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Optimization of Capital Structure using Operations Research Techniques

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ABSTRACT

This research paper aims to optimise the capital structure of a company using operations research techniques. All companies require financing for day-to-day operations and expansion. The two major sources of financing are equity finance and debt finance. Raising capital by selling shares of a company is known as equity finance whereas bank loans, bonds, securities and overdrafts are some sources of debt finance. Now the question that arises is what is the appropriate capital structure that the company must follow to achieve maximum profit at the lowest cost. To solve this problem, our paper proposes a simple mathematical model that can be applied to various companies. Using the Simplex method of solving LPP (Big M method) we have developed a model to optimise the capital structure of a company that helps to minimize the overall cost of capital while taking into account various other factors that influence it like risk of insolvency, tax shield and expenses incurred to acquire the funds.

Keywords— *Capital structure; Cost of capital; Equity; Debt; Profitability; Simplex Method; Linear Programming*

1. INTRODUCTION

A study by US Bank found that 82% of the business fail because of poor cash flow management or capital structure optimisation skills (Flint, 2020). Capital structure refers to the amount of money inducted by the company for its working and financing of its assets. The same company usually raises money in the mix of debt and equity. Now the question that arises is what is the appropriate capital structure that the company must follow to achieve maximum profit. The solution is to form a capital structure that will result in the lowest cost to obtain it. (Shailaja, Optimization of Capital Structure for Increased Profitability, 2019)

The Operations Research technique used in this research paper is Linear Programming Problem (LPP). This method helps us to achieve the best possible outcome in a mathematical problem. The outcome can include the lowest cost, maximum profit or best possible price. In our case, it will be the lowest cost.

For a company, major decisions related to finance are how to raise funds and allocate them with maximum efficiency, as well as to have the best possible combination of risk and return. LPP helps to achieve the best possible decision for the above case.

There isn't adequate material available that is easy enough to be implemented by undergraduate students and most of the studies are one-dimensional in their approach. Using the Simplex method of solving LPP (Big M method) we have developed a model to optimise the capital structure of a company that helps to minimize the overall cost of capital while taking into account various other factors that influence it like risk of insolvency, tax shield and expenses incurred to acquire the funds. It is a simple mathematical model that can be applied to various companies by modifying it as per the specifications of that particular company.

2. LITERATURE REVIEW

The research done in earlier papers shows that operations research techniques have proved to be extremely useful in analysing various finance problems such as investment strategy, portfolio optimization, the valuation of financial instruments, capital budgeting decisions, and decisions regarding the capital structure of firms. Such problems can be easily formulated as mathematical problems and solved for feasible solutions. Different programming techniques such as Linear, Quadratic, Non-Linear, Integer, Goal, and Dynamic are widely used. The objective in finance problems is to maximize profit or minimize risk (Kaur & Singh, 2014).

An important application of OR techniques for firms is regarding their capital structure decisions, that is, determining the most optimal mix for them to raise capital from the financial markets for the smooth functioning of their operations. A study by Brick, Mellon, Surkis, and Mohl (1983) put forward a multi-period, chance-constrained mathematical programming model to calculate the firm's optimal debt to equity ratio for each period. The choice between the funding alternatives can also be formulated as a linear goal programming problem as per Hong (1981). Kornbluth and Vinso (1982) computed the model for the financing decision of a multi-national corporation keeping in mind two objectives- minimizing the overall cost of capital and achieving the debt-to-equity ratio targets in each country. Another perspective of looking at the debt problem is to presume that the target debt-equity ratio has been achieved by the firm, and now its main concern is with raising the required debt at the lowest possible cost. Bierman (1966) and Litzenberger and Rutenberg (1972) worked on this idea and employed the inventory model wherein debt was taken as an input to the productive process, and the model was used to determine the optimal "reorder" times and quantities (Board, Sutcliffe, & Ziemba, 2003).

The goal of optimizing the capital structure of a company is to maximize its value by minimizing the overall capital cost. This cost is the weighted average cost of capital since firms employ various sources of funds. A study conducted to analyse the formation of optimal capital structure in pharmaceutical companies concluded that the capital structure of such companies had not achieved optimality yet. The optimal capital structure using the Modigliani Miller approach consists of 30% debt and 70% equity whereas the actual average proportion of their capital structure was 18.43% debt and 81.57% equity. A lower WACC with increased debt could be achieved to optimize the capital structure (Nurwulandari, Hasanudin, & Burhan, 2021).

The capital structure of a firm is the ratio of its debt capital to equity capital. Studies reveal that the capital structure is influenced by four factors, namely macro factors, minor factors, and the impact of seven different types of negative and positive factors. There exists a positive relationship between tangible assets and capital structure leverage ratio. The structure of intangible capital is negatively influenced by the value of the intangible capital market and corporate earnings, and the fourth factor is capital concentration in ownership. For the optimization of capital structure, the company must follow the given steps: Use of Finance Leases; Increase the Proportion of Long-term Borrowing; Use Commercial Credit; Expand Financing Channels; Introduce Investment from Financial Institutions and optimize the Company's Ownership Structure. The high asset-liability ratio, the high proportion of current liabilities, the single financing channel, and the high concentration of ownership are all difficulties with enterprise capital structure. The external environment and the company's operating conditions both have an impact on an enterprise's capital structure, but the impact of the company's own elements is stronger. Therefore, a corporation must continue to change its capital structure in response to changing circumstances. (Gong, 2021)

The capital structure has been determined with the sole objective of maximizing shareholder wealth. The capital structure data of 100 IT companies in India for 6 years has been used for analysis. It optimizes capital structure to minimize cost. It analyses capital structure from the investor's perspective. It tries to establish a connection between capital structure and business revenue as well as capital structure and profitability. Optimization has been done based on statistical methods such as measures of central tendency, ratio analysis, and simple regression. The findings are that the return on capital employed decreases with an increase in debt. However, some of the limitations of this study are that it applies only to IT companies, and the only variable taken into account is profitability from revenue and cashflows. There are various other factors that influence the capital structure of the company like true cost over a relatively long and extended period (debt continues to give tax benefits till it is paid off completely whereas equity shareholders have to be given returns continuously), flexibility to use the funds for the intended purposes in order to maximize cash flows. In addition to the financing costs (interest and profit returns), the cost of acquiring the funds from the sources also affects profitability. The major benefit of this study is that it separately analyses the capital structure of companies with small, medium, and large asset bases hence taking into account the size and nature of the company for determining capital structure (Shailaja, 2019). The objective of our research is to apply OR techniques to develop a model that will optimize the capital structure of a company taking into account all the relevant constraints.

A model based on logistic regression where the optimal capital structure of a company has been determined based on the probability of financial distress. This is also known as the trade-off approach. An algorithm is used to calculate the future probability and cost of financial distress and based on that the optimal level of debt for the company is determined. It is basically an indicator of the maximum amount of debt that could be serviced by the company in the future. The importance and relevance of this approach stem from the fact that it gives effect to the tax shield phenomenon of debt and also helps to estimate the cost of raising future capital based on the risk factors. However, determining the amount of financial leverage only from a risk standpoint is still a myopic way of treating capital structure. The type and size of the company as well as the company life cycle stage need to be given some amount of weight while determining the level of financial leverage. Just because a company can service a certain level of debt doesn't mean it is the optimal level as fixed contractual payments could hamper growth if the company is in the early growth stage. Different models could be created for different sizes of companies (Pirogova, Makarevich, Ilina, & Ulanov, 2019).

Myers and Majluf (1984) developed the Pecking Order Theory based on the asymmetry of information between internal stakeholders and external providers of the firm. Unlike other methods, the pecking order theory does not attempt to find an optimal capital

structure by studying the trade-off between the advantages and disadvantages of financing through debt. Instead, this theory assumes that a company complies with a given hierarchy, and thus, companies follow steps in an established pecking order which allows them to raise finance in the most efficient manner, as they prefer internal financing to external financing. The order is as follows:

1. Use all retained earnings available;
2. Issue debt;
3. As a last resort, issue equity

The pecking order is important because it indicates to the public how the company is performing. If a company is financed internally, that indicates stability, whereas if a company finances itself through debt, it is a sign that management is confident in the company's ability to meet its monthly obligations. However, if a company finances itself through the issue of new stock, it is normally seen as a negative signal, as it indicates that the company considers its stock overvalued and seeks to make money prior to the decline of its share price.

The steps to determine the optimal capital structure, maximize the profit (EPS) and corporate value (stock price), and minimize the cost of capital (WACC) are to first calculate the capital structure by analysing the company's capital structure from 2011 to 2015 (ratio of total debt and total equity). Second, calculate the leverage ratio (debt ratio and debt to equity ratio/ DER). Third, calculate the profitability (EPS). Fourth, see the corporate value from the stock price. Fifth, check for the optimization of capital structure by comparing the company's capital structure, the smallest cost of capital, profits of the largest, and stock prices of the largest since the year 2011 - 2015. And lastly, use MS. Excel 2010 to calculate the financial ratio. According to the findings, the company has the best capital structure according to Brigham and Daves (2007) and Modigliani and Miller's trade-off theory models (1958). The capital structure of each company is unique. In this study, the pecking order theory is inappropriate and cannot be considered ideal. (Effendi, 2017)

The goal of this study was to figure out the best capital structure for maximizing profitability and company value. They employed a method of quantitative descriptive analysis. Secondary data was also utilized. Any corporation's goal is to increase shareholder wealth and corporate value. This can be accomplished through capital structure optimization. For links with other financial choice variables, the capital structure is also one of the most complex parts of the financial decision. They selected 12 companies for their research, which were consistent from 2011 to 2015. The researcher employs two theories to determine the Optimal Capital Structure: trade-off theory and pecking order theory.

3. ANALYSIS AND FINDINGS

3.1 Case

ABC Ltd. is a publicly listed company that wants to raise further capital for a greenfield project. It needs 10 lakh Rupees initially to acquire the land and further capital to setup the facility after they get the permissions. The company wants to optimize the capital structure such that the cost of capital for the company is minimized. The cost of equity (Ke) is 13%, the cost of preference share capital (Kp) is 8% and the cost of debt (Kd) is 11%. Due to risk factors and limited ability to service interest payments the company wants the owned funds to be at least twice that of the fixed cost bearing capital. However, debt is very advantageous for the company as it is a cheaper source of funds and it provides tax benefits as well. After taking these benefits into account the company has arrived at a conclusion that at least 2 lakh Rupees of debt is to be raised. Simplex method is used to illustrate how the capital structure can be optimized by giving effect to the variables affecting fund requirements of a company.

Find solution using Simplex method (BigM method)

Let x1, x2 and x3 represent the amounts of equity share capital, preference share capital and debt respectively.

MIN Z = 0.13x1 + 0.08x2 + 0.11x3
subject to
x1 + x2 + x3 >= 1000000
x1 - 2x2 - 2x3 >= 0
x3 >= 200000
and x1,x2,x3 >= 0

Solution:

Step 1: Standardisation

Problem is

$$\text{Min } Z = 0.13x1 + 0.08x2 + 0.11x3$$

subject to

$$x1 + x2 + x3 \geq 1000000$$
$$x1 - 2x2 - 2x3 \geq 0$$
$$x3 \geq 200000$$

and $x1, x2, x3 \geq 0$;

The problem is converted to canonical form by adding slack, surplus and artificial variables as appropriate.

1. As the constraint-1 is of type '$\geq$' we should subtract surplus variable $S1$ and add artificial variable $A1$

2. As the constraint-2 is of type '≥' we should subtract surplus variable $S2$ and add artificial variable $A2$

3. As the constraint-3 is of type '≥' we should subtract surplus variable $S3$ and add artificial variable $A3$

After introducing surplus and artificial variables

$$\text{Min } Z = 0.13x1 + 0.08x2 + 0.11x3 + 0S1 + 0S2 + 0S3 + MA1 + MA2 + MA3$$

subject to

$$x1 + x2 + x3 - S1 + A1 = 1000000$$
$$x1 - 2x2 - 2x3 - S2 + A2 = 0$$
$$x3 - S3 + A3 = 200000$$

and $x1, x2, x3, S1, S2, S3, A1, A2, A3 \geq 0$

Step 2:

Table-1: First Simplex Table

Iteration-1		*Cj*	0.13	0.08	0.11	0	0	0	*M*	*M*	*M*	
Basis	***CB***	***Bi***	***x*1**	***x*2**	***x*3**	***S*1**	***S*2**	***S*3**	***A*1**	***A*2**	***A*3**	**MinRatio *Bi/x*1**
*A*1	*M*	1000000	1	1	1	-1	0	0	1	0	0	1000000/1=1000000
***A*2**	*M*	0	**(1)**	-2	-2	0	-1	0	0	1	0	0/1=0→
*A*3	*M*	200000	0	0	1	0	0	-1	0	0	1	---
Z*=1200000*M		***Zj***	**2*M***	**-*M***	**0**	**-*M***	**-*M***	**-*M***	***M***	***M***	***M***	
		Cj-Zj	-2*M*+0.13↑	*M*+0.08	0.11	*M*	*M*	*M*	0	0	0	

Negative minimum Cj-Zj is -2M+0.13 and its column index is 1. So, the entering variable is x1.

Minimum ratio is 0 and its row index is 2. So, the leaving basis variable is A2.

∴ The pivot element is 1.

Entering =*x*1, Departing =*A*2, Key Element =1
*R*2(new)=*R*2(old)
*R*1(new)=*R*1(old) - *R*2(new)
*R*3(new)=*R*3(old)

Step 3:

Table-2: Second Simplex Table

Iteration-2		*Cj*	0.13	0.08	0.11	0	0	0	*M*	*M*	
Basis	***CB***	***Bi***	***x*1**	***x*2**	***x*3**	***S*1**	***S*2**	***S*3**	***A*1**	***A*3**	**MinRatio *Bi/x*3**
*A*1	*M*	1000000	0	3	3	-1	1	0	1	0	1000000/3=333333.3
*x*1	0.13	0	1	-2	-2	0	-1	0	0	0	---
***A*3**	*M*	200000	0	0	**(1)**	0	0	-1	0	1	200000/1=200000→
Z*=1200000*M		***Zj***	**0.13**	**3*M*-0.26**	**4*M*-0.26**	**-*M***	***M*-0.13**	**-*M***	***M***	***M***	
		Cj-Zj	0	-3*M*+0.34	-4*M*+0.37↑	*M*	-*M*+0.13	*M*	0	0	

Negative minimum Cj-Zj is -4M+0.37 and its column index is 3. So, the entering variable is x3.

Minimum ratio is 200000 and its row index is 3. So, the leaving basis variable is A3.

∴ The pivot element is 1.

Entering =*x*3, Departing =*A*3, Key Element =1

*R*3(new)=*R*3(old)
*R*1(new)=*R*1(old) - 3*R*3(new)
*R*2(new)=*R*2(old) + 2*R*3(new)

Step 4:

Table-3: Third Simplex Table

Iteration-3		*Cj*	0.13	0.08	0.11	0	0	0	*M*	
Basis	***CB***	***Bi***	***x*1**	***x*2**	***x*3**	***S*1**	***S*2**	***S*3**	***A*1**	**MinRatio *Bi/x*2**
***A*1**	*M*	400000	0	**(3)**	0	-1	1	3	1	400000/3=133333.3333→
*x*1	0.13	400000	1	-2	0	0	-1	-2	0	---
*x*3	0.11	200000	0	0	1	0	0	-1	0	---
***Z*=400000*M*+74000**		***Zj***	**0.13**	**3*M*-0.26**	**0.11**	**-*M***	***M*-0.13**	**3*M*-0.37**	***M***	
		Cj-Zj	0	-3*M*+0.34↑	0	*M*	-*M*+0.13	-3*M*+0.37	0	

Negative minimum *Cj-Zj* is -3*M*+0.34 and its column index is 2. So, the entering variable is *x*2.

Minimum ratio is 133333.3333 and its row index is 1. So, the leaving basis variable is *A*1.
∴ The pivot element is 3.

Entering =*x*2, Departing =*A*1, Key Element =3
*R*1(new)=*R*1(old)÷3
*R*2(new)=*R*2(old) + 2*R*1(new)
*R*3(new)=*R*3(old)

Step 5:

Table-4: Fourth Simplex Table

Iteration-4		*Cj*	0.13	0.08	0.11	0	0	0	
Basis	***CB***	***Bi***	***x*1**	***x*2**	***x*3**	***S*1**	***S*2**	***S*3**	**MinRatio**
*x*2	0.08	133333.3333	0	1	0	-0.3333	0.3333	1	
*x*1	0.13	666666.6667	1	0	0	-0.6667	-0.3333	0	
*x*3	0.11	200000	0	0	1	0	0	-1	
***Z*=119333.3333**		***Zj***	**0.13**	**0.08**	**0.11**	**-0.1133**	**-0.0167**	**-0.03**	
		Cj-Zj	0	0	0	0.1133	0.0167	0.03	

Since all *Cj-Zj*≥0

Hence, optimal solution is arrived with value of variables as:

*x*1=666666.6667, *x*2=133333.3333, *x*3=200000

Min *Z*=119333.3333

Step 6: Solution
Therefore, the optimal capital structure of the company can be achieved with ₹666666.6667 equity share capital, ₹133333.3333 preference share capital and ₹200000 debt. The cost of capital is minimised to ₹119333.3333.

4. CONCLUSION
Thus, the appropriate implementation of the Big M Simplex method of LPP in the case helps to arrive at a suitable capital structure for the company that not only minimizes cost but also optimizes it in a way that is company specific. The model also returns an optimized figure for the amount of funds to be raised considering the various aspects. In the above case the optimal fund raise of the company should be Rs 1000000 to maintain financial stability. Out of the total requirement the majority portion of Rs 666666.67 is to be raised in the form of equity even though it has the highest cost thus showing the impact of risk profile of the company. The debt to be raised stands at Rs 200000 ($1/5^{th}$ of the total capital) even though it bears a higher fixed payment than preference share capital showing the impact of the tax benefit that debt provides. Lastly, by giving consideration to the sheer advantage of lowest cost, the model suggests an amount of Rs 133333.33 to be raised through preference shares even though it lacks other significant benefits as the main objective of the study was to minimize the cost of capital. This shows that the research gives a more holistic and bird's eye view of the capital structure of the company since it is a multi-variable mathematical model that solves a critical financial problem. The key lies in its simplicity and flexibility to be applied to all companies while considering each of their unique factors such as their respective risk profiles, tax slab rates ad fund requirements as per size, industry, project, etc. The model can be

successful in avoiding a certain degree of financial distress that is a nightmare for various stakeholders at a micro as well as macro level.

5. LIMITATIONS

(a) Operations research techniques do not account for the human element in business. For example, an investor with the highest number of shares in the firm may demand that a fixed percentage of funding be used in a scenario that is not the most viable according to operations research.
(b) Other qualitative factors such as dilution of control due to additional shareholders although important are not taken into consideration as they cannot be quantified.
(c) There exists a certain information gap between the OR specialists and managers. The OR specialists are not well-versed with the business problems and the managers do not completely understand the complicated working of OR, due to which they are hesitant to adopt such models.
(d) When the basic parameters are subject to constant changes, including them in the OR model is costly.
(e) A prerequisite for the simplex method is that the linear programming problem must be expressed in the standard form but not all problems appear in such a form. Thus, they first have to be converted and only then they can be solved further. This is difficult in some cases.
(f) A huge disadvantage of the simplex method is that the number of tables increases exponentially with the number of constraints which becomes extremely time-consuming, complex and costly.
(g) This method does not guarantee integer-valued solutions. In such a scenario where the capital structure is to be optimized, raising funds with decimal values is infeasible and rounding off the solution will not yield the optimal value then.

6. RECOMMENDATIONS

(a) This model can be developed using the Interior point method which is generally better for large-scale problems. Here the iteration count is independent of the size of the problem and it is faster to achieve optimality due to the lesser number of iterations. However, it is relatively more expensive than the simplex method.
(b) Additionally, integer programming can be explored here which will ensure that the decision variables have integer values.

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