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Corporate Governance and Equity Evaluation: Nonlinear Modeling via Neural Networks

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Abstract

This study queries the linear information dynamics (LIM) assumption of the Ohlson (1995) valuation model, for it is as if the assumption of linear information dynamics (LIM) does not exist. Prior studies used the OLS model to estimate the relationship between firm value and corporate governance but in the wrong way. This may have been due to problems with the model's specifications which led to the wrong empirical results. Thus, the purpose of this paper is to demonstrate that the artificial neural network (ANN) model is better than the OLS model. Moreover, we will examine whether a nonlinear model created by an artificial neural network (ANN) model will perform the best in predicting firm value.

The empirical results indicate that the proposed neural network model can forecast firm values more accurately and have better explanatory power than the conventional OLS model. Even after 100 epochs of iterative simulation, the neural network still outperforms the OLS model in terms of explaining the training sample, verification sample, testing sample, and the holdout sample, with the confidence levels ranging from 99%~100%. The forecasted results are also tested using differential analysis. It is discovered that the MSE is extremely low, meaning that the accuracy of the neural network model is very high. The 100-epoch simulation and sensitivity test both empirically validate the robustness of the research results. The superior forecasting capability of neural networks found in this paper can be a reference for both the regulator concerned and for investors in decision making.

Keywords: Neural network, Ohlson model, Corporate governance

1. Introduction

In the estimation of firm value, information regarding a variety of aspects should be considered. Many studies have thus been dedicated to firm valuation. The valuation model proposed by Ohlson (1995) integrates accounting information and estimates firm value on the basis of the financial statements. It is one of the most common methods adopted by researchers in the accounting area. Ohlson's valuation model (1995) is based on the concepts of book value, abnormal earnings, and net surplus. It estimates a firm's market value by taking into account the equity book value, current abnormal earnings, and other non-financial information.

Ohlson's (1995) valuation model is the first to consider accounting information in the estimation of firm value. The question then arises concerning the assumptions in the valuation model. The linear information dynamics (LIM) assumption is judged to be the most important among them. This study use corporate governance to replace the other non-financial information in the valuation model. Other studies including Hermalin and Weisbach (1988), Morck et al. (1988), Wruck (1989), McConnell and Servaes (1990), Hermalin and Weisbach (1991), Rosenstein and Wyatt (1997) and Han (2006) have discovered the nonlinear relationship between board composition, ownership structure and firm value. Thus, when we link corporate governance with Ohlson's (1995) valuation model, we must adopt a stricter mathematical design to discuss this issue. We would like to focus attention on the nonlinear relationship between corporate governance and firm value. First, this paper in referring to the concept of Ohlson's (1995) valuation model examines the board composition and ownership structure of corporate governance and replaces the other information in Ohlson's (1995) valuation model. Secondly, the research design of this paper considers the advantages of artificial neural networks which simulate any functional pattern. In sum, this study constructs Ohlson's (1995) valuation model based on the corporate governance view and the artificial neural network method.

The soft computing of computational intelligence has been applied in a huge number of financial studies in the last decade. Núñez-Letamendia (2007) listed a few of these studies, including Ju, Kim, and Shim's (1997) prediction of interest rates, the forecasting of financial crises by Varetto (1998), the foreign exchange market modeling of Neely and Weller (1999), the optimal technique transaction system of Allen and Karjalainen (1999), the prediction of market volatility by Neely and Wller (2002), and the financing decisions of Noe, Rebello, and Wang (2003). The artificial neural networks are similar to biological neural networks in that they comprise many nonlinear computing units (neurons and processing elements). Through learning, they can be used to solve complicated, non-linear, and uncertain problems. Basically, neural networks perform three major functions, including learning, recall, and generalization (Fi-John Chang and Li-Chiu Chang, 2005). Given sufficient historic data, neural networks can find patterns in data or simulate any kinds of function even without any predefined assumption. Therefore, they can overcome the deficiencies of conventional econometric methods in estimation.

Moreover, the economic consequence of corporate governance is reflected in the firm value. In previous research on the relationships between corporate governance factors and firm value, Tobin's Q or the share price were usually used as a proxy for firm value, and how to construct a firm equity valuation model was not really addressed by corporate governance. In recent years, corporate financing approaches and business items have become more diversified, making the financial structure of a firm more complicated and valuation more difficult. Since a variety of factors affecting firm value should be considered, the valuation process is usually viewed as a "Black Box". Hence, the valuation of a firm's value is a complicated process that general linear models may not be able to capture. In this paper, artificial neural networks are introduced to construct an equity valuation model. Through learning, recall, and generalization of neural networks, we attempt to extract the relationships between equity book value, current abnormal earnings, corporate governance factors and equity market value. This method is expected to correctly present the extended Ohlson's (1995) valuation model and serve as a reference for investors and the regulator concerned.

In the empirical analysis, the NN-based model, due to its advantages in modeling any kinds of function, can capture the nonlinear impact of corporate governance on firm value and can also correctly predict firm value. Besides, it also offers superior explanatory power than the conventional OLS model. Even after an 100-epoch iterative simulation, the neural network model still outperforms the conventional OLS model in the explanation of the training sample, verification sample, testing sample, and holdout sample, with the confidence levels ranging from 99%~100%. In a further comparison between the forecasted and actual firm values using differential analysis, it is found that the mean error is -0.4277 (in absolute terms), indicating that the accuracy of the neural network model is very high. The results of the 100-epoch iterative simulation and sensitivity analysis validate the robustness of the research results.

The remainder of this paper is organized as follows. Section 2 provides a review of the literature. Section 3 explains the sample selection, data sources, research model, and variable measurement. The empirical results are presented in the section 4. Finally, the conclusions, suggestions and research limitations are presented in section 5.

2. Literature Review

Ohlson (1995) introduced the method of using accounting information as the basis of equity valuation. This method was mainly based on the application of a clean surplus relation (CSR) and the condition that dividends would reduce current book value but not influence current earnings. It was assumed that in an economy individuals were risk neutral and had common beliefs. Given that the interest rate is non-random and static, a firm's market value is the present value of expected dividends (PVED). If CSR holds and the time series of abnormal earnings complies with a random process—linear information dynamics (LIM), a firm's market value is equal to its equity book value plus the present value of future expected abnormal earnings. It can also be written as a function comprising three variables, including equity book value, current abnormal earnings, and other information.

Ohlson (1995) included both financial and non-financial factors in the equity valuation model but did not elaborate on non-financial factors. As a result, many follow-up researchers have attempted to explore these factors and fill the gap. Chen et al. (2005) further extended the non-financial information in the equity valuation model. They incorporated factors not encompassed in accounting information to verify the relevance of these factors, i.e., corporate governance factors, to firm value. It was discovered that the Ohlson's equity valuation model integrated with corporate governance factors was a more complete valuation model. However, they used multiple regression analysis to estimate firm value that could have led to model specification error. We thus consider a more complex relationship between corporate governance and firm value, for a general linear estimation method can not capture it. This paper is based on the advantages of an artificial neural network that captures any function style. The empirical model in this study takes into consideration book value, abnormal earnings and corporate governance, such as board composition and ownership structure. In brief, we use an artificial neural network to simulate a nonlinear function and test for corporate governance by extending Ohlson's (1995) valuation model.

The life cycle of a firm influences firm value. Wu and Cheng (2006) pointed out that Ohlson's (1995) equity valuation model was theoretically more suitable for the valuation of firms in the maturity phase. They divided each of the life cycle factors, including the dividend payout ratio, sales growth, R&D fee, capital expenditure, and firm age, into three levels—high, mid, and low—and a score was given to each level. The life cycle phase for each sample firm was then determined by the majority of the levels it belonged to. This general classification of a firm's life cycle phase could help generate a closer equity valuation model (Ohlson's equity valuation model or real options valuation model). However, it could not capture the complicated and nonlinear pattern of the impact of the life cycle on firm value, and nor could it derive a general equity valuation model. Therefore, in considering the advantage of neural networks in that modeling can be achieved with sufficient and correct historic data even in the absence of assumptions, we make use of the learning, recall, and generalization functions of neural networks, integrating accurate data rather than fragmented data to construct a general valuation model.

In recent years, corporate governance systems have been much emphasized. A firm's financial performance is important, but its corporate governance system affects the functioning of the entire corporate body. The research on corporate governance systems focuses on two aspects: policy implementation and economic consequences. Successful implementation of a corporate governance system can not only facilitate the operations of a company but, more importantly, can enhance its economic consequences—firm value. Over the past few years, much attention has been paid to the issues related to corporate governance and firm value by academia (Gompers, Ishii, and Metrick, 2003; Bebchuk, Cohen, and Ferrel, 2005; Brown and Caylor, 2006). Corporate governance encompasses a board of directors, an ownership structure, a financial structure, property rights, law, and managerial motivation (Shun, 2002). Corporate governance mechanisms can be divided into internal and external mechanisms. The internal mechanisms stress the control of board size, board composition (the ratio of inside/outside directors), and ownership structure, all of which are focal points in this paper.

In corporate governance, board composition is also affected by several factors, including board size, CEO duality, inside directors, and outside directors. First of all, board size really influences firm value, yet a conclusion regarding such influence has not been achieved so far. Yermack (1996) and Karamanou and Vafeas (2005) discovered that a large board consists of experts from various fields, but an excessive number of board directors will drag down the efficiency of the board and also the effectiveness of corporate governance mechanisms. Dalton et al. (1999) argued that a large board is more likely to provide high-quality advice and suggestions for managers. Follow-up research also pointed out that firm value and board size are characterized by a U-shaped relationship, indicating that the optimal board size is either extremely small or extremely large (Coles, Daniel, and Naveen, 2008). Secondly, the drawback of CEO duality lies in the possibility that the board and agendas may be dominated by one person. The board chairperson taking dual positions is likely to safeguard his or her personal interests more than the interests of the company and may also fail to reasonably evaluate or supervise his performance as a CEO (Dayton, 1984). On the contrary, Tan, Chng, and Tan (2001) indicated that CEO duality brings more benefits to a firm in complicated management environments. Therefore, CEO duality has both a positive and negative impact on firm value. Lastly, outside directors play the role of supervisors. Byrd and Hickman (1991) and Bhagat et al. (1994) mentioned that a board with more outsiders than insiders will be more objective. For instance, in case of the low performance of the management, the board can quickly replace unqualified managers with less obstruction. However, Klein, Shapiro, and Young (2005) pointed out that not all factors of corporate governance affect firm value and independence of the board is not associated with firm value.

Ownership structure also involves a number of factors, including the director's shareholding, managerial shareholding, substantial shareholding, and institutional shareholding. First of all, many researchers have pointed out that insider shareholding and firm value exhibit a non-linear relationship. McConnell and Servaes (1990) discovered that insider shareholding and firm value have a parabolic relationship. Morck et al. (1988), Wruck (1989), and Hermalin and Weisbach (1991) also presented the same finding. However, Demsetz (1983) argued that the ownership structure is an endogenous outcome of a competitive selection in which various cost advantages and disadvantages are balanced to arrive at an equilibrium organization of the firm. Therefore, a firm's ownership structure is not correlated with firm profits. Secondly, based on the convergence of interests hypothesis, Kim and Lyn (1988) and Leech and Leahy (1991) proposed that the managerial shareholding is positively correlated with firm value or firm performance. Tan, Chng, and Tan (2001) mentioned that the managerial shareholding and firm value are simultaneously determined. Firm performance has positive effects on the managerial shareholding, while the managerial shareholding also has positive effects on firm value. On the contrary, the entrenchment hypothesis says that a higher managerial shareholding gives the management greater control of the company and reduces the effects of external controls on the management. It was discovered that the managerial shareholding exhibits a negative relationship with firm value (Mueller, 1986). Many researchers have also found a correlation between the managerial shareholding and firm value and indicated that relationship is possibly nonlinear (Morck et al., 1988; Wruck, 1989; McConnell and Servaes, 1990).

Thirdly, if a large-block shareholder is an outsider, driven by the incentives from external supervision, this shareholder will endeavor to monitor the managerial performance. Such external supervision can result in an improvement of firm performance (Holderness, 2003). However, according to Demsetz and Lehn (1985), the substantial shareholding is not significantly correlated with firm performance. Mínguez-Vera and Martín-Ugedo (2007) viewed ownership concentration as being endogenously determined. They applied two-stage least squares regression (2SLS) and found that ownership concentration had positive effects on firm value, but not vice versa. Lastly, institutional shareholders possess professional knowledge and supervising abilities, so they are more capable of monitoring the operations of a firm (Fama and Jensen, 1983) and of making contributions to firm value (McConnell and Servaes, 1990; Chaganti and Damanpour, 1991; Barzegar and Babu, 2008). Besides, Caspar (2007) employed the three-stage least squares approach to find that institutional shareholdings had no significant effects on firm value. In a further analysis of the result, it was found that there are two major institutional shareholders among the listed firms in Denmark and they have significantly negative effects on the performance of these firms. Only some institutional shareholders, such as banks or a small number of insurance companies, can have a positive effect on the performance of these firms.

Control deviation results from the information asymmetry between ownership and management. Since La Porta et al. (1999) proposed the concept of cash flow rights and control rights, issues associated with ultimate control, pyramid structures, and cross-shareholdings have been much emphasized. It was proposed that cash flow rights should be measured by calculating the sum of the products of all direct and indirect control rights, so that the interest conflicts of controlling shareholders could be really captured. Therefore, the method introduced by La Porta et al. (1999) and La Porta et al. (2002) is adopted to calculate the cash flow rights of controlling shareholders. Besides, according to the convergence of interests hypothesis, if the managerial shareholding is high, the interest of the management will be more consistent with that of external shareholders (Mehran, 1995). Hence, if the controlling shareholders have higher cash flow rights, there will be stronger incentives for them to accept supervision. This reveals that better corporate governance mechanisms can lead to a higher firm value (La Porta et al., 2002; Claessen et al., 2000). The agency problem occurs when there is a conflict between cash flow rights and control rights. Previous studies have indicated that the degree of control right deviation can be used to measure the quality of corporate governance mechanisms (La Porta et al., 2000; Claessen et al., 2000). The larger the deviation, the more that controlling shareholders will be motivated to erode the assets of the firm as well as the interests of external investors. In this case, the quality of corporate governance mechanisms will also be worse.

In conclusion, we find that corporate governance truly affects firm value. Although corporate governance and firm value have been an object of study for a long time, there is little agreement on the results of prior studies. That, however, is not central to this issue and the problem has to do with a more complex relationship between corporate governance and firm value. In the recent literature, the emphasis has been on using OLS, then 2SLS, and 3SLS as well as threshold regression. In brief, they all seek to study the complex relationship between corporate governance and firm value. We believe that traditional estimation does not solve the problem. Thus, we must use artificial neural networks to construct the valuation model. Artificial neural networks could eliminate the problem of model specification and wrong inference in traditional estimation, e.g., OLS.

3. Research Design

In this study, neural networks are used to construct an extended Ohlson’s (1995) equity valuation model to forecast firm value. Based on Ohlson’s (1995) model, the other information variable in the model is replaced with corporate governance factors. In considering the nonlinear relationship between corporate governance factors and firm value, we use neural networks to capture the effects of corporate governance factors on firm value and avoid the model specification error caused by using the conventional OLS method.

3.1. Data Sources and Sample Selection

The research subjects of the current study are companies listed on the stock exchange and in the OTC market during the period from 1996 to 2006. The research samples do not include the financial industry, insurance, and securities companies or other industries different than those listed in the regulations. In addition, we believe that there is a relationship between firm value and operation. Thus, we exclude abnormal companies and financial crisis companies. There are thus only normal companies in our research sample. The data source of this study is the Market Observation Post System of the Taiwan Stock Exchange Corporation (TSEC). The financial data and corporate governance information and market value of the stock are collected from the TEJ database.

The sample selection process used in the current study is as follows. First, the observations in the research sample number 12,632 companies from the TEJ database. In addition, a total of 1,897 companies are deleted which have corporate governance data omitted from the sample. In addition, the sample does not include the omitted firm value of stock for about 2,694 companies. Lastly, observations that are incomplete or insufficient are not included (about 450 companies). Based on the above selection criteria, a total of 7,591 sample companies, which include 5,372 listed companies and 2,219 OTC companies, are examined.

The final sample amounts to 7,591 observations. There are 3,549 observations belonging to electronics industry companies (about 46.75% in the full sample), and the others belong to the non-electronics industry companies (about 53.25% in the full sample). Moreover, we find the data for OTC companies is more incomplete. In addition, we discover research sample that have the similar numbers between the electronics industry companies and non-electronics industry companies. We consider industry effect; and then take the dummy variable to control the electronics industry effect in our model.

3.2. Operating Definitions of Variables

According to on Ohlson’s (1995) equity valuation model, the proposed model is designed to include firm market value in relation to equity book value, abnormal earnings, and corporate governance factors. The neural networks can be used to simulate any kinds of function, so they are much better suited to constructing the equity valuation model. Besides, the extended Ohlson (1995) valuation model using the estimation of the conventional multiple regressions is used as the benchmark model. The variables of the proposed valuation model are explained as follows:

3.2.1. Independent Variables

Based on Ohlson’s (1995) equity valuation model, firm value is measured by equity market value in this study.

3.2.2. Experiment Variables

The experimental variables are board composition and ownership structure. Board composition includes board size, CEO duality, the ratio of inside directors and the ratio of outside directors, while ownership structure includes the directors’ shareholding, managerial shareholding, substantial shareholding, and institutional shareholding. The above variables are respectively explained as follows:

Board Composition

First of all, in regard to board composition, board size (DSIZE) is measured by the number of directors on the board. CEO duality (CHAIR) is represented by a dummy variable. CHAIR=1 if the board chairman also serves as the CEO, and CHAIR=0 if not. The ratio of outside directors (OUTRATIO) is the number of outsiders (including individual outside directors, directors from outside unlisted firms, directors from outside organizations, and directors from outside listed firms) divided by the number of directors on the board.

Ownership structure

In terms of ownership structure, the directors' shareholding (STK_IDS) is the ratio of shares held by directors and supervisors minus the ratio of shares collateralized by directors and supervisors. The managerial shareholding (STK_CEO) is the ratio of shares held by the CEO to the total shares of the company. The substantial shareholding (STK_BLOCK) is the ratio of the top 10 share blocks (excluding the shares held by directors, the CEO, and institutions) to the total shares of the company. The institutional shareholding (STK_INST) is the ratio of shares held by institutions (according to the TEJ, institutional shareholders include government institutions, domestic financial institutions, domestic securities and funds, domestic corporations, domestic organizations, overseas financial institutions, overseas institutions, and overseas securities and funds) to the total shares of the company.

Considering that control right deviation is the consequence of information asymmetry between ownership and management and an important indicator of moral hazard and adverse selection, control right deviation is also included in this model as an experimental variable. The control right deviation (DEV) is defined as the control right over the cash flow right, where the control right is also called the voting right. It is the sum of the direct and indirect ownership of the ultimate controlling shareholder. Following La Porta's approach, the terminal ownership on the control chain is taken as the indirect ownership (TEJ Database). The cash flow right is the direct cash flow right of the ultimate controlling shareholder plus the sum of the product of the ownership stakes along all control chains, not including the shares of family organizations (such as funds) and shares of listed firms (TEJ Database). The cash flow right can be used to explore the effects of control right deviation on firm value.

3.2.3. Control Variables

The control variables are designed to include factors that affect firm value but are not the focus of this study in the model. These factors include firm characteristics, firm age, and years of public offering. These factors are explained as follows:

Firm Size (SIZE)

When a firm's size varies, its value will be affected (Shin and Stulz, 2000). Therefore, firm size is controlled in the model and measured by taking the logarithm of the total firm assets.

Number of Years Established (AGE)

A firm's value is also affected by its history of establishment (Shin and Stulz, 2000). Besides, Claessens et al. (1999) argued that the longer that a firm has been established, the more it will be affected by family controlled factors. Hence, it is listed in the model and measured by the period from the year of establishment to 2007.

Debt Ratio (LEV)

Jensen and Meckling (1976) mentioned that the debt ratio affects the amount of agency costs and further affects the guarantee for creditors. If a firm's capital structure is better, its value will be higher. Booth and Deli (1999) discovered that when a firm needs debt financing, it tends to employ commercial banks as a member of the board. Therefore, the debt ratio is controlled in the model and is defined as (total debt/total assets)*100.

Number of Years Listed (LISTYEAR)

The longer that a firm has been publicly listed, the longer it has been raising funds from the public, and the more dispersed the ownership will be. The ownership structure concerned with corporate governance may be affected. Thus, it is included in the model and measured by the period from the year of the IPO to 2007.

Operating Sales (SALES)

A firm's earning pattern also affects its financial structure as well as its value. It is controlled in the model and measured by net sales income for the year.

Electronics Industry (IT)
Different industries have different features and profit patterns. Profit patterns may affect a firm's value. For instance, in the high-tech industry, R&D is considered to be highly important, so a higher ratio of investment will be placed on R&D. Besides, the value added created by the intangible assets in this study is also relatively higher. Because industry type has both positive and negative effects on firm value, it should be controlled in the model. A dummy variable is thus defined for this factor. 1 indicates that the firm is from the IT industry, and 0 denotes otherwise.

3.3. Empirical Model

The economic consequence of a corporate governance system is mainly reflected by firm value. Based on Ohlson's (1995) equity valuation model, an extended model was developed by replacing the other information with corporate governance factors and incorporating other factors that affect firm value into the model as control variables. We use neural networks to construct the model and overcome the problem of model specification error. It is expected that the empirical model will be more comprehensive than Ohlson's (1995) model, and the adopted modeling method will also be superior to the conventional OLS method of the Benchmark model. The empirical model is listed as follows:

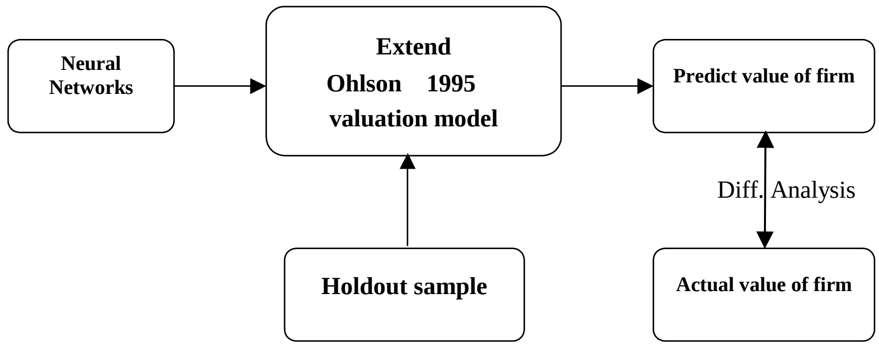
3.3.1. NN-Based Model

In this study, Artificial Neural Networks are adopted for their ability to address issues involving large amounts of numerical data, to produce good results in complicated areas, and to process continuous and categorical variables (Sung et al., 1999; Su-Ping Chen, 2002; Chao-Hui Li, 2007). Moreover, the fitness functions can also be adapted to various functions to capture nonlinear relationships and have the feature of self-learning. They do not require the pre-setting of the function type and are not applicable to the assumptions of the probability distribution (Odom and Sharda, 1990).

The concept of on Artificial Neural Network (ANN) stems from the biological neural networks. Logically, an ANN resembles a biological neural network in its components and structure. Like human neurons, an ANN is composed of numerous artificial neurons. The ANN was first introduced by McCulloch and Pitts in 1943. Among the many existing artificial neural network paradigms, the back-propagation network (BPN) is the most widely used network for several applications. A BPN is a form of a multilayer perceptron (MLP). Its general learning method is referred to as an Error Back Propagation (EBP) or BP (back propagation) algorithm. The combination of MLP and EBP is referred to as a back propagation network (BPN) (Fi-John Chang and Li-Chiu Chang, 2005).

In this study, Ohlson's (1995) equity valuation model is extended by integrating corporate governance factors and firm properties. By taking advantage of ANN, historic data may be processed through training, testing, and validation. An ANN consists of three major layers, including an input layer, hidden layer, and output layer. Through BPN, the mapping between the input layer and the output layer becomes a nonlinear optimization problem. The holdout sample is then substituted in the constructed neural network model to forecast firm value. Later, the differences between the forecasted and the actual firm values are further analyzed. The conceptual framework is shown in Fig 1.

Figure 1: The conceptual structure of this study



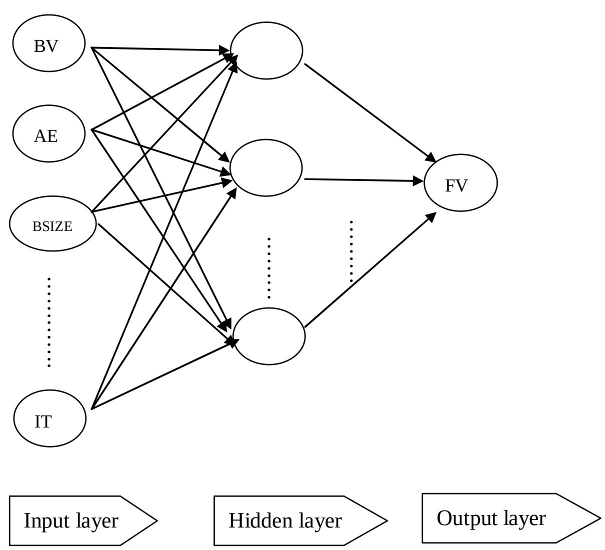
This study expend Ohlson (1995) valuation model. The empirical models, NN-based model and OLS model, are as follows.

Neural network empirical model: Extend Ohlson's (1995) valuation model, as follows:

$FV_{i,t} = f(BV_{i,t}, AE_{i,t}, BSIZE_{i,t}, CHAIR_{i,t}, OUTRATIO_{i,t}, STK\_IDS_{i,t}, STK\_CEO_{i,t}, STK\_BLOCK_{i,t}, STK\_INST_{i,t}, DEVi, t, SIZEi, t, AGEi, t, LEVi, t, LISTYEARi, t, SALESi, t, ITi, t)$ (1)

The concept of our artificial neural network is depicted in Figure 2. According to Figure 2, we can find one input layer, one hidden layer and one output layer in our model. There are sixteen units (e.g., BV, AE, BSIZE, CHAIR, OUTRATIO, STK_IDS, STK_CEO, STK_BLOCK, STK_INST, DEV and control variables) in the input layer, nine units in the hidden layer[1] and one unit (FV) in the output layer.

Figure 2: The concept of neural networks in this paper



3.3.2. Benchmark Model—OLS Model

We note that prior studies use the OLS model to estimate the extension of Ohlson's (1995) model as a benchmark model in this paper.

OLS model: Extend Ohlson's (1995) valuation model, as follows:

[1] Based on experience, unit numbers of hidden layers equal to the number of units of input layers plus the number of units of output layers, divided by 2.

$$FV_{i,t} = \alpha_0 + \alpha_1 BV_{i,t} + \alpha_2 AE_{i,t} + \alpha_3 BSIZE_{i,t} + \alpha_4 CHAIR_{i,t} + \alpha_5 OUTRATIO_{i,t} + \alpha_6 STK\_IDS_{i,t} + \alpha_7 STK\_CEO_{i,t} + \alpha_8 STK\_BLOCK_{i,t} + \alpha_9 STK\_INST_{i,t} + \alpha_{10} DEV_{i,t} + \alpha_{11} SIZE_{i,t} + \alpha_{12} AGE_{i,t} + \alpha_{13} LEV_{i,t} + \alpha_{14} LISTYEAR_{i,t} + \alpha_{15} SALES_{i,t} + \alpha_{16} IT_{i,t} + \varepsilon_{i,t}$$

Definitions of Variables:

$FV_{i,t}$		is the firm value of company i in term t, measured by market value per share.
$BV_{i,t}$		is the book value per share of company i in term t.
$AE_{i,t}$		is the abnormal earnings per share of company i in term t. It is measured by EPS minus the interest rate on three months' fixed deposits at the Bank of Taiwan multiplied by the book values per share at the beginning of the year.
$BSIZE_{i,t}$		is the total number of directors on the board of company i in term t.
$CHAIR_{i,t}$		is a dummy variable; where a 1 is given if the board chair perform of company i in term t also serves as the general manager, and 0 if otherwise.
$OUTRATIO_{i,t}$		is the ratio of outside directors divided by the number of directors on the board in term t for company i.
$STK\_IDS_{i,t}$		is the share holding of directors and supervisors in term t for company i.
$STK\_CEO_{i,t}$		is the share holding of the CEO in term t for company i.
$STK\_BLOCK_{i,}$		is the share holding of the first ten block holders in term t of company i, excluding the shareholdings of directors, supervisors, the CEO and institutional investors.
$STK\_INST_{i,t}$		is the share holding of institutional investors in term t for company i.
$DEV_{i,t}$		is the deviation level of cash flow rights and control rights in term t for company i.
$SIZE_{i,t}$		is the log for the value of total assets at the end of the fiscal accounting period for company i in term t.
$AGE_{i,t}$		is the number of years from company i establishment to 2007.
$LEV_{i,t}$		is the debt ratio in term t for company i, calculated by total liabilities divided by total assets.
$LISTYEAR_{i,t}$		is the number of years from the time when company i went public until 2007.
$SALES_{i,t}$		is the net sales revenue in term t of company i.
$IT_{i,t}$		is a dummy variable; a value of 1 is given if the industry of company i is the electronics industry and 0 if otherwise.
α_0	=	Intercept.
$\varepsilon_{i,t}$	=	Error term.

4. Empirical results

The neural networks are adopted to construct the extended Ohlson's (1995) equity valuation model. The other information variable of the original model is replaced by corporate governance factors, including board composition, ownership structure, and control right deviation. Besides, firm characteristics are also included in the model as control variables. The conventional OLS method is used as the benchmark model to confirm that the proposed neural network model features a superior degree of accuracy (i.e., MSE is lower; R^2 is higher).

The empirical results of the proposed argument[2] will be analyzed and explained. The methods to be applied include descriptive analysis, correlation coefficient analysis, the estimation of conventional quantitative methods, the estimation of the use of NN in an extended Ohlson's model (1995), and a sensitivity test.

4.1. Descriptive statistics

The descriptive statistics of all the variables are listed in Table 1. From Table 1, it can be discovered that the mean market value per share (FV) is 28.77, and the median is 18.44; the mean book value per share (BV) is 15.16, and the median is 14.16. The equity market value of the sample firm is higher than its book value. The mean of the abnormal earnings per share (AE) is 0.98, and the median is 0.69, which is a positive figure. This implies that, on average, this firm has positive excess returns.

In terms of board composition, the average number of members on the board (DSIZE) is 7, and CEO duality (CHAIR) accounts for nearly 30% (29.46%) of all samples. The mean ratio of insiders on the board (IDRATIO) is 68.58%, and the median is 66.67%. The mean ratio of outsiders on the board (OUTRATIO) is 31.42%, and the median is 33.33%. It can be discovered that, in most of the sample firms, inside directors outnumber outside ones.

In terms of ownership structure, the directors' shareholding (STK_IDS) has a mean of 12.81% and a median of 17.43%. The CEO shareholding (STK_CEO) has a mean of 1.56% and a median of 0.27%. This shows that, in general, the CEO shareholding is very low. The large block shareholding (STK_BLOCK) has a mean of 15.57% and a mean of 14.06%. The institutional shareholding (STK_INST) has a mean of 34.61% and a mean of 31.34%. This reveals that, in the sample firms, institutional shareholders hold the majority of the shares. The control right deviation (DEV) is defined as the control right over the cash flow right. The mean is 3.33 and the median is 1.06. In general, the control right is higher than the cash flow right, and the deviation is considerably high. This echoes the argument of La Porta et al. (1999).

As for the control variables, the mean of firm size (SIZE) is 6.66, with a median of 6.59. The mean firm age (AGE) is 28.93, with a median of 28 years. The mean debt ratio is 44.30%, and the median is 44.81%. The mean years of being listed (LISTYEAR) is 12.36 years, with a median of 9 years. The mean net sales (SALES) is $10,609 (thousand dollars), and the median is $2,826 (thousand dollars). Of the sample firms, 46.75% are in the electronics industry.

[2] The proposed equity valuation model, which is extended from Ohlson's model (1995), is better than the conventional quantitative methods and can also avoid incorrect inference resulting from model error.

Table 1: Descriptive statistics

Full sample（N=7,591）					
Variables[a]	**Mean**	**Std. Dev.**	**Median**	**Min**	**Max**
FV	28.7661	37.6425	18.4394	0	645.6193
BV	15.1649	6.8026	14.1600	-10.8400	219.3900
AE	0.9844	2.8114	0.6922	-18.2864	56.1073
BSIZE	7.1082	3.0236	7	0	27
CHAIR	0.2946	0.4559	0	0	1
IDRATIO	0.6858	0.2130	0.6667	0	1
OUTRATIO	0.3142	0.2130	0.3333	0	1
STK_IDS	12.8123	27.7336	17.4250	-94.7400	89
STK_CEO	1.5573	2.8448	0.2700	0	29.8600
STK_BLOCK	15.5747	11.3124	14.0600	0	74.2000
STK_INST	34.6102	21.7505	31.3400	0	100
DEV	3.3287	29.3367	1.0600	0	810.4400
SIZE	6.6622	0.5751	6.5929	5.0175	8.7970
AGE	28.9316	12.1751	28	3	63
LEV	44.3007	17.2774	44.8100	1.5500	214.0100
LISTYEAR	12.3595	9.1176	9	0	46
SALES	10,608,787	31,934,218	2,825,849	-271,204	911,773,358
IT	0.4675	0.4990	0	0	1

[a:] $\mathbf{FV}_{i\,t}$ is the firm value of company i in term t, measured by market value per share in term t of company i. $\mathbf{BV}_{i\,t}$ is the book value per share in term t of company i. $\mathbf{AE}_{i\,t}$ is the abnormal earning per share in term t of company i. $\mathbf{BSIZE}_{i\,t}$ is the total number of directors on the board of company i in term t. $\mathbf{CHAIR}_{i\,t}$ is where the chair of the board of directors of company i in term t also serves as the general manager and is given 1 and 0 otherwise. $\mathbf{OUTRATIO}_{i\,t}$ is the ratio of outside directors to the number of directors on the board in term t for company i. $\mathbf{STK\_IDS}_{i\,t}$ is the share holding of directors and supervisors in term t of company i. $\mathbf{STK\_CEO}_{i\,t}$ is the shareholdings of the CEO in term t of company i. $\mathbf{STK\_BLOCK}_{i\,t}$ is the shareholding of the first ten block holders in term t of company i, excluding the shareholding of directors, supervisors, the CEO and institutional investors. $\mathbf{STK\_INST}_{i\,t}$ is the shareholding of institutional investors in term t of company i. $\mathbf{DEV}_{i\,t}$ is the deviation level of cash flow rights and control rights in term t of company i. $\mathbf{SIZE}_{i\,t}$ is the log of the value of total assets of the end of the fiscal accounting period of company i in term t. $\mathbf{AGE}_{i\,t}$ is the number of years since company i was established to 2007. $\mathbf{LEV}_{i\,t}$ is the debt ratio in term t of company i, calculated by total liabilities divided by total assets. $\mathbf{LISTYEAR}_{i\,t}$ is the number of years from company i's publicly issued stock to 2007. $\mathbf{SALES}_{i\,t}$ is the net sales revenue in term t of company i. $\mathbf{IT}_{i\,t}$ is a dummy variable; 1 is given if the industry of company i is the electronics industry and 0 is given otherwise.

Table 2 presents the Pearson correlation coefficient for each variable. It can be discovered that most of the coefficients are below 30%[3], indicating a low level of correlation. The correlation between market value per share (FV) and abnormal earnings per share (AE) has the highest coefficient, followed by the correlation between book value per share (BV) and abnormal earnings per share (AE). This result is affected by how abnormal earnings (AE) are measured. AE is defined as (earnings per share for the year – the Bank of Taiwan's interest rate on 3-month term savings) * initial book value per share. The third highest coefficient exists in the correlation between firm age (AGE) and years of being listed (LISTYEAR). Therefore, the relatively higher levels (60~70%) of these three coefficients are reasonable. Besides, the VIF test shows that all the VIF values are below 10, indicating that the collinearity problem between our model[4] variables does not exist (Neter et al., 1990).

4.2. Empirical Analysis

[3] $r \leqq |0.3|$: low correlation; $|0.3| < r < |0.7|$: intermediate correlation; $r \geqq |.7|$: high correlation.

[4] To avoid the multicollinearity problem, we do not include inside directors in our empirical model.

4.2.1. Benchmark Model—OLS Model

In the application of the OLS method, it is assumed that the relationship between the independent variable and the dependant variables is linear. However, previous studies (Hermalin and Weisbach, 1988; Morck et al., 1988; Wruck, 1989; McConnell and Servaes, 1990; Hermalin and Weisbach, 1991; Rosenstein and Wyatt, 1997; Han, 2006) have discovered that the relationship between firm value and corporate governance may be nonlinear. Therefore, we use the conventional OLS method as a benchmark model. The estimation results are provided in Table 3.

Full sample

In Table 3, the empirical results are listed in three categories, including the full sample, the sample for the electronics industry, and the sample for the in non-electronics industries. In Panel A, the Adjusted R^2 for the full samples is 57.19%. The F-value is 618.5 (P-value=0), indicating that the fitness of the model has reached the level of significance. The empirical results also indicate that both the book value per share (BV) and abnormal earnings per share (AE) are positively correlated with firm value at the 1% level of significance. In terms of the board composition, board size (DSIZE) exhibits a negative relationship with firm value at the 10% significance level. This implies that the larger the board is, the less efficient the board will be, and the more that firm value will be negatively affected. In the full sample, CEO duality (CHAIR) and the ratio of outsiders on the board (OUTRATIO) have no significant impact on firm value.

Table 2: Pearson correlation matrix（N=7,591）[b]

Variables [a]	**FV**	**BV**	**AE**	**BSIZE**	**CHAIR**	**OUT_RATIO**	**STK_IDS**	**STK_CEO**	**STK_BLOCK**	**STK_INST**	**DEV**	**SIZE**	**AGE**	**LEV**	**LISTYEAR**	**SALES**	**IT**
FV		0.6365***	0.7104***	-0.0237**	-0.0116	0.0824***	0.1506***	0.1487***	-0.0677***	0.1509***	0.0071	0.1096***	-0.1933***	-0.1843***	-0.1417***	0.1447***	0.2492***
BV			0.6798***	0.0570***	-0.0309***	0.0540***	0.1553***	0.0927***	-0.0641***	0.2179***	0.0168	0.2942***	-0.0870***	-0.2761***	-0.0995***	0.2343***	0.1859***
AE				-0.0187*	-0.0259**	0.0989***	0.2242***	0.1286***	-0.0120	0.1832***	-0.0016	0.1096***	-0.1698***	-0.2651***	-0.2033***	0.1616***	0.1703***
BSIZE					-0.1873***	0.1461***	0.0107	-0.0542***	-0.1537***	0.1707	0.0497**	0.3206***	0.2449***	-0.0267**	0.3101***	0.1516***	-0.1729***
CHAIR						0.0478***	0.0048	0.0425***	0.0372***	-0.1322***	-0.0297***	-0.1498***	-0.0855***	-0.0124	-0.0847***	-0.0541***	0.1162***
OUTRATIO							0.1936***	0.0295**	0.0011	-0.0560***	-0.0494***	-0.2703***	-0.2831***	-0.0340***	-0.3259***	-0.1251***	0.2189***
STK_IDS								0.1399***	-0.0372***	0.1840***	0.0913***	-0.2586***	-0.2519***	-0.1924***	-0.3349***	-0.0298***	0.1478***
STK_CEO									-0.0486***	-0.1752***	0.0027	-0.1758***	-0.2360***	-0.0685***	-0.2088***	-0.0482***	0.2431***
STK_BLOCK										0.1694***	-0.0623***	-0.1306***	-0.0267**	0.0621***	-0.1131***	-0.0161	-0.0794***
STK_INST											0.1136***	0.3469***	-0.0403***	0.0163	0.0852***	0.2368***	-0.0529***
DEV												0.1104***	0.0272**	0.0462***	0.0004	0.0877***	-0.0077
SIZE													0.2989***	0.2132***	0.4501***	0.5597***	-0.1134***
AGE														0.0666***	0.6651***	0.0375***	-0.5598***
LEV															0.0566***	0.0967***	-0.0883***
LISTYEAR																0.1407***	-0.4354***
SALES																	0.0588***
IT																	

[a]: **$FV_{i\,t}$** is the firm value of company i in term t, measured by market value per share in term t of company i. **$BV_{i\,t}$** is the book value per share in term t of company i. **$AE_{i\,t}$** is the abnormal earning per share in term t of company i. **$BSIZE_{i\,t}$** is the total number of directors on the board of company i in term t. **$CHAIR_{i\,t}$** is where the chair of the board of directors of company i in term t also serves as the general manager and is given 1 and 0 otherwise. **$OUTRATIO_{i\,t}$** is the ratio of outside directors to the number of directors on the board in term t for company i. **$STK\_IDS_{i\,t}$** is the share holding of directors and supervisors in term t of company i. **$STK\_CEO_{i\,t}$** is the shareholdings of the CEO in term t of company i. **$STK\_BLOCK_{i\,t}$** is the shareholding of the first ten block holders in term t of company i, excluding the shareholding of directors, supervisors, the CEO and institutional investors. **$STK\_INST_{i\,t}$** is the shareholding of institutional investors in term t of company i. **$DEV_{i\,t}$** is the deviation level of cash flow rights and control rights in term t of company i. **$SIZE_{i\,t}$** is the log of the value of total assets of the end of the fiscal accounting period of company i in term t. **$AGE_{i\,t}$** is the number of years since company i was established to 2007. **$LEV_{i\,t}$** is the debt ratio in term t of company i, calculated by total liabilities divided by total assets. **$LISTYEAR_{i\,t}$** is the number of years from company i's publicly issued stock to 2007. **$SALES_{i\,t}$** is the net sales revenue in term t of company i. **$IT_{i\,t}$** is a dummy variable; 1 is given if the industry of company i is the electronics industry and 0 is given otherwise. [b] Right-up consists of the Pearson correlation coefficients, and left-down the Spearman correlation coefficients. *, **, *** Denote significance at the 10 percent, and 5 percent, and 1 percent levels, respectively (two-tailed).

In terms of the ownership structure, the directors' shareholding (STK_IDS) is negatively correlated with firm value at the 1% significance level. This indicates that insider shareholding has a negative relationship with firm value. The higher the insider shareholding is, the more likely it is that directors will make decisions in favor of personal interests, giving rise to a negative impact on firm value. The managerial shareholding (STK_CEO) is positively correlated with firm value at the 1% significance level. This finding supports the positive convergence of interests hypothesis and verifies that the managerial shareholding has positive effects on firm value. The substantial shareholding (STK_BLOCK) has a negative relationship with firm value at the 1% significance level. Disregarding the finding that large-block shareholders are more motivated to engage in external supervision, ownership concentration has negative effects on firm value. The institutional shareholding (STK_INST) is positively correlated with firm value at the 1% significance level. This confirms that institutional shareholders, having professional knowledge and supervising abilities, can really effectively monitor a firm's operations and increase its value.

The control right deviation (DEV) is measured by the ratio of control rights to cash flow rights. At the 5% significance level, a positive relationship between DEV and firm value is found. This is not the expected result. Theoretically, a larger control right deviation means worse corporate governance mechanisms and lower firm value. However, the findings show a significant positive relationship between DEV and firm value to exist. We further divide the sample into firms in the electronics industry and firms in the non-electronics industries. The empirical results reveal that among the firms in the electronics industry, DEV is positively correlated with firm value (at the 10% significance level), but among the firms in the other industries, DEV is negatively correlated with firm value. This negative relationship is the expected result but does not reach the significance level. Therefore, it can be inferred that in high-tech firms, ownership dispersion is a common situation, so that DEV does not have negative impact on firm value.

From the aspect of control variables, firm size (SIZE) is negatively correlated with firm value (at the 1% significance level), meaning that a large firm size will make management more challenging and impede the growth of firm value. Firm age (AGE) has a negative relationship with firm value (at the 1% significance level). This indicates that a firm with a longer history is likely to have gone through the growth and maturity phases, so its value will either be more stable or else decline. The debt ratio (LEV) is positively correlated with firm value (at the 1% significance level). Firms obtain capital through financing. If the leverage is greater, the firm value will also be higher. The number of years of being listed (LISTYEAR) has a positive relationship with firm value (at the 1% significance level). This means that the longer that a firm can remain listed, it can meet the requests of the regulator as it is more capable of sustaining its business. A firm with a long LISTYEAR has healthy financial conditions, so it is not likely to be listed as a full-cash trading stock. Thus, a longer LISTYEAR leads to higher firm value. Net sales income (SALES) is not correlated with firm value. The electronics industry (IT) has a positive relationship with firm value (at the 1% significance level). The value added created in the high-tech industry is relatively higher, so the earning pattern of this industry has positive effects on firm value.

Electronics industry sample

In Table 3 Panel B, the Adjusted R^2 of the electronics industry sample is 58.59 %. The F-value is 331.77 (P-value=0), indicating that the fitness of the model has reached the level of significance. The empirical results also indicate that both book value per share (BV) and abnormal earnings per share (AE) are positively correlated with firm value at the 1% level of significance. It is the same with the results for the full samples. In terms of board composition, board size (DSIZE) has a negative relationship with firm value at the 1% significance level. This implies that the board is larger and the more that firm value will be negatively affected. The CEO duality (CHAIR) has a negative relationship with firm value at the 10% significance level. That indicates that the CEO duality may have to do with self-interest and not with the benefit of the firm as a first priority. The ratio of outsiders on the board

(OUTRATIO) has a negative impact on firm value. However, it does not reach a significant level. This result indirectly matches the results of Coles et al. (2008).[1]

In terms of ownership structure, the directors' shareholding (STK_IDS) is no significantly correlated with firm value. The managerial shareholding (STK_CEO) is positively correlated with firm value at the 5% significance level. This finding supports the positive convergence of interest hypothesis. This result also verifies that the higher the managerial shareholding, the more the CEO focuses on the operations of the firm. The company growth strategy decided by the CEO could further enhance the firm's value. The substantial shareholding (STK_BLOCK) has a negative relationship with firm value at the 5% significance level. The results indicate that the large-block shareholders' power does not have an effect. The institutional shareholding (STK_INST) is positively correlated with firm value at the 5% significance level. This confirms that the institutional shareholders' supervising abilities can really work and produce good operating results. The control right deviation (DEV) is positively correlated with firm value at the 10% significance level. This result is the opposite of that predicted and the same as the finding for the full sample.

Table 3: The relationship between corporate governance and firm value (Development variable: FV)

Variables [a]	Predict [b] sign	Panel A：Full sample[C]		Panel B：electronics industry [C]		Panel C：non-electronics industry [C]	
		(N =7,591)		(N =3,508)		(N =4,083)	
C		28.4712 (0.0000)	***	36.7513 (0.0002)	***	28.4323 (0.0000)	***
BV	+	1.6806 (0.0002)	***	1.6348 (0.0044)	***	1.6809 (0.0000)	***
AE	+	6.9535 (0.0000)	***	8.3418 (0.0000)	***	3.2658 (0.0000)	***
BSIZE	?	-0.1653 (0.0634)	*	-0.9468 (0.0055)	***	0.0795 (0.1610)	
CHAIR	?	-0.6971 (0.1451)		-1.7715 (0.0559)	*	-0.2009 (0.3361)	
OUTRATIO	?	-0.6799 (0.3296)		-1.1349 (0.3516)		3.3389 (0.0014)	***
STK_IDS	?	-0.0425 (0.0004)	***	-0.0035 (0.4482)		-0.0156 (0.0228)	**
STK_CEO	?	0.4409 (0.0052)	***	0.4127 (0.0377)	**	0.1516 (0.0843)	*
STK_BLOCK	?	-0.1514 (0.0000)	***	-0.1588 (0.0133)	**	-0.0942 (0.0000)	***
STK_INST	?	0.0516 (0.0008)	***	0.0578 (0.0479)	**	0.0536 (0.0000)	***
DEV	-	0.0112 (0.0675)	**	0.0979 (0.0741)	*	-0.0032 (0.1311)	
SIZE	?	-5.7473 (0.0006)	***	-6.0256 (0.0248)	**	-5.5944 (0.0000)	***
AGE	?	-0.2346 (0.0000)	***	-0.4149 (0.0000)	***	-0.1372 (0.0000)	***
LEV	?	0.1279 (0.0003)	***	0.1658 (0.0009)	***	0.0747 (0.0000)	***
LISTYEAR	+	0.4652 (0.0000)	***	1.3175 (0.0000)	***	0.1936 (0.0000)	***
SALES	+	0.0000 (0.2164)		0.0000 (0.4371)		0.0000 (0.0003)	***
IT	+	7.5362 (0.0000)	***				
		Adjusted R^2	0.5719	Adjusted R^2	0.5859	Adjusted R^2	0.4786
		F value	618.50	F value	331.77	F value	238.96
		(P-Value)	(0)	(P-Value)	(0)	(P-Value)	(0)

[a:] **C:**Intercept. **$FV_{i\,t}$** is the firm value of company i in term t, measured by market value per share in term t of company i. **$BV_{i\,t}$** is the book value per share in term t of company i. **$AE_{i\,t}$** is the abnormal earning per share in term t of company i. **$BSIZE_{i\,t}$** is the total number of directors on the board of company i in term t. **$CHAIR_{i\,t}$** is where the chair of the board of directors of company i in term t also serves as the general manager and is given 1 and 0 otherwise. **$OUTRATIO_{i\,t}$** is the ratio of outside directors to the number of directors on the board in term t for company i. **$STK\_IDS_{i\,t}$** is the share holding

[1] Coles et al. (2008) discover that, in R&D firms, when the ratio of inside directors on the board is higher, Tobin's Q is also higher. This finding is consistent with insiders holding professional knowledge.

of directors and supervisors in term t of company i. $\mathbf{STK\_CEO_{i\,t}}$ is the shareholdings of the CEO in term t of company i. $\mathbf{STK\_BLOCK_{i\,t}}$ is the shareholding of the first ten block holders in term t of company i, excluding the shareholding of directors, supervisors, the CEO and institutional investors. $\mathbf{STK\_INST_{i\,t}}$ is the shareholding of institutional investors in term t of company i. $\mathbf{DEV_{i\,t}}$ is the deviation level of cash flow rights and control rights in term t of company i. $\mathbf{SIZE_{i\,t}}$ is the log of the value of total assets of the end of the fiscal accounting period of company i in term t. $\mathbf{AGE_{i\,t}}$ is the number of years since company i was established to 2007. $\mathbf{LEV_{i\,t}}$ is the debt ratio in term t of company i, calculated by total liabilities divided by total assets. $\mathbf{LISTYEAR_{i\,t}}$ is the number of years from company i's publicly issued stock to 2007. $\mathbf{SALES_{i\,t}}$ is the net sales revenue in term t of company i. $\mathbf{IT_{i\,t}}$ is a dummy variable; 1 is given if the industry of company i is the electronics industry and 0 is given otherwise.

According to control variables, firm size (SIZE) is negatively correlated with firm value (at the 5% significance level), meaning that large firm size will have a negative effect on the value of the firm. Firm age (AGE) exhibits a negative relationship with firm value (at the 1% significance level). This indicates that a firm with a longer history can hardly have more superior performance. The debt ratio (LEV) is positively correlated with firm value (at the 1% significance level). It shows how a firm's leverage effect works to enhance firm value. The number of years of being listed (LISTYEAR) has a positive relationship with firm value (at the 1% significance level). This means that a firm can remain listed for a long time; it can confirm a nice reputation of the firm and benefit the company. Net sales income (SALES) is not correlated with firm value, either.

Non-electronics industry sample

In Table 3 Panel C, the Adjusted R^2 for the non-electronics industry sample is 47.86%. The F-value is 238.96 (P-value=0), indicating the fitness of the model has matched the level of significance. The empirical results also indicate that both book value per share (BV) and abnormal earnings per share (AE) are positively correlated with firm value under the 1% level of significance. In regard to board composition, board size (DSIZE) and CEO duality (CHAIR) are not correlated with firm value. The ratio of outsiders on the board (OUTRATIO) has a positive relationship with firm value (at the 1% significance level). That indicates that outside directors in the non-electronics industry sample have monitoring abilities, objective standard, and propose suggestions based on neutrality. Thus, when the ratio of outside directors is higher, firm value is also higher; the results indirectly support the findings of Coles et al. (2008)[2].

In the ownership structure, the directors' shareholding (STK_IDS) is negatively correlated with firm value at the 5% significance level. This indicates that the inside shareholding has a negative relationship with firm value. The managerial shareholding (STK_CEO) is positively correlated with firm value at the 10% significance level. This finding supports the positive convergence of the interest hypothesis, and confirms that the managerial shareholding is higher and could reduce the moral hazard problem of the CEO. Moreover, it could enhance the value of the firm. The substantial shareholding (STK_BLOCK) exhibits a negative relationship with firm value under the 1% significance level and it is the same with the findings of Table 3 panel A & B. The institutional shareholding (STK_INST) is positively correlated with firm value at the 1% significance level, too. This indicates that institutional shareholders could really effectively monitor a firm's operations and increase its value. There is no significant relationship between control right deviation (DEV) and firm value. That means that the control right deviation (DEV) can not affect firm value significantly in the non-electronics industry sample.

From the results of the control variables, firm size (SIZE) is negatively correlated with firm value (at the 1% significance level). Firm age (AGE) exhibits a negative relationship with firm value (at the 1% significance level). The debt ratio (LEV) is positively correlated with firm value (at the 1% significance level). The number of years of being listed (LISTYEAR) is a positively related with firm value (at the 1% significance level). These findings are the same as those for the full sample and

[2] Coles et al. (2008) find the ratio of inside directors to be higher and Tobin's Q to be higher; on the other hand, the result does not apply to non-R&D firms.

electronics industry sample. Net sales income (SALES) is positively related to firm value (at the 1% significance level) but the coefficient is only 0.0000000371. That means that the revenue pattern has a positive impact on the firm value; nevertheless, its effect is very small.

4.2.2. Expanded Ohlson (1995) valuation model — The NN-based model

The data from 1996 to 2005 are used as the development sample (6,259 observations), and the data for 2006 are used as the holdout sample (1,139 observations). Validation of the proposed NN-based valuation model is conducted to compute the estimation error and explanatory power of the model and measure the accuracy of the NN-based valuation model. The conventional OLS method is also used as a benchmark model for comparative analysis purpose.

The simulation results for the neural networks are stochastic, and so the constructed model is simulated for 100 epochs to ensure the robustness of the empirical results. Besides, the constructed model is also compared with the benchmark model using the conventional OLS method. The training with the development sample (6,259 observations) is conducted 100 times and the testing of the holdout sample (1,139 observations) is also conducted 100 times to count how many times the NN-based model derives a more accurate result than the OLS-based model. Then, we use this result to compute its confidence level.

The NN-based model is developed as a BPN, and the development sample (6,259 observations) is used to construct the NN-based equity valuation model. The model is developed through training, validation, and testing. The development sample is divided into three parts, where 60% is used as the training sample (3,755 observations), 20% as the validation sample (1,252 observations), and 20% as the testing sample (1,252 observations). The learning rate is 0.01. In addition, the holdout sample (1,139 observations) is used to test the accuracy of the NN-based equity valuation model. The results are shown in Table 4.

It can be discovered that through 100 iterative simulations of the model and testing it 100 times, that the mean explanatory power of the model for the training sample, validation sample, test sample, and holdout sample (84.69%, 80.77%, 80.39%, and 87.13%) is superior to that of the OLS-based model (57.19% for the full sample, 58.59% for the IT sample, and 47.86% for the non-IT sample). Moreover, from the lowest levels of explanatory power, it can be found that the NN-based model is inferior to the OLS-based model only once, when dealing with the firms in the IT industry (58.59%). Therefore, it can be concluded that, in terms of explanatory power, the NN-based model is superior to the conventional OLS model.

Table 4: The descriptive statistics for the numerical data on 100 simulations of the neural networks models

(simulated frequency =100 times)					
Variables	**mean**	**median**	**max**	**min**	**Std. Dev.**
Training_Samples	3755	3755	3755	3755	0
Training_MSE	338.2160	336.4517	468.1254	231.4474	45.9555
Training_R^2	0.8480	0.8469	0.8993	0.7981	0.0193
Validation_Samples	1252	1252	1252	1252	0
Validation _MSE	435.7289	413.5311	977.8917	282.5101	112.1129
Validation_R^2	0.8014	0.8077	0.8581	0.6488	0.0378
Testing_Samples	1252	1252	1252	1252	0
Testing _MSE	461.4993	426.9011	2362.7900	297.3733	212.1187
Testing _R^2	0.7955	0.8039	0.8500	0.5739	0.0388
ReTesting _Samples	1139	1139	1139	1139	0
ReTesting _MSE	828.1307	743.1048	8309.8130	599.3787	760.7012
ReTesting _R^2	0.8658	0.8713	0.8889	0.6690	0.0265

[a:] **Training_Samples:** numbers of observations in training sample. **Training_MSE:** mean square error of training sample. **Training_ R^2:** explanatory power of model in training sample. **Validation_Samples:** numbers of observations in validation sample. **Validation _MSE:** mean square error of validation sample. **Validation_R^2:** explanatory power of model in validation sample. **Testing_Samples:** numbers of observations in testing sample. **Testing _MSE:** mean square error of testing sample. **Testing _R^2:** explanatory power of model in testing sample. **ReTesting _Samples:** number of observations in retesting sample of holdout sample. **ReTesting _MSE:** mean square error in retesting sample of holdout sample. **ReTesting _R^2:** explanatory power of model in retesting sample of holdout sample.

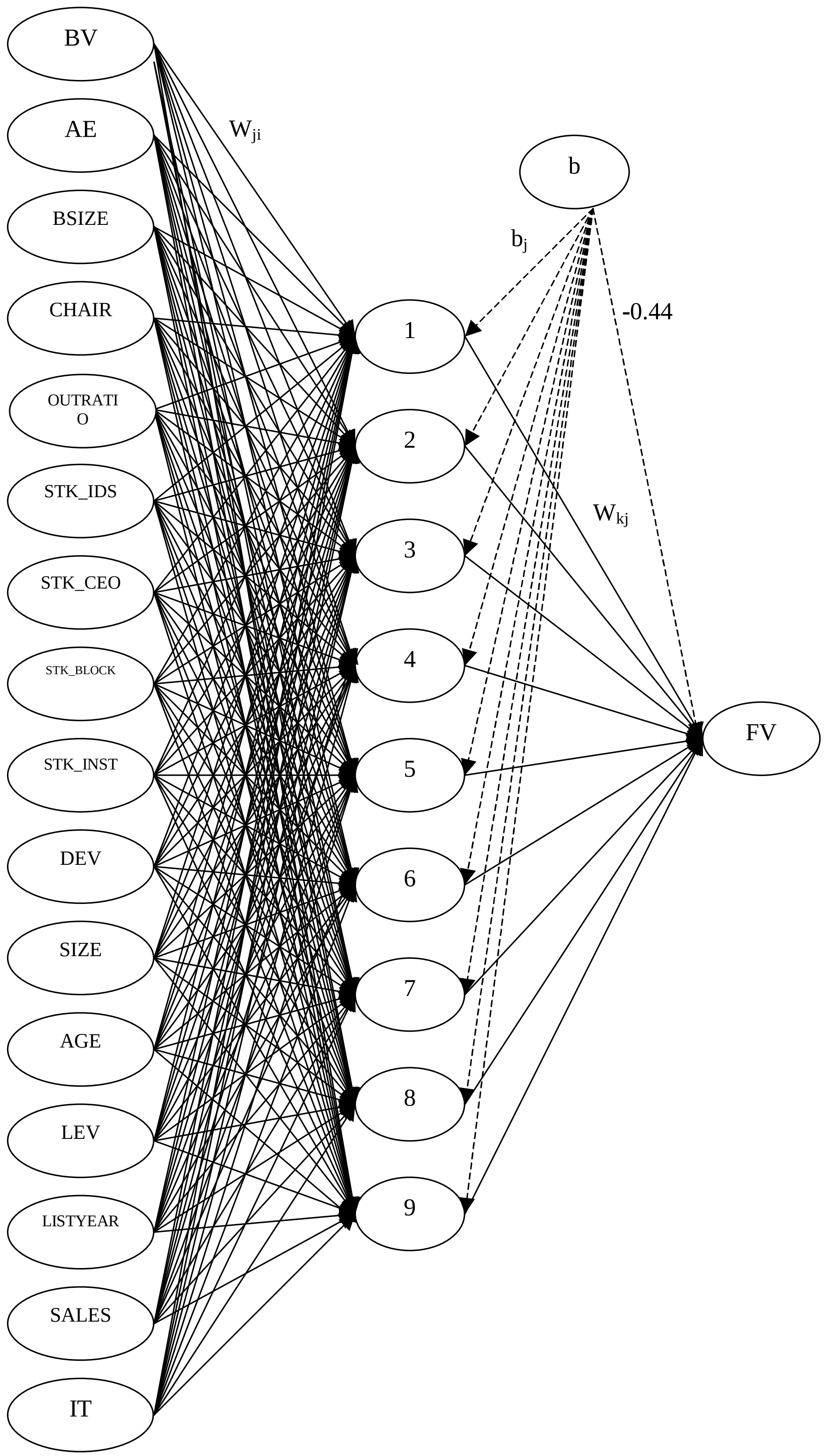
In the aspect of the confidence level, for all records in the training sample, the NN-based model has a better explanatory power than the conventional OLS model. The confidence level is 100%. For all records in the validation sample, it also outperforms the conventional OLS model, and the confidence level is 100%. For the testing sample, it outperforms the conventional OLS 99 times out of 100 times of simulation. The beat occurs when explaining the IT firms (57.39% vs. 58.59%). Thus, the confidence level is 99%. To avoid overestimation of the explanatory power, the holdout sample is employed and tested again. It is found that the NN-based model is also superior to the conventional model in the explaining of all results. The confidence level is also 100%.

From the above empirical results, we can conclude that the NN-based model is more effective and robust than the conventional OLS model. To explain the development of the NN-based model, one of the models simulating 100 epochs is selected and illustrated in Fig 3. The weights of the model are also shown in Table 5.

Table 5: The weights of the neural networks model

The weights of the hidden layers (Wji)									
Hid. Lay / Var.	1	2	3	4	5	6	7	8	9
BV	-7.89	-11.73	-9.42	-15.93	-4.57	39.58	3.42	141.48	-0.26
AE	-1.41	-11.68	-24.97	-5.63	-14.95	-16.18	2.78	-23.20	-4.60
BSIZE	0.35	0.49	2.80	-2.58	-1.41	2.87	0.34	15.20	0.60
CHAIR	0.26	0.19	2.75	4.27	-1.13	1.49	0.07	-4.18	0.05
OUTRATIO	-0.56	0.06	-0.68	-3.01	3.85	0.91	-0.06	8.80	0.23
STK_IDS	-0.56	-0.53	-0.83	-0.37	0.31	1.06	-0.38	-6.23	-0.46
STK_CEO	-0.38	-1.04	-6.31	-12.35	-7.55	0.80	-0.07	29.43	0.15
STK_BLOCK	1.05	0.30	2.57	-0.82	2.00	-0.72	0.05	-7.64	0.41
STK_INST	0.27	0.13	1.58	-3.84	-3.21	-0.84	0.72	14.94	0.31
DEV	38.41	46.20	97.76	-63.19	-73.10	92.66	3.47	-698.82	-0.12
SIZE	1.44	1.03	-1.87	-0.59	-0.29	1.04	-0.14	-27.01	-0.06
AGE	-0.04	-0.03	5.82	5.48	1.19	-0.29	-0.24	4.70	-0.38
LEV	0.02	-0.65	-21.41	-1.18	-2.48	-1.79	-0.44	12.26	0.43
LISTYEAR	3.33	-0.81	-0.80	-1.70	-0.79	-0.23	1.17	10.76	-0.32
SALES	2.53	5.43	29.54	-5.76	2.00	0.76	2.55	-0.30	-0.32
IT	-1.10	-0.01	0.90	1.49	-1.03	0.10	0.10	8.14	-0.59
The weights of the input layers (W_{kj})									
FV	-0.03	-0.05	-0.01	0.00	0.01	0.01	0.07	-0.01	-0.46
Bias vector									
b_j	33.22	39.53	95.70	-93.92	-86.48	121.19	9.57	-537.00	1.91

Figure 3: Empirical results of neural networks model in this study



Compared with the actual firm values, the forecasted firm values have a mean error of -0.4277[3]. For instance, Taiwan Cement Corporation's actual value in 1996 is 60.0362, and the forecasted value is 59.6085. It can be discovered that the forecast is very accurate. To sum up, the weights of the NN-based model can be used as the basis of forecasting a firm's value. Because NN has the advantage of simulating any kind of function, the data pattern it captures can be used to resolve the relationship between corporate governance factors and firm value. The NN-based model is a better method for accurately forecasting firm value.

4.3. Sensitivity analysis

To ensure the robustness of the empirical results, a sensitivity test is conducted as follows:

4.3.1. Change the ratio of the training sample, validation sample and testing sample

The development sample (6,259 observations) is divided into three parts, where 80% (5,007 observations) is used as the training sample, 15% (939 observations) as the validation sample, and 5% (313 observations) as the testing sample. The learning rate is 0.01. Iterative simulation is conducted 10 times. The holdout sample (1,139 observations) is also used to test the accuracy of the NN-based equity valuation model. In the sensitivity analysis, it is found that, regardless of whether the training sample, validation sample, testing sample or the holdout sample is used, the mean explanatory power of the NN-based model based on the retest sample (84.52%, 81.43%, 78.90%, and 87.62%, respectively) and the lowest explanatory power of the NN-based model (82.51%, 70.24%, 73.52%, and 84.97% respectively) are superior to those of the conventional OLS model (57.19% for the full sample, 58.59% for the IT sampls, and 47.86% for the non-IT sample). Therefore, the robustness of the empirical results is confirmed.

4.3.2.Take an average of the simulated NN-based model result

Neural networks are characterized by randomness. To validate the robustness of the empirical results, a simulation of the model for 100 epochs on the training sample, validation sample, testing sample, and holdout sample is conducted to test the explanatory power of the model. It is discovered that the confidence level[4] reaches 100%. Besides, in terms of the lowest levels of explanatory power, only the confidence level for the test sample drops to 99%. The confidence levels for the other samples, i. e., the training sample, validation sample and testing sample, also reach 100%.

5. Conclusions and suggestions

In recent years, more and more attention has been paid to the application of neural networks in the financial area based on computational intelligence. Neural networks can be used to take the place of some conventional quantitative methods which sometimes require unreasonable assumptions in their estimation. For instance, the conventional OLS method assumes that the relationship to be tested is linear. Such as assumption, when applied to the correlation between corporate governance and firm value, is questionable. Therefore, previous studies have not reached a commonly agreed conclusion regarding this correlation. Many studies have also attempted to make breakthroughs by using different methods, but their methods are still incomparable to the neural networks which can seek solutions in parallel spaces and simulate global and nonlinear functions.

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[3] To maintain brevity, only the derived results are listed, and the forecasting error of each record (stock) is not provided.

[4] Through iterative simulation of the NN-based model for 100 epochs, the number of times that it can beat the conventional OLS model is counted to calculate the confidence level. In other words, if the conventional OLS model has a better explanatory power than the NN-based model, the proposed hypothesis is rejected (α); if not, there is no evidence that can deny the proposed hypothesis that the NN-based model is superior to the conventional OLS model. Thus, confidence level=beat times/total simulation times.

In this study, a comparison with the conventional OLS method and NN-based method on the models' explanatory power is conducted to validate the research objective. It is discovered that the NN-based model is superior to the conventional OLS model, and even after 100 epochs of simulation, regardless of whether the training sample, validation sample, testing sample or the holdout sample is used, the NN-based model still outperforms its benchmark model results, with the confidence level ranging between 99% and 100%. Therefore, the robustness of the empirical results is validated. These results also explain the advantage of neural networks in simulating any kinds of function, and such capability allows us to capture the nonlinear impact of corporate governance on firm value and accurately forecast firm value. In a comparison between the forecasted firm values and the actual firm values, it is discovered that the NN-based model has a mean error of -0.4277 (in absolute terms), which is a high level of accuracy.

From the aspect of managerial implications and suggestions, the empirical results indicate that firm value should be forecasted using a nonlinear model—neural network model. With a neural network model, all it takes to forecast firm value is to input related factors into the model. The result of this study can be a reference for both the authority concerned and investors.

Despite the attempt to complete this research in a scrupulous manner, this study is subject to some limitations. First of all, neural networks are characteristic of randomness, so there will be slight difference in each simulation result. To overcome this problem, it is suggested that more simulations be conducted to take the mean level. Besides, in model development, many parameters should be set, including the learning rate, the ratio of the training sample, the ratio of the validation sample, and the ratio of the testing sample. Therefore, to derive robust results, these parameters should be changed in the sensitivity test and an empirical analysis should be performed again to validate the robustness of the results.

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