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Estimating the Capital Structure of High Tech and Traditional Corporations' Capital Structure: Artificial Neural Networks vs. Multiple Linear Regressions

Hsiaotien Pao

Tenpao Lee

Leeing Tong

ESTIMATING THE CAPITAL STRUCTURE OF HIGH TECH AND TRADITIONAL CORPORATIONS' CAPITAL STRUCTURE: ARTIFICIAL NEURAL NETWORKS VS. MULTIPLE LINEAR REGRESSIONS

Hsiao-Tien Pao

Department of Management Science, National Chiao Tung University, Hsin-Chu, Taiwan

EMAIL: htpao@cc.nctu.edu.tw

Tenpao Lee

Department of Commerce, Niagara University, New York 14109

EMAIL: tlee@niagara.edu

Lee-Ing Tong

Department of Industrial Engineering and Management, National Chiao Tung University, Hsin-Chu, Taiwan,

EMAIL: litong@cc.nctu.edu.tw

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ABSTRACT

This study adopted multiple linear regression models and artificial neural networks (ANNs) to analyze the important determinants of capital structures of the high tech and traditional corporations in Taiwan, respectively. The ten independent variables (determinants) employed herein included seven corporation feature variables and three external macro-economic variables. The following conclusions were reached:

1) From the root MSE, the ANN model achieved a better fit than the regression model.
2) The capital structure of high tech corporations does not differ significantly from that of traditional corporations, but differences do exist in the determinants of the capital structure.
3) Macro-economic variables more significantly affect the sensitivity of the capital structure of high tech corporations than traditional corporations.
4) Business risk has positive/negative impacts on capital structure of high tech/traditional corporations, respectively.
5) Six features of corporations have the same impacts on both high tech and traditional corporations, namely: firm size (+), growth opportunities (+), profitability (-), collateral value (+), non-debt tax shield (-), and dividend policy (-).

In optimizing capital structure, the following policy implications can be drawn for any company based on the results of this study:

- Larger corporations can borrow more than small corporations, and thus enjoy the benefit of greater financial leverage.
- Corporations with higher growth opportunities need to borrow more to meet their capital needs.
- Corporations with higher profitability need to borrow less to meet their capital needs.
- Corporations with higher collateral value (fixed assets) can borrow more than those with lower collateral value.
- Increased non-debt tax shield will lower the tax

benefits of financial leverage and hence reduce incentives for borrowing.

- Corporations with higher cash dividend payments generally borrow less than corporations with lower cash dividend payments.

Managers can apply the analytical results above to optimize capital structure and maximize firm value.

1. INTRODUCTION

The revolution and evolution of the new economy created non-traditional channels. Newly developed high tech corporations attracted numerous investors and were able to raise capital in the 1990s. Consequently, the capital structure of high tech corporations could differ significantly from that of traditional corporations.

Although the determinants of capital structure and the impact of capital structure on firm value have been investigated, no capital structures among industries have never been compared. Nearly all studies were based on multiple linear regression techniques, with various assumptions being made regarding residual value. For example, Bowman [1] confirmed the relevance of measuring the market value of debt in assessing leverage. Meanwhile, Chaganti and Damanpour [2] determined the relationship among institutional ownership, capital structure, and firm performance. Furthermore, Fischer, Heinkel, and Zechner [3] evaluated the dynamic capital structure choice, while Friend and Hasbrouck [4] assessed the determinants of capital structure. Additionally, Hamada [5] estimated the effect of a firm's capital structure on the systematic risk of common stocks. Also, Jensen, and Meckling [7] found a method of simultaneously determining insider ownership, debt, and dividend policy. Furthermore, Myers [9] tried to solve the capital structure puzzle. Meanwhile, Titman and Wessels [13] identified the determinants of capital structure choice. Finally, Moh'd, Perry, and Rimbey [8] employed an extensive time-series cross-sectional analysis to examine the dynamic response of capital structure to agency problems.

This study investigates the following: 1) whether if the capital structure of high tech corporations differs from that of traditional corporations; 2) whether if the determinants of the capital structure of high tech corporations differ from those of traditional corporations; 3) whether if non-linear models provide better model parameter estimates than linear models; and 4) whether if tools are available to assist managers in optimizing capital structure and maximizing firm value.

2. THE DATA

Corporations are classified into two categories herein: high tech and traditional. High tech corporations include electronics, telecommunications, computer hardware, software, networking, information systems, and other related corporations. All other corporations are classified as traditional corporations, and include such businesses as clothing, textiles, trading, agriculture, and manufacturing.

Corporations with sound financial statements are selected to create a database which included 42 corporations which are listed in the stock market in Taiwan from 1996 to 1999. There are 21 high tech corporations and 21 traditional corporations. Therefore, the database includes a total of 168 firm-year observations, one independent variables and ten dependent variables. Ten variables related to analyzing the capital structures of these corporations are compiled by the Taiwan Economic Journal. Additionally, basic statistics are obtained to describe each variable collected and T-tests were conducted to determine if the variables of high tech corporations differed from those of traditional corporations. Correlation analysis is also employed to help identify potential multicollinearity problems.

3. ANALYSIS METHODS

3.1 Multiple linear regression model

This study developed a multiple linear regression model, based on the work of previous studies (Moh'd, Perry, and Rimbey [8] , Friend and Hasbrouck [4]) , to investigate the determinants of the capital structures of high tech and traditional corporations in Taiwan, respectively. The model was specified as follows:

$$Y_{it} = a_0 + a_1 X_{1it} + a_2 X_{2it} + \ldots + a_{10} X_{10it} + \varepsilon_{it} \qquad i=1,..N; \qquad t=1,..T \qquad (1)$$

The dependent variable (Y) of the model was capital structure, measured by the debt ratio of the corporation. The model included ten independent variables to reflect various features of the corporation as well as external macro-economic factors: the seven variables describing corporation features were firm size (X_1), measured by corporation's total asset; growth opportunities (X_2), measured by revenue growth rate; profitability (X_3), measured by rate of return on total assets; asset structure (X_4) or collateral value of the company, measured by total fixed assets/total assets; non-debt tax shield (X_5), measured by total depreciation/net sales; dividend policy (X_6), measured by cash dividend/stockholders' equity; and business risk (X_7), measured by variance of firm profitability; meanwhile, the three external macro-economic variables were capital market factor (X_8), measured by rate of return of the overall stock market; money market factor (X_9), measured by annual growth rate of M2; and inflation level (X_{10}), measured by producers' price index.

3.2 Artificial Neural network models

As the dependence of the capital structure on the above ten determinants may not be linear, the artificial neural network (ANN) model, a non-parametric data-driven approach, was applied herein to calculate sensitivities of all the determinants of the model. Among the available neural network algorithms, the Back Propagation based multi-layer perception (MLP), designed by Rumelhart, Hinton and Williams [12], was selected for use herein. The ANN used herein consisted of one input layer with ten input nodes, one hidden layer with eight nodes, and one output layer with one node. MLP used the log-sigmoid transfer function $G(a)=(1+Exp(-a))^{-1}$. The architecture included nine bias nodes (one for each hidden node and one for the output node), and produced a total of 97 parameters: eight output-to-hidden-node connections ($w_{1j}(2)$), 80 hidden-to-input-node connections ($w_{jm}(1)$), and nine biases. (Adding more hidden nodes and/or layers would cause over fitting and poor forecasting performance.)

All initial values for the weights and biases were randomly generated from a uniform distribution in the range [0.1,0.5] (Weigened et al. [14]). Small values significantly slow the convergence while large values cause oscillation around a local minimum. All inputs to the ANN were linearly normalized to [-1,1] and all target outputs were linearly normalized to (0,1). The weights were trained by using the standard Back Propagation algorithm, and input and target output pairs. After normalization, the debt ratio of the corporations served as the target value for the ANN. Assume the relationship of Y and X_i is monotone, the sensitivity S_{im} of each of the outputs to each of the inputs is calculated as a partial derivative of the output with respect to the input (Hwang, Choi, Os, and Marks [6]).

$$S_{im} = \frac{\partial y_i}{\partial x_m} = y_i[1 - y_i] \sum_{j=1}^{N_h} w_{ij}(2)\, w_{jm}(1)\, a_j(1)\, [1 - a_j(1)] \qquad (2)$$

where y_i denotes the i-th output of the network and i = 1, x_m represents the m-th input to the network, m=1,…,10, $a_j\ (l)$ is the j-th element of the hidden layer of the network, N_h = number of neurons in the hidden layer, $w_{jm}(l)$ denotes the weight representing the connection to the m-th input from the j-th hidden node, $w_{ij}(2)$ denotes the weight representing the connection to the j-th hidden node from the i-th output node. The independent variable with higher sensitivity has the higher impact on capital structure.

In summary, the step-by-step process is given as follows:

1. Training a neural network on all available data.
2. These weights are used to compute the sensitivity for each input variable.

The results from applying linear regression models were then compared to those for applying ANN models.

4. EMPIRICAL RESULTS

4.1 Regression Results

Table I lists statistics describing all variables and also T-tests for the difference in variables between high tech and traditional corporations. The results in Table I indicated that 1) the capital structure (Y), firm size, and asset structure (collateral value) of the high tech corporations did not differ significantly from those of traditional corporations; but 2) significant differences did exist in the growth opportunities (higher), profitability (higher), non-debt tax shield (higher), dividend policy (lower), and business risk (higher) of the high tech corporations compared to the traditional corporations. Therefore, we can infer that although the capital structure measured by the debt ratio of the high tech corporations did not differ significantly from that of the traditional corporations, the determinants of the capital structure of the high tech corporations could differ significantly from the traditional corporations.

Table I: Descriptive statistics and results of T-tests (Phase I).

	Mean value		Std. Error		Min. value		Max. value		
Variable	HC[1]	TC[2]	HC[1]	TC[2]	HC[1]	TC[2]	HC[1]	TC[2]	T-test [3]
Y(debt %)	0.37	0.39	0.11	0.13	0.12	0.14	0.71	0.67	-1.08
X_1(size)	6.88	6.99	0.45	0.60	5.98	5.71	7.66	8.01	-1.34
X_2(growth)	0.35	0.10	0.35	0.16	-0.35	-0.23	1.28	0.80	5.95*
X_3(ROA)	0.12	0.09	0.07	0.05	-0.07	-0.01	0.35	0.23	3.20*
X_4(FA%)	0.26	0.32	0.17	0.17	0.04	0.04	0.64	0.68	-1.53
X_5(t-shield)	0.08	0.05	0.09	0.04	0.001	0.001	0.32	0.12	2.79*
X_6(dividend)	0.21	0.49	0.48	0.59	0.00	0.00	2.00	3.00	-3.37*
X_7(risk)	4.45	2.41	4.67	1.21	0.23	0.27	24.45	5.91	3.88*
X_8(market)	0.16		0.22		-0.22		0.34		
X_9(M2)	8.56		0.38		8.30		9.20		
X_{10}(PPI)	97.83		2.26		95.58		100.14		

1 High tech corporations

2 Traditional corporations

3 T for H_0: $\mu_1=\mu_2$ (High tech corporation = Traditional corporation)

* Significant at 5% level.

Table II lists the results of multiple regression model. The results indicated that: 1) no significant association existed between any of the three external macro-economic variables and the capital structure of both high tech traditional corporations; 2) the estimated variance inflation factor (VIF) coefficients of all three macro-economic variables were high, namely, VIF > 20 or R_j^2 > .95, creating a multicollineaity and thus inefficient estimates; and 3) the estimated root mean squares (RMS) were relatively high for both the high tech and the traditional corporations, as since all variables were normalized. To enhance our estimates, insignificant variables with high VIF were deleted sequentially (stepwise) and the results of the reduced models were listed in Table III. Compared with Table II, Table III had virtually the same implications, but with no statistical improvement.

4.2 ANN Results

Since the results from the linear regression models are unsatisfactory, the neural network sensitivity model is employed to further analyze the possible non-linear relationship. From the 84 firm-year observations in the high tech and traditional corporations of the database, 44 observations were randomly selected as training samples, while a further 40 observations were selected as testing samples. Adopting a back-propagation network with a {10-8-1} framework, Table Ⅲ lists the sensitivity of each independent variable to capital structure.

Clearly, the impact on capital structure of each independent variable resembles the result from regression analysis. However, the RMS values of testing samples are 0.0992 for the high tech corporations and 0.0885 for the traditional corporations, much lower than for the regression analysis. Figure 1-2 displayed the actual and predicted debt ratio (Y) of the testing samples for high tech and traditional corporations.

Table II: Results of multiple regression.

(Dependent variable: capital structure measured by debt ratio)

Independent Variable	High tech co.	VIF	Traditional co.	VIF
X_1(size)	0.4092 (0.1380)*	2.11	0.7292 (0.0800)*	1.81
X_2(growth)	0.1255 (0.1166)	1.50	0.2565 (0.0664)*	1.25
X_3(ROA)	-0.3500 (0.1253)*	1.74	-0.3220 (0.0806)*	1.84
X_4(FA%)	0.2546 (0.1606)	2.85	0.1790 (0.0865)*	2.12
X_5(t-shield)	-0.6569 (0.1877)*	3.90	-0.3323 (0.0937)*	2.49
X_6(dividend)	-0.1527 (0.1192)	1.57	-0.2404 (0.0783)*	1.74
X_7(risk)	0.3341 (0.1264)*	1.77	-0.1663 (0.0641)*	1.16
X_8(market)	-0.7520 (0.4974)	27.42**	0.1563 (0.2925)	24.26**

X_9(M2)	1.8734	147.24**	-0.4366	130.97**
	(1.1527)		(0.6796)	
X_{10}(PPI)	-1.9364	178.12**	0.5262	161.62**
	(1.2679)		(0.7549)	
Root MSE	0.8654		0.54105	
R-square	0.3322		0.7390	
F-value	3.68*		20.95*	
Sample size	84		84	

* Significant at 5% level (standard error).

** $R_j^2 > .95$ (Independent variable j is highly correlated with other independent variables) (VIF: Variance inflation factor)

Table III: Results of improved multiple regression and sensitivity from ANN.

(Dependent variable: capital structure measured by debt ratio)

Independent	High tech co.		Traditional co.	
Variable	Multi reg.	Sensitivity	Multi reg.	Sensitivity

X_1(size)	0.3453	1.552	0.7237	3.478
	(0.1323)*		(0.0789)*	
X_2(growth)	0.0943	0.467	0.2651	1.200
	(0.1118)		(0.0628)*	
X_3(ROA)	-0.2539	-0.619	-0.3293	-2.105
	(0.1151)*		(0.0790)*	
X_4(FA%)	0.2214	0.701	0.1806	1.297
	(0.1578)		(0.0852)*	
X_5(t-shield)	-0.6399	-3.319	-0.3360	-1.416
	(0.1873)*		(0.0923)*	
X_6(dividend)	-0.2203	-1.172	-0.2142	-1.396
	(0.1121)		(0.0718)*	
X_7(risk)	0.3422	1.226	-0.151	-0.776
	(0.1253)*	(0.0617)*		
X_8(market)	N/A	-1.340	N/A	0.385
X_9(M2)	N/A	1.075	N/A	-0.562
X_{10}(PPI)	N/A	0.034	N/A	-0.252

RMS	0.8693	0.5352
RMS of training samples	0.0776	0.0595
RMS of testing samples	0.0992	0.0885
R-square	0.2990	0.7343
F-value	4.692*	30.396*
Sample size	84	84

*

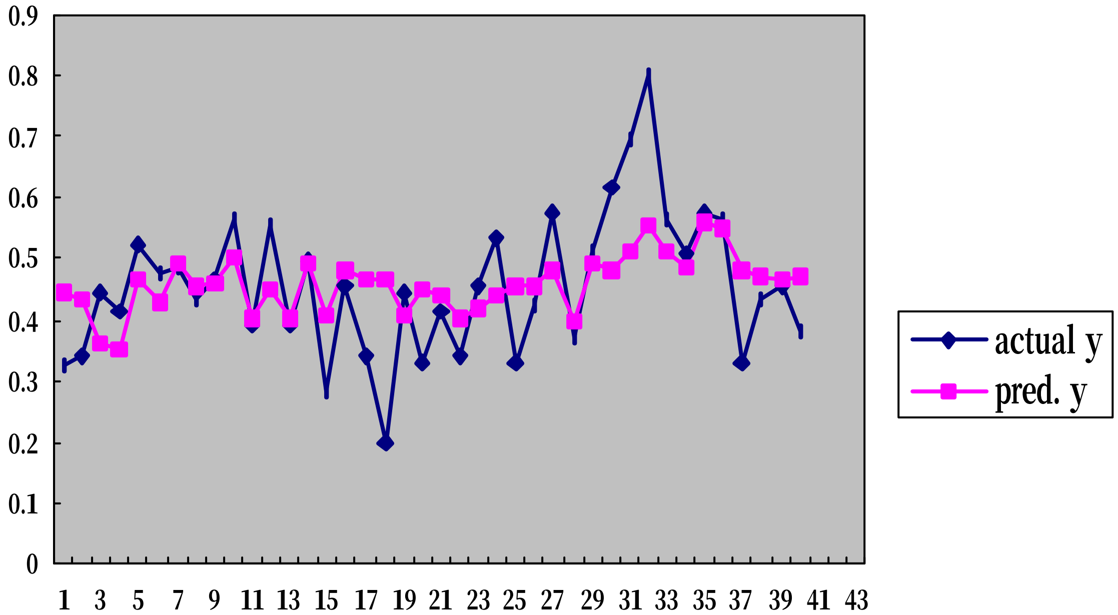

Figure 1: Testing data for high tech corporations

Significant at 5% level. N/A: independent variable was deleted stepwise.

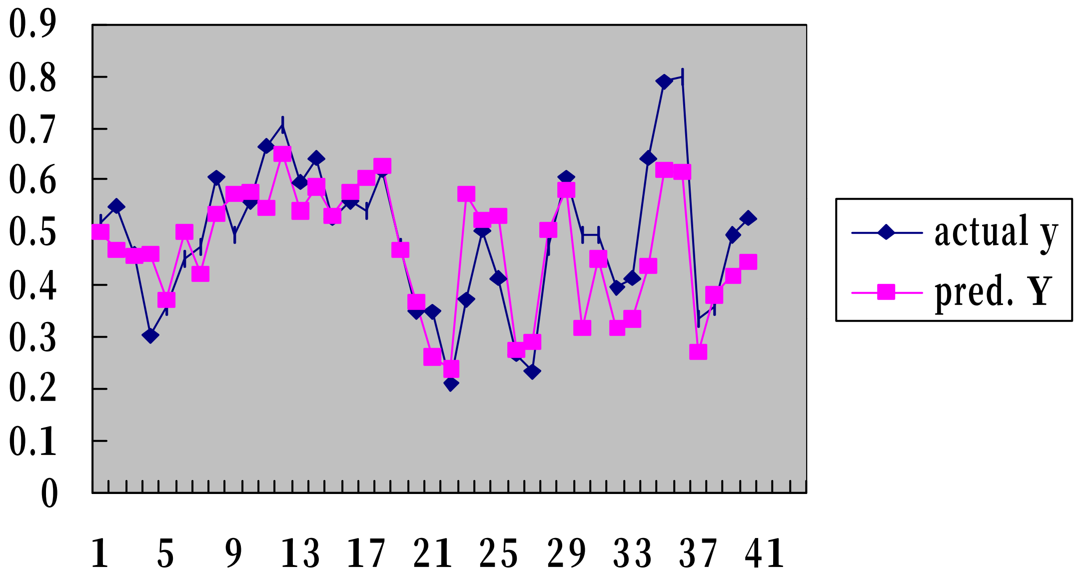

Figure 2: Testing data for traditional corporations

Based on the results of the ANN model, the determinants of capital structure were discussed as follows:

(1) Firm size (X_1) measured by corporation's total assets.

Many previous studies argued that the capital structure of a firm might be positively influenced by firm size, since larger firms had a greater ability to borrow money to realize the benefits of financial leverage. The results of this study were consistent with this presumption, and debt ratio increased with firm size for both high tech and traditional corporations.

(2) Growth opportunities (X_2) measured by revenue growth rate.

Myers [10] argued that growth opportunities had a significant and negative impact on capital structure based on the argument that firms with a greater investment in intangible assets used less debt to reduce the agency costs associated with risky debt. In contrary, this study found that growth opportunities had a positive impact on capital structure for both high tech and traditional corporations. Corporations with higher growth opportunities had a higher demand for capital to sustain their growth opportunities and borrowed more than their peers with lower growth opportunities.

(3) Profitability (X_3) measured by rate of return on total assets.

Myers [9] postulated that managers have a pecking order for meeting their financial needs in which retained earnings are the first choice, followed by debt financing, and finally equity. If true, the above would imply a negative relationship between profitability and capital structure. The results of this study were consistent with previous studies and confirmed that the profitability of both high tech and traditional corporations negatively impacted capital structure.

(4) Asset structure (X_4) (collateral value) measured by total fixed asset/total asset

Since higher collateral value enabled firms to increase their borrowings, previous studies suggested that the collateral value of firms was positively correlated with their capital structure. The results of this study were consistent with previous studies and confirmed that the collateral value of both high tech and traditional corporations had a positive impact on capital structure.

(5) Non-debt tax shield (X_5) measured by total depreciation/net sales.

Since a non-debt tax shield could reduce the benefits of financial leverage, previous studies suggested a negative relationship existed between non-debt tax shield and capital structure. The results of this study confirmed that non-debt tax shield negatively impacted capital structure for both high tech and traditional corporations.

(6) Dividend policy (X_6) measured by cash dividend/stockholders' equity.

As higher cash dividend payments reflected lower capital demand, previous studies suggested that a negative relationship should exist between cash dividend and capital structure. According to our results, a negative relationship existed between cash dividend and capital structure for both high tech and traditional corporations.

(7) Business risk (X_7) measured by variance of firm profitability.

As financial leverage accelerates firm's profitability and vice versa, a positive relationship was expected herein between capital structure and business risk, especially when business risk was measured by the variance of firm profitability. The results of this study indicated that a positive and significant relationship existed between business risk and capital structure for high tech corporations, but that the relationship was negative and insignificant for traditional corporations. Apparently, most traditional corporations with lower business risk sustain a higher financial risk, that is have a higher borrowing ability (Ross [11]).

(8) Capital market factor (X_8) was measured by the rate of return of the overall stock market.

Referring back to Myers' [9] argument, "retained earnings always represented the first choice in meeting managers' financial needs," a negative relationship would be expected between capital market factor and capital structure. The results herein confirmed that a negative and significant relationship existed between capital structure and the overall rate of return of the stock market for high tech corporations.

(9) Money market factor (X_9) measured by annual growth rate of M2.

Increased money supply (M2) implied lower interest rates and created an incentive for managers to increase their borrowing (positive relationship). The results herein confirmed that a positive relationship existed between M2 and capital structure for high tech corporations.

(10) Inflation level (X_{10}) measured by producers' price index

The impact of inflation level on the capital structure of high tech corporations was insignificant.

(11) Table III listed the sensitivities of all three macro-economic variables, revealing that they were relatively low in relation to the capital structure for traditional corporations.

5. SUMMARY AND CONCLUSION

The newly developed high tech (new economy) corporations attracted numerous investors and were able to raise capital to meet their needs without difficulty in the 1990s.

Consequently, the determinants of the capital structure of high tech corporations could differ significantly from those of traditional or old economy corporations.

This study adopted a multiple regression model and an ANN model with 10 independent variables (determinants) to estimate the capital structures for high tech and traditional corporations, respectively. From the root of MSE, the ANN model generated the best fit for the data set used herein.

The results of this analytical study found that capital structure of high tech corporations did not differ significantly from that of traditional corporations. However, the determinants of the capital structure of high tech corporations differed from those of traditional corporations:

Three macro-economic variables and business risk (X_7) had different impacts on the capital structures of high tech and traditional corporations, namely: a) macro-economic variables had a greater sensitivity impact on the capital structure of high tech corporations than on traditional corporations; and b) business risk (X_7) had a positive/negative impact on capital structure of the high tech/traditional corporations, respectively.

Six corporation determinants had the same impact on both high tech and traditional corporations, namely: firm size (+), growth opportunities (+), profitability (-), collateral value (+), non-debt tax shield (-), and dividend policy (-).

Managers can apply the results of this study to their dynamic adjustment of capital structure for optimizing and maximizing firm value. For example, a manager may be able to enhance the benefit of financial leverage if the corporation becomes larger and/or more profitable.

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