06	0.47	-1.07
CETES	0.38	-0.00	0.61	0.04	-0.42	0.00	-0.02	0.17	0.08	0.39
INPC	-0.71	-0.02	0.40	-0.00	-0.07	0.02	0.42	0.32	-0.02	-0.55
CPI	0.35	0.04	-0.10	-0.02	1.23	-0.23	0.10	0.08	-0.30	0.12

This table shows the synaptic weights between input layer and hidden layer.

Following the methodology described, the sensitivity analysis is presented in Table 3. According to Connection Weight Approach, the variable International Reserves has the greatest impact (36.8 %) while the Garson's Algorithm placed second with 16.5%, considering the Exchange Rate in the first place (20%). We see that both results are similar but the Connection Weight Approach has the added advantage of showing the positive or negative effect of input on output.

Table 3: Relative Importance of Inputs

Input	Garson's Algorithm		Connection Weight Approach	
	Relative Importance (%)	Ranking	Relative Importance (%)	Ranking
RI	16.5	2	36.8	1
M1	15.4	3	13.7	3
DJIA	13.1	5	-7.3	5
TC	20.0	1	-5.5	6
CETES	9.5	7	12.9	4
INPC	12.2	6	-3.5	7
CPI	13.2	4	20.3	2

This table shows the relative importance of different inputs as per Garson's Algorithm and the Connection Weight Approach.

CONCLUSION

In this paper, the relationship between main factors, according to economic theory, that act as determinants of Index of Prices and Quotations (IPC) on the Mexican Stock Exchange was analyzed. The goal was to determine the relative variable impact of each variable. We used a methodology based on artificial neural networks because they provide the best approach for this type of variables. The architecture implemented was Multilayer Perceptron with a hidden layer. We used the Garson's algorithm and the Connection Weight Approach to determine significance of each variable. But, there are other methods that can be applied. From the results of this analysis, we note that behavior of Index of Prices and Quotations is mostly determined by International Reserves. A change of one percentage point in that variable causes a variation of 36.8% in the Index of Prices and Quotation. The same relation applies to the remaining variables according to the sensitivity analysis presented in Table 3. The artificial neural network model allowed us to verify the relationship and determine the significance of each variables proposed. This study adds to research that prove the efficiency of artificial neural networks for simulation and provides a methodology that can be used to determine the relative importance of financial economic variables.

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