Modeling of the Relationship between Corporate Social Responsibility and Stock Price with Artificial Neural Network

Duraya Sukthomya
Department of Accounting,
Faculty of Business Administration
Chiang Mai University
e-mail: duraya.s@cmu.ac.th

Wimalin Laosiritaworn
Department of Industrial Engineering,
Faculty of Engineering
Chiang Mai University
e-mail: wimalin@hotmail.com

***Abstract*—Corporate social responsibility (CSR) is an important issue for organization due to the increasing attention of the firm responsibility to their stakeholders. Most of the literature in this area attempt to use statistical method to investigate the relationship of CSR to various firm performance indexes such as stock price, cost of capital, and return on asset. However, most of the works have low adjusted R square value due to the complexity of problem which leads to validity of the conclusion derived from that model. This paper presents the application of artificial neural network (ANN), one of the machine learning tools capable of modeling complex and non-linear relationship between variables. In this work, data from Thai companies listed in Market for Alternative Investment (mai) were used to train ANN. The trained ANN achieved significantly high adjusted R square value comparing with the statistical method.**

Keywords-corporate social responsibility (CSR); stock price; artificial neural network

I. INTRODUCTION

Corporate social responsibility (CSR) has been recognized as a legitimate business function because it is a foundation for the sustainable growth of the capital market in the long run. CSR gains a more significant role as investors give more weight to the CSR factor when making investment decisions and thus are inclined to invest in a company or do business with a partner that places extra concerns over environmental, social, and governance issues (ESG factors). CSR concept has been steadily promoted and received widespread interest from global investors. A number of related terminologies such as ESG index, SROI (Social ROI), SDGs (Sustainable Development Goals) are major concerns in capital market all over the world. Business scholars and practitioners agree that the way of doing business is beyond what is required for profit maximization.

This study investigates the impact of CSR practice on stock prices in order to examine that companies engage in socially responsible behaviors gain benefit from increased competitiveness and improved stock performance. The components of CSR in this study consist of Fair operating practices, Anti-corruption, Human rights, Labor practices, Consumer issues, Environmental concerns, Community involvement, and Innovations which is in line with the GRI standards [1]. This study attempts to alleviate limitations of traditional statistical method such as bias of the OLS estimator, low adjusted R square, and lacks accuracy with the application of artificial neural networks (ANN).

II. LITERATURE REVIEW

A. CSR and Stock Market Performance

Although there has been considerable research into the impact of CSR on stock market and financial performance, prior empirical results find that CSR is not systematically correlated with companies' economic fundamentals. With reference to stakeholder theory, Roberts [2] finds that only one specific CSR activity i.e., social responsibility disclosure, is significantly related to stakeholder power, strategic posture, and economic performance. The empirical model used by Roberts [2] is significant at the 0.001 level with a Chi-square statistic of 34.29 and coefficient correlation for the logistic regression (R) of 0.296. Jensen [3] introduces the concept called "enlightened value maximization" that applies stakeholder theory structure which take into account the interests of all stakeholders, however, social responsibility seems to be maximized when a firm maximizes its total market value.

Positive relationship of CSR and firm performance is also found in studies by Orlitzky, et al. [4], Bird, et al. [5]. Orlitzky, et al. conduct a meta-analysis from 52 empirical studies using Hunter and Schmidt [6] statistical aggregation techniques in order to estimate cumulating correlations across various studies. The meta- analysis shows positive relationship between corporate social performance and financial performance which tends to be bidirectional and simultaneous. Bird, et al. examine the relationship between CSR activities and equity performance of S&P500 index stocks during 1991 – 2003 using several regression models. The models Bird, et al. report include the analysis of CSR over entire 13 years period and analysis of CSR over two sub-periods. Independent CSR activities and combined scores across all CSR activities are separately investigated in each model. Bird, et al. find evidence to support positive relationship between CSR activities and stock value, however the adjusted R squares of all models are relatively low (1.13% - 9.47%).

On the contrary, there are empirical studies that find no significant relationship between CSR and stock performance, for example, Alexander and Buchholz [7] Aupperle, et al. [8].

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Evidence of a negative relationship between CSR and stock performance which implies that CSR results in negative value to a company is found in Jones, et al. [9], [10]. Cordeiro and Sarkis find significant, negative relationship between environmental proactivism and industry security analyst one-year and five-year earnings per share forecast, however, the regression models adjusted R square are relatively low (5%-7.6%). Jones, et al. [9] analyze the relationship between sustainability disclosure and two dimensions of stock market and financial performance. Systematic negative relationship between sustainability disclosure and abnormal returns is found, however, definitive conclusions of the association cannot be drawn because only few of the t-values are statistically significant (Adjusted R square 4.5% and 4.2% for the models that t-values statistically significant at the .05 level)

B. Artificial Neural Network

Artificial Neural Network is inspired by human nervous system in an attempt to construct an algorithm that is capable of learning highly complex, nonlinear and parallel data the same way human made decisions [11]. Human nervous system consists of neurons or nerve cells that receive, process and transmits information through electrical and chemical signals. In human brain, there are about a hundred billion of these cell connected together.

ANN consists of neurons, or processing element that receive, process and transmits signal in terms of numbers. These processing elements are connected together and the strength of the connection is quantified by 'weight'. By adapting a set of weights, NN can be used to learn relationships between sets of inputs and outputs. There are many types of ANN. This research applied the multi-layer neural network trained with back-propagation algorithm which is one of the most extensively adapted ANN [12].

In multi-layer neural network neurons are located in layers (Figure 1) which are input, hidden and output layer. The input layer takes data from the outside of the neural network. Hidden layer is where the actual calculation is done through weigh alteration and sent back through output layer. These neurons are connected together and the strength of the connection is quantifying by number called weight which initially, was set to small random number.

Back-propagation algorithm[13] was used to alter these weight via ANN training process. First, weight weighted sum (*Sj*) of training sample for every neurons, as in the following equation:

$$S_j = \sum_i a_i w_{ij} \tag{1}$$

where a_i is the activation level of unit *i,* and w_{ij} is the weight from unit *i* to unit *j*. Then, the logistic transfer function, $g(x) = \frac{1}{1+e^{-x}}$, where $x = S_j$, was applied to the output. Then, $g(x = S_j)$ becomes the output of unit *j*, and the same procedure repeats for all neurons.

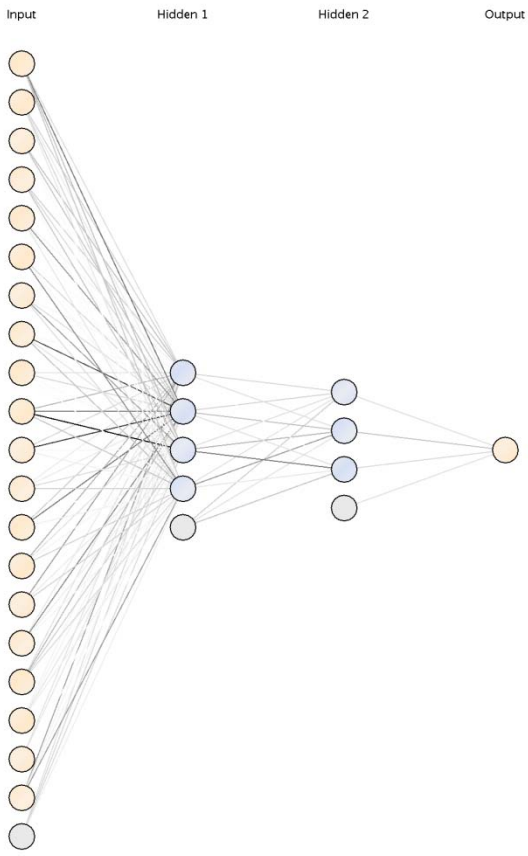


Figure 1. ANN architecture of CSR and stock price modeling

After that, the Back-Propagation performs a 'backward pass', where the error is calculated to update (adjust) the weight for each neuron for the output layer, using the following equation:

$$\delta_j = (t_j - a_j) g'(S_j) \tag{2}$$

For the hidden layer, equation 3 is used:

$$\delta_j = \left[\sum_k \delta_k w_{kj} \right] g'(S_j) \tag{3}$$

In these equations, t_j is the target value for unit *j*, a_j is the output value for unit *j*, $g'(x)$ is the derivative of the logistic function *g* and S_j is the weighted sum of inputs to *j*. Then, the weight adjustment is calculated as $\Delta w_{ji} = \eta \delta_j a_i$, where η is the learning rate. These forward and backward processes repeat with new input vectors until the stopping criteria are met.

III. RESEARCH METHOD

A. Data Collection

In this study, 183 observations from Thai companies listed in Market for Alternative Investment (mai) comprising 83 companies from 2013 and 100 companies from 2014 are used to train ANN. Companies' stock prices and financial data used are extracted from Bloomberg Data History.

TABLE I. DESCRIPTIONS OF VARIABLES

Abbreviation	Description
STO	5 days average of stock price during submission of annual registration statement to the SEC[a]
SIZ	Natural logarithm of total assets
IND	Industry types: Agro (Agro & Food); Resources; Technology; Financial; Services; Industrials; Consumer Products; Property (Property & Construction)
PRO	Net profit[a]
FAI	Fair operating practices
COR	Anti-corruption
HUM	Human rights
LAB	Labor practices
CON	Consumer issues
ENV	Environmental concerns
COM	Community involvement
INN	Innovations and sharing
CSR	Aggregated CSR
YEA	Year

a.(Unit: Thai Baht)

CSR data are obtained from the checklist conducted by Yawichai [14] which contains 44 CSR items extracted from companies' annual registration statement submitted to the security and exchange commission (SEC). Annual report and company's website are also sources of CSR information.

We hypothesize that a firm's stock price depends on level of CSR, size, industry types, and profitability. Factors affecting stock price studied in this research are shown in Table I.

B. ANN Architecture

ANN architecture refers to number of hidden layer and hidden neurons in each layer. The architecture used in this research is shown in Figure 1. There are 21 neurons the input layer, which correspond to 20 inputs in Table 2 plus one bias node. There is only one neuron in the output layer which represents stock price. Number of neurons in hidden layer were determined by training ANN with changing number of neurons in hidden layer 1 and 2 for Up to 30 neurons in each hidden layer, therefore the total of 900 ANN were trained. The network with lowest root mean square error (RMSE) was selected.

C. Data Preprocessing

The data used for ANN training has significant different in range. For example, from Table II PRO has the range between -375.7 to 255.9 while most of the other input has the range between 0 to 1. To prevent error due to higher valued variables having a greater effect than lower magnitude variables, data scaling should be done [15]. Z-transform was applied to scale data into the same range. Z-transform value of the original x value is calculated from (x-average)/(standard deviation).

TABLE II. VARIABLES USED FOR ANN MODELING

Name		Role	Type	Min	Max	Average
NAM		ID	Text	n/a	n/a	n/a
STO		Output	Real	0.4	29.75	5.582
SIZ		Input	Real	2.347	3.941	2.944
IND	Agro	Input	Binominal	0	1	n/a
	Resources	Input	Binominal	0	1	n/a
	Technology	Input	Binominal	0	1	n/a
	Finance	Input	Binominal	0	1	n/a
	Services	Input	Binominal	0	1	n/a
	Industrial	Input	Binominal	0	1	n/a
	Consumer	Input	Binominal	0	1	n/a
	Property	Input	Binominal	0	1	n/a
PRO		Input	Real	-375.7	255.9	39.1
FAI		Input	Real	0	1	0.275
COR		Input	Real	0	1	0.446
HUM		Input	Real	0	1	0.262
LAB		Input	Real	0	1	0.392
CON		Input	Real	0	1	0.367
ENV		Input	Real	0	0.86	0.314
COM		Input	Real	0	1	0.483
INN		Input	Real	0	1	0.224
CSR		Input	Real	0	0.723	0.345
YEA		Input	Binominal	0	1	n/a

D. Artificial Neural Network Training

ANN was implemented with RapidMiner software 7.0 which is a leading software platform for implementing data preparation, machine learning and predictive model deployment. ANNs were trained with 10-fold cross validation method. In 10-fold cross validation, 183 records of data used for training ANN were split into 10 subgroups. Data from 9 subgroups were used for training, leaving one subgroup out for testing. The process was repeated 10 times with different testing data from each subgroup. Then the average performance was calculated. This method provides a more accurate estimation of model performance.

IV. RESULTS AND DISCUSSION

A. Hidden Node Search Result

The result of architecture search of hidden node is shown in Figure 2 in the form of 3D plot between number of node in hidden layer1 and hidden layer 2 with root mean square error (RMSE). It was founded that adding more node only made RMSE worse (higher RMSE).

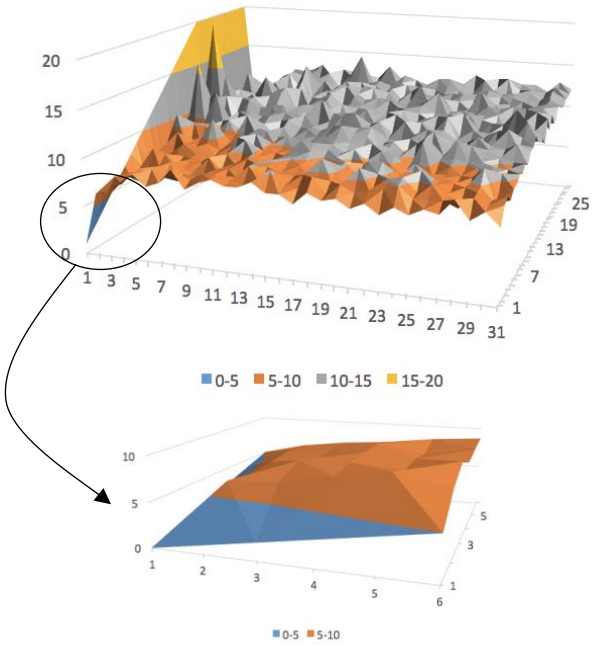
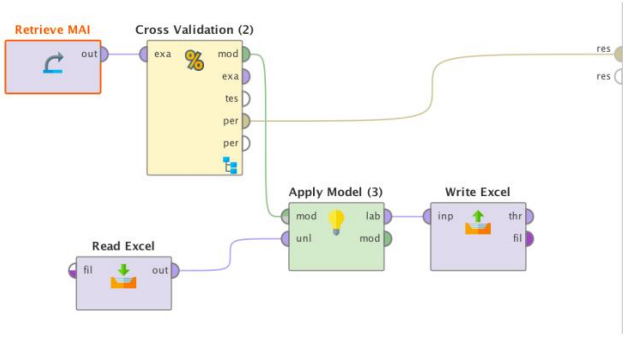


Figure 2. 3D plot of RMSE when adding up to 30 nodes in hidden layer 1 and 2

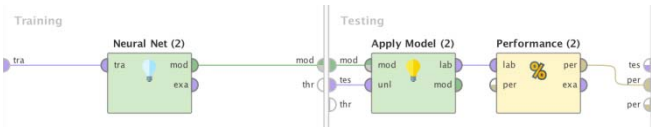
The network with lowest RMSE was the one with 4 nodes in hidden layer 1 and 3 nodes in hidden layer 2. Therefore the final network has the architecture of 20-4-3-1 where numbers represent number of node in input, first hidden, second hidden and output layer respectively.

B. *RapidMiner Process for ANN Training*

RapidMiner implements tasks through RapidMiner process. RapidMiner process is a series of operators. Each operator performs a specific task and sent out the result or output to the next operator. Figure 3 shows RapidMiner process used to implement ANN. The main process is shown in Figure 3a which start by loading excel file that contains raw data into the workflow. The file then passed to cross validation operator. Cross validation operator is a nested operator. Inside cross validation, there was a process for training and testing ANN as shown in Figure 3b starting by ANN training then applying the trained model with testing data. After cross validate training, the trained ANN was applied to predict stock price with apply model operator and the result was written in to excel file.



a) main process



b) nested process inside cross validation operator

Figure 3. RapidMiner process for ANN training

C. *Prediction from ANN*

Figure 4 is a scatter plot between actual stock price in the X-axis vs. the ANN predicted stock price in Y-axis. Ideally, to have a perfect prediction the plot should form straight line along diagonal of the graph and R^2 should be close to 1. R square of 0.5085 means that the model accounts for 50.85% of the variance.

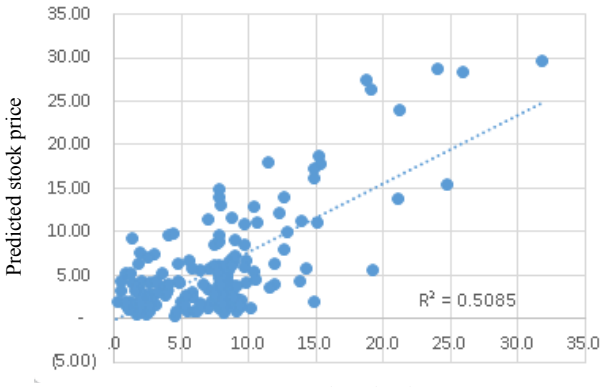


Figure 4. RapidMiner process for ANN training

Table III provides the summary of regression statistics. Even though adjusted R square of 0.5058 is considered low but in stock prediction, it is common to be expected low value of R square and adjusted R square. Most work achieved ad used R square between 0.01- 0.30. As a result, ANN has shown significantly improvement in modeling stock price in comparison with the traditional method.

TABLE III. REGRESSION STATISTICS OF THE PREDICTON FROM ANN

Regression Statistics	
Multiple R	0.71312149
R Square	0.50854225
Adjusted R Square	0.50582702
Standard Error	3.5708866
Observations	183

V. CONCLUSION

The relationship between corporate social responsibility and stock price is reexamined using improved technique. The result reveals that the artificial neural networks create higher explanatory power comparing to traditional statistical method which can only capture linear relationships. The adjusted R square of 50.58% indicates the ability of the model to predict important part in stock price. ANN model

can evaluate the interaction effect among variables. Therefore, it can help explain complex data pattern providing better prediction tool. This modeling technique can be applied as an analytical tool for company strategic setting, organizational planning, and stock analyst forecast.

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