Investigation of Target Capital Structure for Electronic Listed Firms in Taiwan

Chien-Chung Nieh, Hwey-Yun Yau, and Wen-Chien Liu

ABSTRACT: This paper investigates the existence of an optimal debt ratio for the electronic listed firms in Taiwan, using balanced panel data for a sample of 143 selected electronics companies listed in the Taiwan Stock Exchange (TSE) from the first quarter of 1999 to the third quarter of 2004. The result shows that there is a single threshold effect of debt ratio on firm value when return on equity (ROE) is used to proxy firm value. Furthermore, based on our combined findings of ROE and earnings per share (EPS) triple threshold estimations, we find that the appropriate debt ratio range for the electronic listed firms in Taiwan should not be over 51.57 percent or below 12.37 percent. To ensure and enhance the firm's value, the optimal range of debt ratio should be within 12.37 percent and 28.70 percent. The implications of the findings for financial managers and shareholders' welfare are discussed.

KEY WORDS: capital structure, debt-to-assets ratio, firm value, panel threshold effect.

A financial manager in a corporation is responsible for establishing financial policy and planning to maximize firm value and stockholders' welfare. One important element is deciding how much leverage should be applied. Generally, a higher debt ratio can enhance the rate of return on equity capital. However, a higher debt ratio also increases the risk of the firm's earning. Therefore, a capital structure decision involves trade-offs between risk and capital return. This paper aims to find an optimal debt ratio (debt to total assets, D/TA) for the capital investment and investigating effects of financial leverage on a firm's performance or firm value for the electronic listed firms in Taiwan.

In the past several decades, the effect of a firm's capital structure on policy has been important in the field of corporate finance. Modigliani and Miller (1958; 1963) first discussed the relation between firm value and capital structure. Traditionally, there have been two main conflicting theories. The trade-off theory mainly describes the benefit and cost of debt, such as the benefit of tax deductibility of interest (Modigliani and Miller 1963), agency costs of debt and equity (Harris and Raviv 1990; Jensen 1986; Jensen and Meckling 1976; Myers 1977; Stulz 1990), and asymmetric information (Leland and Pyle 1977; Ross 1977). The pecking-order theory (Chirinko and Singha 2000; Frank and Goyal 2003; Myers 1984; Myers and Majluf 1984; Shyam-Sunder and Myers 1999) states that managers do not pursue a particular capital structure due to the presence of asymmetric information between better-informed managers and less-informed investors. Therefore,

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firms gather capital first through internally retained earning, then through low-risk debt. Equity is the last resort, under duress.

Recently, in addition to the traditional trade-off and pecking-order theory mentioned above, there have been some newly developed points of view about the decisions of capital structure. Baker and Wurgler (2002) illustrate the effect of equity issuance timing on capital structure. Other examples that also refer to the patterns of market timing theory include Alti (2006), Graham et al. (1999), Hovakimian (2006), Huang and Ritter (2007), Jenter (2005), Kim and Wu (1988), and Kisgen (2006). In addition, Welch (2004) finds that equity price shocks have a long-lasting effect on corporate capital structures and stock returns are the primary determinant of capital structure changes. Both of these two points of view are inconsistent with the trade-off theory, which pursues a particular optimal capital structure. However, other studies provide direct evidence that firms indeed have optimal capital structures and adjust toward them—consistent with trade-off theory (Fama and French 2002; Flannery and Rangan 2006; Jalilvand and Harris 1984; Marsh 1982; Taggart 1977).

Taiwan, a typical island and export-oriented country, is one of the major suppliers of electronics and information technology (IT) products to the United States and the rest of the world. Taiwan's economy now relies more on capital-intensive goods than ever. Whiting (1991) has pointed out that its weighted average debt as a percentage of total capital within the electronics industry is higher than within other types of industry.[1] Therefore, it is worth exploring the effect of financial leverage on firm value for listed electronic companies in Taiwan. This paper applies a threshold regression model to the observed balanced panel data to study the effect of the D/TA ratio on firm value, the threshold effect, and any asymmetrical response, if it exists.

This paper contributes to the previous literature in four aspects. First, we apply the advanced panel threshold regression model developed by Hansen (1999) to test if there exists a threshold of optimal debt usage. In contrast to the traditional linear model, this nonlinear threshold model can describe the trade-off between the benefits of tax shelters that come from more debt and the disadvantages of costs from additional debts that may negatively affect corporate performance or value. Second, we closely examine the financial characteristics of the electronic listed companies to solve the short period sample problems. Third, we use both accounting measurements of ROE and EPS to proxy firm value. Finally, two related control variables are considered and added to the regression analysis to make our nonlinear model more realistic.

Methodological Issues

Hansen's (1999) panel threshold regression model is an extension of the traditional least-squared estimation method. It requires that the variables in the model be stationary to avoid a "spurious regression."[2] We thus employ a unit-root test in our first step. Because the data sets are all panels in our investigation, both well-known LLC (Levin et al. 2002) and IPS (Im et al. 2003) techniques are employed for our panel unit-root tests.[3]

Assuming that the optimal debt proportion appears to be relevant to corporate performance or the value of listed electronic firms in Taiwan, this paper aims to find if there is a threshold effect and tries to use a threshold regression model to estimate the ratio appropriately. This may capture the relation between financial leverage and firm value as well as help financial managers make decisions. As a second step, we introduce the procedure briefly, as follows.[4]

According to Hansen (1999), we set up the panel threshold regression model with fixed effects, as follows:

$$v_{it} = \begin{cases} \mu_i + \theta' h_{it} + \alpha_1 d_{it} + \varepsilon_{it} & \text{if } d_{it} \leq \gamma \\ \mu_i + \theta' h_{it} + \alpha_2 d_{it} + \varepsilon_{it} & \text{if } d_{it} > \gamma \end{cases} \tag{1}$$

$$\theta = (\theta_1, \theta_2)', \; h_{it} = (s_{it}, g_{it})'.$$

where v_{it} represents proxy variables for the firm value. These variables are e_{it} (ROE) and p_{it} (EPS). The value d_{it}, the D/TA ratio, is the threshold variable; γ represents the specific estimated threshold value. Two control variables, s_{it} (growth rate of operating sales) and g_{it} (growth rate of total assets), are also incorporated into our model for their possible influences upon firm value. Besides, μ_i, the fixed effect, represents the heterogeneity of companies under different operating conditions. The error term, ε_{it}, is assumed to be independent and identically distributed with mean zero and finite variance $\sigma^2(\varepsilon_{it} \sim iid(0, \sigma^2))$. The values i and t denote different companies and periods, respectively.

In estimations, we first eliminate the individual effect μ_i using within-transformation estimation techniques in the traditional fixed-effect model of panel data. By using ordinary least squares and minimizing the concentrated sum of squares of errors, $S_1(\gamma)$, we can obtain the estimators of our threshold value and the residual variance, $\hat{\gamma}$ and $\hat{\sigma}^2$, respectively.

For the testing procedures, we first examine the null hypothesis of no threshold effect, H_0: $\alpha_1 = \alpha_2$, which can be based on the likelihood ratio test: $F_1 = (S_0 - S_1(\hat{\gamma})/\hat{\sigma}^2$, where S_0 and $S_1(\hat{\gamma})$ are sums of squared errors under null and alternative hypotheses, respectively. However, as the asymptotic distribution of F_1 is nonstandard, we use the bootstrap procedure to construct the critical values and p-value.

Upon the existence of a threshold effect, H_0: $\alpha_1 \neq \alpha_2$, we test for the asymptotic distribution of threshold estimate, H_0: $\gamma = \gamma_0$, and adopt the likelihood ratio test, $LR_1(\gamma) = (S_1(\gamma) - S_1(\hat{\gamma})/\hat{\sigma}^2$, with the asymptotic confidence intervals as follows:[5]

$$c(\alpha) = -2\log\left(1 - \sqrt{1-\alpha}\right).$$

Furthermore, if a single threshold indeed exists, we can extend the panel threshold regression model with single threshold to the double as follows:

$$v_{it} = \begin{cases} \mu_i + \theta' h_{it} + \alpha_1 d_{it} + \varepsilon_{it} & \text{if } d_{it} \leq \gamma_1 \\ \mu_i + \theta' h_{it} + \alpha_2 d_{it} + \varepsilon_{it} & \text{if } \gamma_1 < d_{it} \leq \gamma_2 \\ \mu_i + \theta' h_{it} + \alpha_3 d_{it} + \varepsilon_{it} & \text{if } \gamma_2 \leq d_{it}, \end{cases} \tag{2}$$

where threshold value $\gamma_1 < \gamma_2$.

Following the same procedure, we can go further to triple or multiple thresholds: $(\gamma_1, \gamma_2, \gamma_3, \ldots, \gamma_n)$.

Data and Empirical Results

Data Description

We use balanced panel data for a sample of 143 selected electronics companies listed on the TSE from the first quarter of 1999 to the third quarter of 2004. A total of 3,289 observations are adopted for each variable considered.

Table 1. Descriptive statistics for each variable

Variables	Mean	Standard deviation	Maximum	Minimum
e_{it}	1.69	6.96	30.86	–139.72
p_{it}	0.43	0.80	5.30	–1.45
d_{it}	37.44	15.36	99.07	3.32
s_{it}	25.09	81.53	2,987.66	–95.99
g_{it}	21.55	48.59	925.26	–84.22

Notes: e_{it}, p_{it}, d_{it}, s_{it}, and g_{it} represent ROE, EPS, D/TA ratio, growth rates of operating sales, and total assets, respectively. The data are from *Taiwan Economic Journal* Data Bank and the sample contains 146 electronic firms listed on the Taiwan Stock Exchange from the first quarter of 1999 to the third quarter of 2004. All variables are in the form of panel data series.

For the firm value, we choose the accounting measurements EPS and ROE, which are commonly used to indicate or proxy variables to evaluate firm performance or value. There are two categories of explanatory variables in our panel data examination. The first is the threshold variable, which is the key variable used to find out if there is an asymmetric threshold effect of financial leverage on firm value. The D/TA ratio indicates the debt ratio of the firms; it is widely used in the literature. The second category of explanatory variable is the control variable, which we adopt to make our nonlinear function form more persuasive. Most listed electronics companies in Taiwan are highly profitable, with high growth prospects. Therefore, we have included two control variables in our analysis: the growth rates of operating sales and total assets. These two variables are presumed to influence firm value. All data sets are obtained from the *Taiwan Economic Journal* (*TEJ*) Data Bank of Taiwan. Table 1 shows descriptive statistics of the variables.

Results of Panel Unit-Root and Threshold Regression

The results of the stationary test for each panel—explained variables, threshold variables, and control variables—are shown in Table 2. All of the variables are presumed to carry stationary characteristics—that is, the type I(0) series, as the null hypotheses of unit root are all rejected in the findings from both the LLC and IPS tests. These stationary findings enable us to estimate the panel threshold regression further.

We employ the panel threshold model elaborated by Hansen (1999) to test for single-, double-, and triple-threshold effects, respectively, of the debt ratio on firm value. Table 3 shows that the test for a single threshold is significant at the 10 percent level only when ROE is adopted to proxy firm value. Moreover, when testing for double- and triple-threshold effects, no matter which proxy variable, ROE or EPS, is used for firm value, the threshold effects are insignificant. We thus conclude that there only exists a single threshold effect of debt ratio on firm value when ROE is selected to proxy firm value. The estimated threshold value (γ) is found to be 75.31 percent; it separates all of the observations into two regimes. Table 4 illustrates that the coefficients of both regimes are negative: $\hat{\alpha}_1 = -0.0193$ and $\hat{\alpha}_2 = -0.0817$, though only $\hat{\alpha}_2$ of the upper regime is significant at the 1 percent level.

Although the test for a triple-threshold effect is insignificant, we can find some important evidence to help us make capital structure decisions. The empirical results of the regression slope estimates and White-corrected standard errors for the triple threshold

Table 2. Panel unit-root tests

	t-statistic	
	LLC	IPS
e_{it}	–17.61***	–17.50***
p_{it}	–17.46***	–18.06***
d_{it}	–7.84***	–8.83***
s_{it}	–11.80***	–17.29***
g_{it}	–11.66***	–11.32***

Notes: e_{it}, p_{it}, d_{it}, s_{it}, and g_{it} represent ROE, EPS, D/TA ratio, growth rates of operating sales, and total assets, respectively. LLC and IPS represent the Levin et al. (2002) and Im et al. (2003) panel unit-root techniques, respectively. *** , **, and * represent significance at the 1 percent, 5 percent, and 10 percent levels, respectively. The *t*-statistic critical value for LLC and IPS at 1 percent, 5 percent, and 10 percent significance levels is (–1.65, –1.96, –2.58), respectively.

Table 3. Tests for threshold effects between the debt ratio and proxy variables for firm value

Firm-value variables	Threshold value of γ (percent)	F	p-value	Critical values (10 percent, 5 percent, 1 percent)
Single-threshold effect test				
EPS	28.70	9.31	0.57	(19.30, 22.96, 29.03)
ROE	75.31	24.33	0.06*	(20.92, 24.75, 23.81)
Double-threshold effect test				
EPS	12.37 28.70	6.07	0.85	(14.95, 16.46, 19.88)
ROE	51.75 75.31	5.47	0.82	(16.92, 19.40, 29.17)
Triple-threshold effect test				
EPS	12.37 28.70 37.39	2.96	0.99	(12.23, 13.93, 18.20)
ROE	37.39 51.75 75.31	3.95	0.89	(11.57, 13.85, 16.64)

Notes: F-statistic and p-value result from repeating bootstrap procedure 200 times for each of the three bootstrap tests. ***, **, and * represent significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 4. Estimated coefficients for each proxy variable for firm value in single threshold model

Firm value	Coefficients	Estimated value	White standard error
EPS	$\hat{\alpha}_1$	0.0059**	0.0027
	$\hat{\alpha}_2$	0.0010	0.0016
ROE	$\hat{\alpha}_1$	–0.0193	0.0151
	$\hat{\alpha}_2$	–0.0817*	0.0430

Notes: There exists a single-threshold effect when ROE is selected as the proxy for firm value, and the estimated threshold value (γ) is found to be 75.31 percent. For EPS, γ is found to be 28.70 percent from Table 3. ***, **, and * represent significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

Table 5. Estimated coefficients for each proxy variable for the firm value in triple-threshold model

Firm value	Coefficients	Estimated value	White standard error
EPS	$\hat{\alpha}_1$	–0.0085	0.0089
	$\hat{\alpha}_2$	0.0075**	0.0037
	$\hat{\alpha}_3$	0.0031	0.0027
	$\hat{\alpha}_4$	0.0011	0.0019
ROE	$\hat{\alpha}_1$	0.0316*	0.0173
	$\hat{\alpha}_2$	0.0116	0.0137
	$\hat{\alpha}_3$	–0.0081	0.0158
	$\hat{\alpha}_4$	–0.0704	0.0433

Notes: $\hat{\alpha}_1$, $\hat{\alpha}_2$, $\hat{\alpha}_3$, and $\hat{\alpha}_4$ represent coefficient estimate smaller and larger than threshold values γ_1, γ_2, and γ_3, which are, respectively, 12.37 percent, 28.70 percent, and 37.39 percent for EPS and 37.39 percent, 51.75 percent, and 75.31 percent for ROE. ***, **, and * represent significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

model are shown in Table 5. An ambiguous finding can be observed in Table 5 that the effect values in the three higher regimes of EPS estimation are positive, whereas the values of the two higher regimes are negative in the ROE estimation. However, if we look into the triple-threshold estimation in Table 3, the contradictory finding can be cleared up: The highest threshold value of EPS that proxies firm value equals the lowest value of ROE proxying the firm value (37.39 percent).

Regarding ROE as a proxy for firm value, the negative effects are contingent on the two upper regimes, when the debt ratio is higher than 51.75 percent. Positive effects are associated with the two lower regimes, where the debt ratio is lower than 51.75 percent. However, a significant positive effect appears only in the lowest regime, where the debt ratio is less than 37.39 percent.

The estimated value of the coefficient in the lowest regime, $\hat{\alpha}_1$, is 0.0316, which implies that when the debt ratio increases by 1 percent, ROE increases by 0.0316 percent. In the second-lowest regime, where the debt ratio is above 37.39 percent but below 51.75 percent, the estimated value of the coefficient $\hat{\alpha}_2$ is still positive but insignificant, and the impact value decreases to 0.0116. The negative effects are found in the two upper regimes and are insignificant. Based on the estimated value of $\hat{\alpha}_3 = –0.0081$ and $\hat{\alpha}_4 = –0.0704$, the negative effects on firm value increase gradually along with the increase in the debt ratio. This ROE triple-threshold result confirms that the appropriate debt ratio range should not exceed 51.57 percent.

We further look at the estimation when EPS proxies firm value. In the lowest regime, where the debt ratio is below 12.37 percent, the estimated value of coefficient $\hat{\alpha}_1$ is –0.0085. Nonetheless, when the debt ratio is above 12.37 percent but below 28.70 percent, the estimate of coefficient $\hat{\alpha}_2$ is positive and significant at the 5 percent level. The value of $\hat{\alpha}_2 = 0.0075$ implies that EPS increases by 0.0075 percent with a 1 percent increase in the debt ratio. Though the estimates of coefficients in the higher regimes are still positive ($\hat{\alpha}_3 = 0.0031$ and $\hat{\alpha}_4 = 0.0011$), they are insignificant, and the value decreases gradually with the decrease in debt ratio.

Overall, combined with the findings of both the ROE and EPS triple-threshold estimations, we may conclude that, for listed electronic companies in Taiwan, the appropriate debt ratio range should not be above 51.57 percent or below 12.37 percent for the sake of

Table 6. Estimation of coefficients of control variables in triple-threshold model

Firm value	Coefficients	Estimated value	White standard error
EPS	$\hat{\theta}_1$	0.0028***	0.0004
	$\hat{\theta}_2$	0.0013***	0.0005
ROE	$\hat{\theta}_1$	0.0234***	0.0023
	$\hat{\theta}_2$	0.0038	0.0025

Notes: $\hat{\theta}_1$ and $\hat{\theta}_2$ represent the estimated coefficients of growth rates on operating sales and total assets, respectively. ***, **, and * represent significance at the 1 percent, 5 percent, and 10 percent levels, respectively.

the negative influence of the debt usage on firm value. However, to ensure and enhance the firm's value properly, the optimal range of debt ratio should be within 12.37 percent and 28.70 percent.[6]

The results infer that the increase of the debt ratio at low debt levels—between 12.37 percent and 37.39 percent—can improve the operating performance of firms, and in turn increase firm value, which is consistent with Modigliani and Miller (1963). Costs of leverage and financial distress increase as the debt ratio increases gradually, which counteracts the positive effect of the debt ratio to operating performance. Our finding that $\hat{\alpha}_4 < \hat{\alpha}_3 < \hat{\alpha}_2$ in the EPS triple-threshold model is consistent with this view. The agency theory also explains this result. On one hand, a higher debt ratio means less free cash flow for managers to manipulate, which can reduce agency costs and increase a firm's value. However, when the debt ratio is too high, the conflicts between creditors and shareholders increase agency costs, leading to financial distress and deterioration in the value of firms. Referring to the former result of the ROE single-threshold model, the estimated threshold value (γ) is found to be 75.31 percent; two coefficients are all negative, whereas only $\hat{\alpha}_2$ of the upper regime is statistically significant. This shows that incremental debt usage above 75.31 percent is detrimental to firm value, as the trade-off and agency theories suggest.

The two control variables considered in our paper, growth rates of operating sales and total assets, may also influence firm value. Table 6 shows that both the growth rates of operating sales and total assets significantly and positively influence firm value when EPS is selected as the proxy variable. Only growth rate of operating sales significantly influences firm value when ROE is selected as the proxy variable.

Conclusion

Capital structure decisions made by firms may have significant effects on the firms' expected profitability or performance. This paper aims to find an optimal debt ratio for capital investment and investigates the effects of financial leverage on a firm's value for listed electronic firms in Taiwan.

The evidence from our threshold effect estimation in testing for the optimal capital structure has shown that there exists only a single-threshold effect of debt ratio on firm value when ROE is selected to proxy firm value. The estimated threshold value separates our observations into two regimes; the coefficients of both regimes are negative and only the upper regime is significant. However, for further details, based on our combined findings of ROE and EPS triple-threshold estimations, we find that the appropriate debt ratio range for listed electronic firms in Taiwan should not be over 51.57 percent or below 12.37 percent. To ensure and enhance a firm's value, the optimal range of debt ratio should be within 12.37 percent and 28.70 percent. Our finding is consistent with the trade-off theory that when the debt ratio is too high, conflicts between creditors and shareholders increase agency costs, leading to financial distress and sharply deteriorating firm value. The tax shield is offset by the incremental costs through debt financing, which counteracts the positive effect of the debt ratio on operating performance.

Different industries view the trade-off between debt and equity differently. Most listed electronic firms in Taiwan are highly profitable and generate more internal cash flows. According to our empirical results, an increase of debt ratio at low debt levels can improve the operating performance of listed electronic firms, which in turn increases their firm values. Moreover, the growth rate of operating sales significantly affects firm value, whereas the growth rate of total assets is shown to have no significant effect on firm value. This implies that expanding assets does not necessarily increase firm value. This paper recommends that companies investigate the contingent cash flows for their capital structure strategies and financial managers use leverage wisely to maximize firm values and shareholders' welfare.

Notes

1. Whiting (1991) adopted statistical data from the United States as an example.
2. Spurious regression is argued in Granger and Newbold (1974), as the estimation of the relationship among nonstationary series easily reaches a higher R^2 and *t*-statistics.
3. LLC is a modified version of the LL (Levin and Lin 1992; 1993) panel unit-root technique.
4. For a detailed illustration, see the Appendix and Hansen (1999).
5. Note that $LR_1(\gamma_1)$ is testing for H_0: $\gamma = \gamma_0$, and F_1 is testing H_0: $\alpha = \alpha_2$.
6. This finding is consistent with the former result of the EPS single-threshold model (see Table 4), which shows that the coefficient $\hat{\alpha}_1$, in the lower regime with debt ratio below 28.70 percent, is positive and significant ($\hat{\alpha}_1 = 0.0059$).
7. Note that the statistic (16) is testing a different hypothesis from the statistic (15) introduced in the previous section. $LR_1(\gamma_0)$ is testing $H_0 : \gamma = \gamma_0$, and $F(\gamma)$ is testing $H_0 : \alpha_1 = \alpha_2$.
8. See Hansen (1999), Appendix: Assumptions 1–8.

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Appendix

Threshold Model Construction

Assuming the optimal debt proportion appears to be relevant to corporate performance or value of electronic listed firms in Taiwan, this paper aims at finding whether exists a threshold effect and try to use threshold model to estimate this ratio, which may capture the relationship between financial leverage and the firm value as well as help financial managers make decisions.

Thus, we set up single threshold model as follows:

$$v_{it} = \begin{cases} \mu_i + \theta' h_{it} + \alpha_1 d_{it} + \varepsilon_{it} & \text{if } d_{it} \le \gamma \\ \mu_i + \theta' h_{it} + \alpha_2 d_{it} + \varepsilon_{it} & \text{if } d_{it} > \gamma \end{cases} \tag{A1}$$

$$\theta = (\theta_1, \theta_2)', \; h_{it} = (s_{it}, g_{it})',$$

where v_{it} represents proxy variables for the firm value, which are e_{it}: ROE, p_{it}: EPS, d_{it}, D/TA ratio, which is also the threshold variable; γ, the specific estimated threshold value.

There are two "control variables" (h_{it}) that may have influences on the firm value, which are s_{it}: growth rate of operating sales, g_{it}: growth rate of total assets. Besides, μ_i, the fixed effect, represents the heterogeneity of companies under different operating conditions. The errors ε_{it} is assumed to be independent and identically distributed with mean zero and finite variance $\sigma^2(\varepsilon_{it} \sim iid(0, \sigma^2))$; i represents different companies; t represents different periods.

Another threshold regression model of (A1) is to set

$$v_{it} = \mu_i + \theta' h_{it} + \alpha_1 d_{it} I(d_{it} \le \gamma) + \alpha_2 d_{it} I(d_{it} > \gamma) + \varepsilon_{it}, \tag{A2}$$

where $I(.)$ represents the indicator function.

$v_{it} = \mu_i + \theta' h_{it} + \alpha' d_{it}(\gamma) + \varepsilon_{it}$ can be written as

$$\begin{aligned} v_{it} &= \mu_i + [\theta', \alpha'] \begin{bmatrix} h_{it} \\ d_{it}(\gamma) \end{bmatrix} + \varepsilon_{it} \\ v_{it} &= \mu_i + \beta' x_{it}(\gamma) + \varepsilon_{it} \\ d_{it}(\gamma) &= \begin{bmatrix} d_{it} I(d_{it} \le \gamma) \\ d_{it} I(d_{it} > \gamma) \end{bmatrix}, \end{aligned} \tag{A3}$$

where $\alpha = (\alpha_1, \alpha_2)'$, $\beta = (\theta', \alpha')'$, $x_{it} = (h'_{it}, d'_{it}(\gamma))$.

The observations are divided into two "regimes" depending on whether the threshold variable d_{it} is smaller or larger than the threshold value of γ. The regimes are distinguished by differing regression slopes, α_1 and α_2. We will use known v_{it} and d_{it} to estimate the parameters (γ, α, θ, and σ^2).

Estimation

Note that by taking averages of (A3) over the time index t, we can derive

$$\bar{v}_{it} = \mu_i + \beta' \bar{d}_{it}(\gamma) + \bar{\varepsilon}_{it}, \tag{A4}$$

where

$$\bar{v}_i = \frac{1}{T}\sum_{t=1}^{T} v_{it}$$

$$\bar{\varepsilon}_i = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_{it},$$

and

$$\bar{d}_i(\gamma) = \frac{1}{T}\sum_{t=1}^{T} d_{it}(\gamma) = \begin{bmatrix} \frac{1}{T}\sum_{t=1}^{T} d_{it} I(d_{it} \le \gamma) \\ \frac{1}{T}\sum_{t=1}^{T} d_{it} I(d_{it} > \gamma) \end{bmatrix}.$$

Taking the difference between (A3) and (A4) yields

$$v^*_{it} = \alpha' d^*_{it}(\gamma) + \varepsilon^*_{it}, \tag{A5}$$

where $v^*_{it} = v_{it} - \bar{v}_i$, $d^*_{it}(\gamma) = d_{it}(\gamma) - \bar{d}_i(\gamma)$, and $\varepsilon^*_{it} = \varepsilon_{it} - \bar{\varepsilon}_i$.

Let

$$v^*_i = \begin{bmatrix} v^*_{i2} \\ \vdots \\ v^*_{iT} \end{bmatrix},\ d^*_i(\gamma) = \begin{bmatrix} d^*_{i2}(\gamma)' \\ \vdots \\ d^*_{iT}(\gamma)' \end{bmatrix},\ \varepsilon^*_i = \begin{bmatrix} \varepsilon^*_{i2} \\ \vdots \\ \varepsilon^*_{iT} \end{bmatrix}$$

denote the stacked data and errors for an individual, with one time period deleted. Then let the V^*, $D^*(\gamma)$, and e^* denote the data stacked over all individuals.

$$V^* = \begin{bmatrix} v^*_1 \\ \vdots \\ v^*_i \\ \vdots \\ v^*_n \end{bmatrix},\ D^*(\gamma) = \begin{bmatrix} d^*_1(\gamma) \\ \vdots \\ d^*_i(\gamma) \\ \vdots \\ d^*_n(\gamma) \end{bmatrix},\ e^* = \begin{bmatrix} \varepsilon^*_1 \\ \vdots \\ \varepsilon^*_i \\ \vdots \\ \varepsilon^*_n \end{bmatrix}.$$

Using this notation, (A5) is equivalent to

$$V^*_{it} = D^*_{it}(\gamma)\alpha + e^*_{it}. \tag{A6}$$

Equation (A6) represents the major estimation model of threshold effect. For any given threshold value of γ, the slope coefficient α can be estimated by ordinary least squares (OLS). That is,

$$\hat{\alpha}(\gamma) = \left(D^*(\gamma)' D^*(\gamma)\right)^{-1} D^*(\gamma) V^*. \tag{A7}$$

The vector of regression residuals is

$$\hat{e}^*(\gamma) = V^* - D^*(\gamma)\hat{\alpha}(\gamma) \tag{A8}$$

and the sum of squared errors, SSE, is

$$SSE_1(\gamma) = \hat{e}^*(\gamma)'\hat{e}^*(\gamma) = V^*\left(I - D^*(\gamma)\left(D^*(\gamma)' D^*(\gamma)\right)^{-1} D^*(\gamma)'\right)V^*. \tag{A9}$$

Hansen (1999) recommended estimation of γ by least squares. This is easier to achieve by minimization of the concentrated sum of squared errors (A9). Hence, the least squares estimators of γ is

$$\hat{\gamma} = \arg\min_{r} SSE_1(\gamma). \tag{A10}$$

Once $\hat{\gamma}$ is obtained, the slope coefficient estimate is $\hat{\alpha} = \hat{\alpha}(\hat{\gamma})$. The residual vector is $\hat{e}^* = \hat{e}^*(\hat{\gamma})$, and the estimator of residual variance is

$$\hat{\sigma}^2 = \hat{\sigma}^2(\hat{\gamma}) = \frac{1}{n(T-1)}\hat{e}^{*\prime}(\hat{\gamma})e^*(\hat{\gamma}) = \frac{1}{n(T-1)}SSE_1(\hat{\gamma}), \tag{A11}$$

where n indexes the number of sample, T indexed the periods of sample.

Testing for a Threshold

According to the "trade-off theory" of capital structure, when debt ratio increases, the interest tax shield increases; however, on the other side, leverage-related costs increase to offset the positive effect of debt ratio to the firm value. This paper hypothesizes that there exists a threshold effect between the D/TA ratio and firm value. Therefore, it is important to determine whether the threshold effect is statistically significant. The null hypothesis and alternative hypothesis can be represented as follows:

$$\begin{cases} H_0 : \alpha_1 = \alpha_2 \\ H_1 : \alpha_1 \neq \alpha_2 \end{cases}.$$

When the null hypothesis holds, the coefficient $\alpha_1 = \alpha_2$, the threshold effect does not exist. When the alternative hypothesis holds, the coefficient $\alpha_1 \neq \alpha_2$, the threshold effect exists between the D/TA ratio and firm value.

Under the null hypothesis of no threshold, the model is

$$v_{it} = \mu_i + \theta' h_{it} + \alpha' d_{it}(\gamma) + \varepsilon_{it}. \tag{A12}$$

After the fixed-effect transformation is made, we have

$$V^*_{it} = \alpha'_1 H^*_{it} + e^*_{it}. \tag{A13}$$

The regression parameter is estimated by OLS, yielding estimate $\tilde{\alpha}_1$, residuals $\tilde{e}^*$ and sum of squared errors $SSE_0 = \tilde{e}^{*\prime}\tilde{e}^*$.

Hansen (1999) suggested that we use the F-test approach to test the existence of threshold effect, and use the sup-Wald statistic to test the null hypothesis.

$$F = \sup F(\gamma) \tag{A14}$$

$$F(\gamma) = \frac{\left(SSE_0 - SSE_1(\hat{\gamma})\right)/1}{SSE_1(\hat{\gamma})/n(T-1)} = \frac{SSE_0 - SSE_1(\hat{\gamma})}{\hat{\sigma}^2}. \tag{A15}$$

Asymptotic Distribution of Threshold Estimate

Hansen (1999) showed that when there is a threshold effect $\alpha_1 \neq \alpha_2$, $\hat{\gamma}$ is consistent for γ_0, and that the asymptotic distribution is highly nonstandard. Hansen (1999) argued that the best way to form confidence intervals for γ is to form the "no-rejection region" using the likelihood ratio statistic for tests on γ. To test the hypothesis

$$\begin{cases} H_0 : \gamma = \gamma_0 \ , \\ H_1 : \gamma \neq \gamma_0 \end{cases}$$

we construct the testing model:

$$LR_1(\gamma) = \frac{SSE_1(\gamma) - SSE_1(\hat{\gamma})}{\hat{\sigma}^2}. \tag{A16}$$

Hansen (1999) pointed out that when $LR_1(\gamma_0)$ is too large and the p-value exceeds the confidence interval, the null hypothesis is rejected.[7] Besides, Hansen (1999) indicated that under some specific assumptions[8] and $H_0 : \gamma = \gamma_0$,

$$LR_1(\gamma) = d\zeta, \tag{A17}$$

as $n \to \infty$, where ζ is a random variable with distribution function

$$P(\zeta \leq x) = (1 - \exp(-x/2))^2. \tag{A18}$$

The asymptotic p-value can be estimated under the likelihood ratio. According to the proof of Hansen (1999), the distribution function (A18) has the inverse

$$c(\alpha) = -2\log\left(1 - \sqrt{1-\alpha}\right) \tag{A19}$$

from which it is easy to calculate critical values. For a given asymptotic level α, the null hypothesis $\gamma = \gamma_0$ rejects if $LR_1(\gamma)$ exceeds $c(\alpha)$.

Multiple Thresholds Model

If double thresholds exist, the model is modified as

$$v_{it} = \begin{cases} \mu_i + \theta' h_{it} + \alpha_1 d_{it} + \varepsilon_{it} & \text{if } d_{it} \leq \gamma_1 \\ \mu_i + \theta' h_{it} + \alpha_2 d_{it} + \varepsilon_{it} & \text{if } \gamma_1 < d_{it} \leq \gamma_2 \\ \mu_i + \theta' h_{it} + \alpha_3 d_{it} + \varepsilon_{it} & \text{if } \gamma_2 \leq d_{it}. \end{cases} \tag{A20}$$

where threshold value $\gamma_1 < \gamma_2$. This can be extended to multiple thresholds model (γ_1, γ_2, γ_3, ..., γ_n).