Optimization of Capital Structure by Introduction of Black-Scholes Option Pricing Model

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Abstract: The decision of capital structure is influenced by a variety of factors, this research focus on the capital structure of the company considering agency cost. The introduction of option theory and the Black-Scholes option pricing model provides a scientific and feasible way for company to make the decision.

1. Introduction

Related research shows that the ideal capital structure is influenced by external factors like the enterprise's own characteristics, the macroeconomic environment, institutional constraints and other internal factors, including the change of enterprise scale, profitability, asset tangibility and non-debt tax shield, etc. 1958, Modigliani-Miller published 《Capital Cost, Corporate Value and Capital Structure》 and started theoretical study of the capital structure, followed by the trade-off theory, information asymmetry theory, pecking order theory, stakeholder theory. It has been continuously enriched and developed and became core of financial theory. One of the important characteristics of the enterprise strategy is its adaptability, and the strategy of the enterprise should change with the enterprise itself and the change of the environment. Optimization of the capital structure of an enterprise should adapt to the enterprise strategy, namely the financial and corporate growth strategy, product market competition strategy, asset restructuring strategy (2008, Zhou Guifang).

Han Huibo (2006) made the conclusion that excess growth would affect the company's capital structure, companies in poor financial situation can only passively choose debt financing due to the bottleneck of equity financing methods in his study of “super sustainable growth, passive choice of capital structure and corporate performance”. Lyandres (2002) discusses the optimal financial leverage ratio of the enterprise as well as the relationship between debt maturity and the enterprise's aggressive business strategy. Zhu Wuxiang et al. (2002) found that when the company expects more intensive competition in the future, the lower the current choice of the debt scale, so was financial conservatism caused.

2. Methodology

2.1 Agency cost

The information asymmetry that exists between shareholders and the Chief Executive Officer is generally considered to be a classic example of a principal–agent problem. The agent (the manager) is working on behalf of the principal (the shareholders), who does not observe the actions, or many of the actions, or is not aware of the repercussions of many of the actions of the agent. Most importantly, even if there was no asymmetric information, the design of the manager's contract would be crucial in order to maintain the relationship between their actions and the interests of shareholders. Information asymmetry contributes to moral hazard and adverse selection problems. Agency costs mainly arise due to contracting costs and the divergence of control, separation of
ownership and control and the different objectives (rather than shareholder maximization) of the managers.

As the company's liabilities increase, the agency cost changes are reflected in the following three possible scenarios:

(i) Due to the restrictions on the management board of the company by creditors, the company's operating autonomy will be reduced, resulting in reduced investment opportunities and economic benefits.

(ii) Interest rate rises, and the rate of interest rate increase is higher than the growth rate of debt.

(iii) Mix of situation (i) and situation (ii), where creditors demand not only higher interest rates but also more restrictions on the operation of the company. It can be seen that the agent cost is actually the measurement on default risk of creditor.

2.2 B-S model

The Black-Scholes model is a mathematical model of a financial market containing derivative investment instruments. From the model, one can deduce the Black–Scholes formula, which gives a theoretical estimate of the price of European-style options. The formula led to a boom in options trading and provided mathematical legitimacy to the activities of the Chicago Board Options Exchange and other options markets around the world. It is widely used, although often with adjustments and corrections, by options market participants. Many empirical tests have shown that the Black-Scholes price is "fairly close" to the observed prices.

Based on works previously developed by market researchers and practitioners, such as Louis Bachelier, Sheen Kassouf and Ed Thorp among others, Fischer Black and Myron Scholes came to the formula in the late 1960s.

\[ C = S \cdot N(d_1) - L e^{-rT} N(d_2) \]

\[ d_1 = \frac{\ln \frac{S}{L} + (r + 0.5 \cdot \sigma^2) T}{\sigma \cdot \sqrt{T}} \]

\[ d_2 = \frac{\ln \frac{S}{L} + (r - 0.5 \cdot \sigma^2) T}{\sigma \cdot \sqrt{T}} = d_1 - \sigma \sqrt{T} \]

- \( N \) is the cumulative distribution function of the standard normal distribution
- \( T-t \) is the time to maturity (expressed in years)
- \( S \) is the spot price of the underlying asset
- \( L \) is the strike price
- \( r \) is the risk free rate (annual rate, expressed in terms of continuous compounding)
- \( \sigma \) is the volatility of returns of the underlying asset

2.3 Measurement of default risk

The issuance of bonds by the company is equivalent to the company mortgaging its assets to borrow a certain amount of money.

We can assume that the company has not only made a sum of money in the use of its bonds, but also has a put option.

Bonds are Zero-coupon bond, if the creditors want to obtain bond value of \( D \) in the future, they need to pay the amount of money of \( D_0 \) now; at the same time creditors sell to company a put option of \( P \) at the striking price of \( D \). The default risk can be measured by the Black-Scholes pricing model of the put option. The company is insolvent on the maturity of its debts, namely, default. The value of the put option owned by the shareholder is the measure of the risk of default.
\[
D_0 = D - r_t \cdot P
\]

- \(D\) is the total liabilities of the company
- \(r_t\) is the risk free rate (annual rate, expressed in terms of continuous compounding)
- \(P\) is the price of the put option

According to the previous analysis, the striking price of the put option is bond value \(D\), the option has the same duration as the bond duration, the subject matter is the company's assets, thus we get the formula as follows:

\[
P = D - r_t \cdot N(-d_2) - AN(-d_1)
\]

\[
d_1 = \frac{\ln(A/D) + (R_f + \sigma^2/2)}{\sigma}
\]

\[
d_2 = \frac{\ln(A/D) + (R_f - \sigma^2/2)}{\sigma} = d_1 - \sigma
\]

- \(A\) is the average assets of the company
- \(D\) is the total liabilities of the company
- \(R_f\) is the risk free rate (annual rate, expressed in terms of continuous compounding)
- \(\sigma\) is the volatility of returns of the underlying asset

When the agent cost is in agency cost form

(i). It is the optimal liability of the company when \(D\) meets the requirement of the following formula: (Baocheng Yang, 1999)

\[
T_c = \frac{1 - (1 + R_f)^{-d_1}}{R_f} \left[ \frac{1 + R_f}{1 - (1 + R_f)\cdot F'(D)} - (1 - R_f) \right] = 0
\]

Of which

\[
F(D) = e^{-R_f \cdot N(-d_2(D))} + (e^{-R_f/\sigma})e^{-\frac{(d_1(D))^2}{2}} - (A/D) e^{-\frac{(d_2(D))^2}{2}}
\]

- \(N\) is the cumulative distribution function of the standard normal distribution
- \(T_c\) is the business income tax rate
- \(R_f\) is the risk free rate (annual rate, expressed in terms of continuous compounding)
- \(d_1 = \frac{\ln(A/D) + (R_f + \sigma^2/2)}{\sigma}
\)
- \(d_2 = \frac{\ln(A/D) + (R_f - \sigma^2/2)}{\sigma} = d_1 - \sigma
\)
- \(\sigma\) is the volatility of returns of the underlying asset

3. Case study

The company’s competition strength traces back to its motto of “reduction, reuse and resource conservation” and its strong technical support.

Its development mode and sustainability pursuit come into form under the guidance of its resource-based competitiveness strategy. So far, it has obtained 8 national invention patterns and is distinguished from other non-ferrous metal corporations as a high-tech corporation.

After its incentive stage’s development featured by high innovation and high market orientation during which it is facing with the external environment in a flux, it’s undergoing another stage of
meeting shareholder’s expectation and strive for earning more capabilities such as organizational routines, which is defined as regular and predictable pattern of activity which is made up of a sequence of coordinated actions by individuals (Chang Shu, 2013).

Table 1. The Balance Sheet of the company (three years).

<table>
<thead>
<tr>
<th></th>
<th>2016</th>
<th>2015</th>
<th>2014</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average assets</td>
<td>7,544,902,353</td>
<td>7,145,362,366</td>
<td>7,288,528,774</td>
<td>4,213,032,413</td>
</tr>
<tr>
<td>Liabilities</td>
<td>4,062,939,294</td>
<td>4,248,323,425</td>
<td>4,770,571,274</td>
<td>2,774,429,710</td>
</tr>
<tr>
<td>Asset-liability</td>
<td>0.54</td>
<td>0.59</td>
<td>0.65</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Table 2. Part of the Income Statement.

<table>
<thead>
<tr>
<th></th>
<th>2016</th>
<th>2015</th>
<th>2014</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating revenue(Yuan)</td>
<td>1641171851</td>
<td>81947392.57</td>
<td>73751203.54</td>
<td>67676515.49</td>
</tr>
<tr>
<td>Operating profit(Yuan)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Profit(Yuan)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retained profits(Yuan)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total profit attributable to the owner of the parent company (Yuan)</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) The issuance of bond is zero-interest rate bond, bond period is one year, payment of dividends is also after one year with non-issuance costs.

2) The risk-free interest rate is 1.49%, the annual standard deviation of assets is 0.4., and the company's income tax rate is 0.08% (calculated based on the income statement).

After calculation, we get the result that the best optimized asset-liability ratio is 51.2%. Par value of the bond is 3.863 billion Yuan, and the real liability is 3.806 billion Yuan.

4. Conclusion

This paper introduces the option theory and option pricing model to quantitatively measure the effect of debt on the value of the company when the agent cost exists. And it also introduces a specific calculating form of optimal capital structure (Yang baoccheng, 1999), providing a feasible calculation method for the optimization of company capital structure.

References


