R&D Portfolio Allocation & Capital Financing

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ABSTRACT

The paper offers a straightforward method for estimating R&D portfolios that maximize shareholders' utility. R&D portfolios are generally associated with high returns and high risks. As such, an impressive body of literature has highlighted the risks linked with R&D portfolio allocations. Nevertheless, the role of financing strategies in portfolio allocation has been neglected, and this provides us with the incentive to explore this issue further. As entrepreneurs can feel constrained in terms of budgeting and risk diversification when planning an R&D portfolio, in this paper we propose a linear model which allows us to evaluate the utility of external financing strategies. We discuss the impact of capital budgeting on the choice of R&D portfolio and internal shareholders' benefits and find optimal solutions under different scenarios of capital markets. Firms get more flexibility in their choice of R&D portfolios and increase internal shareholder benefits with the aid of the modeled optimization process. [1]

***Keywords*：** *R&D portfolio, financing strategies, capital allocation*

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INTRODUCTION

R&D portfolios are associated with the features of relatively high risk and high returns in comparison with other types of projects in the firm. Hence, the correlation between risk and returns is a crucial issue when it comes to selecting a pertinent R&D portfolio. Recent studies on R&D portfolios tend to highlight the degree of risk linked with the selection of a certain R&D portfolio. Graves et al. (2000) attempt to ascertain the maximum portfolio rate of return under minimum portfolio risk, while others endeavor to apply the Gini coefficient method (Ringuest et al., 1999) and risk-mitigating methods (Ringuest and Graves, 2005) to calculate the portfolio risk.

Problems such as a shortage of funds and undiversified risk may befall entrepreneurs in the process of R&D portfolio management. These call for capital to be raised from outside sources, or for more shareholders to be brought in by issuing substantial amounts of new shares. The cost of capital when seeking additional funds depends on the level of supply and demand in the market, and because the information is asymmetrical between the fund suppliers and the firm, the cost of capital may be relatively high. The greater part of the previous literature on R&D allocation has not taken much account of the impact of different sources of additional capital on the choice of an R&D portfolio and the welfare of internal stakeholders. Therefore, in this paper, we propose a linear model that enables firms to evaluate the benefits secured by accessing outside sources of capital.

We first illustrate the relationship between the source of capital and R&D portfolios according to the theory of capital budgeting. Then, the decision to raise funding and its benefit to R&D portfolio allocation are accessed, and a fictitious R&D case is conducted together with a sensitivity analysis applied to the utility model to examine the condition of market capital supply and the best choice of a portfolio of R&D projects.

THEORETICAL BACKGROUND

According to the theory of capital budgeting, when evaluating their investment projects, firms should reflect on the performance of the project, the cost of capital and the required level of additional funds in order to ensure an optimal investment portfolio. The source of additional capital could be affected by the information asymmetry in the capital market (Myers, 1977) and the level of capital can be decided by the financing leverage and payback ability of the firms. The firm's optimal financing leverage indicates the amount and cost of addition capital that it could raise from the market. The initiative of capital budgeting is illustrated in Figure I; the investment opportunity schedule (IOS) is ranked according the internal rate of return (IRR) and the amount of available external capital. The marginal cost of capital

[1] We acknowledge the useful comments from participants at the 2007 Chinese Society for Management of Technology (CSMOT) Conference

(MCC) schedule indicates the marginal cost of each available source of capital; this is generated by the difference between the flotation cost and the expected rate of return. The MCC line is used in estimating the expected net cash flows when conducting R&D projects. Hence the optimal cost budgeting is extrapolated by the cross points of the MCC and IOS lines. The following graph shows that, with access restricted to internal capital, the optimal portfolio should consist of only A and B projects. If external capital is available, a portfolio with projects A, B and C should be considered. Finally, project D provides an outcome lower than the cost of capital return; hence, it should not be considered in either scenario.

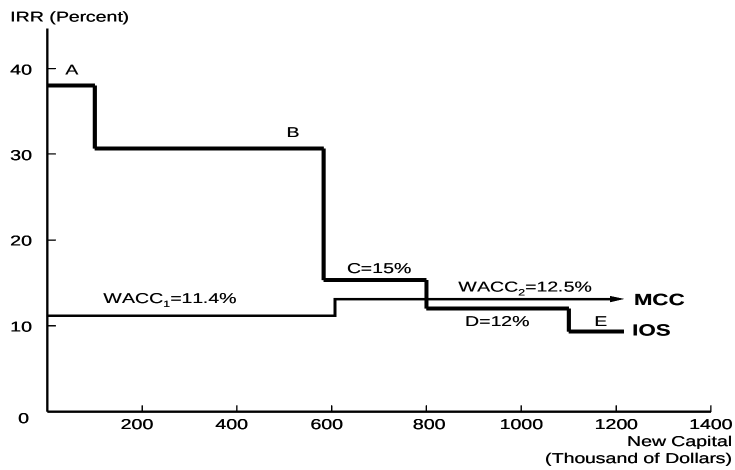


Figure I. Optimal Capital Structure

THE TWO FINANCING RESOURCES

We can further divide the sources of financing into “equity” and “debt”; these two alternatives for capital can have different impacts on firm cash flows.

Equity

The providers of equity capital supply the funds in the form of income from outside shareholders seasonally throughout the term of issuance. The proportion and the value of new shares are determined by the negotiating ability of the inside and outside shareholders. The power of negotiation is underpinned by the supply and demand of the capital and the degree of asymmetry of the information in the market. When internal shareholders possess greater power while negotiating with external shareholders, internal shareholders retain a relatively low cost of capital.

Due to the asymmetry of the information, external shareholders may receive less information than internal shareholders, which may lead them to over-estimate a firm’s value. As a result, the external shareholders could in the end pay a higher cost for capital than for cash flows that could be distributed. Nevertheless, if there is a Lemon market (Akerlof, 1970), a good firm may also be under-valued. This implies that an appalling firm can be over-valued, while a superior firm can also be under-valued.

Debts

The higher the financial leverage, the higher the risk premium required by creditors in order to compensate for the potential default risk. This risk premium can be anticipated according to the relevant credit ranking, the firm’s relationship with banks and the market credit risk premium.

In fact, there should be a trade-off effect between equity and debt financing. To a firm’s internal shareholders, raising capital from an equity seasonality issuance induces so-called dilution effects in terms of the earnings per share, and hence reduces the utility of the existing shareholders. Conversely, high debt leverage can cause banks to set a higher compulsory risk premium. Given such a scenario, it is clear that many firms face a dilemma when considering additional funding resources.

From the above discussion, it can be seen that, in terms of planning capital budgeting, firms have to consider: (a) the risk level and payoffs linked to any new R&D portfolio; (b) retained earnings; and (c) demand and supply in relation to various financing resources. According to the theory of capital budgeting, the selection of an investment portfolio and the choice of financing resources should be a collective decision and should be recognized synchronically. The goal remains the pursuit of the maximum utility for the internal shareholders. Figure II presents a diagram of the R&D portfolio decision-making procedure.

Below we structure a straightforward model to integrate the financing decision with the R&D portfolio allocation. The analysis can be carried out simply using a standard Excel spreadsheet under the Solver function. We also present examples which consider various factors and use linear programming to obtain the optimal choice.

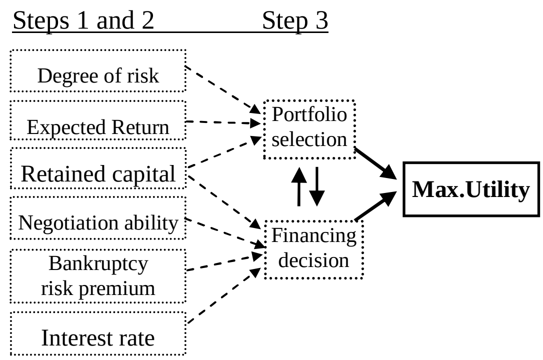


Figure II. The R&D Portfolio Decision-making Procedure

FIVE-STEP ANALYSIS

The analysis leading to optimal R&D portfolios will be performed in the following four-step procedure:

1. Estimate conditions in the R&D portfolio, including expected rate of returns, degree of risk, amount of capital required and degree of correlation between each investment project in the portfolio.
2. Set the internal conditions of the firm and the environment of the external capital market. Conditions include degree of risk aversion of the firm decision-makers, internal capital availability, negotiation ability with external shareholders, risk premium of leverage risk and market interest rates. The negotiation ability is determined according to the firm's internal available capital and the demand and supply of external capital available in the market.
3. Using Excel, we apply a simple linear program which maximizes utility under a given level of related factors. The Solver offers solutions for an optional amount of external capital and the best R&D portfolio, thereby achieving maximum utility for the internal shareholders.
4. Applying Sensitivity analysis, we attempt to estimate maximum utility under different pre-set conditions using the most feasible scenario as the basis in order to check the robustness of the model.

SIMULATION OF THE MAXIMUM UTILITY--AN R&D PORTFOLIO WITH FOUR INVESTMENT PROJECTS

To substantiate the evidence for the above model, we now demonstrate an analysis of a newly founded firm with four research and investment projects, to simulate the utility of budgeting in relation to various factors within our theoretical model.

Assuming there is a start-up firm with relatively high risk, external investors are likely to express enthusiasm to invest in this firm. Nevertheless, banks hesitate to lend money to this type of firm. In Table 1, we assume: (a) Internal Capital equals 5 million dollars; (b) the negotiation ability of the internal shareholders compared to the external shareholders equals 1.1, which means internal shareholders' cashflow rights are 1.1 times higher than their devoted capital; (c) the multiplier of the bankruptcy risk premium equals 0.5; and (d) assuming the market T-bill rate equals 3%, the borrowing rate of the firm equals the T-bill rate plus the multiplier of bankruptcy risk premium (0.5 from (c)) multiplied by the debt ratio.

Table 1. An R&D Portfolio Consists of a Maximum of Four Investment Projects

A. Conditions for each project

Investment Project	Avg. annual return	STDV. of the annual return	Required budget (in $10,000)	Correlation			
				Project A	Project B	Project C	Project D
Project A	0.07	0.9	200	1	0.7	0.8	0.6
Project B	0.13	0.9	300	0.7	1	0.1	0.3
Project C	0.08	0.1	150	0.8	0.1	1	0.2
Project D	0.20	0.7	280	0.6	0.3	0.2	1

B. State of the environment

Parameter	Internal capital (in $10,000s)	Degree of risk aversion	Negotiation ability	External shareholder dilution	Multiplier of bankruptcy risk premium	Interest rate (%)	Borrowing rate (%)
Benchmark	500	0	1.1	1.00	0.5	3	6

RESULTS OF THE SIMULATION

Part 1. Impacts of the financing strategy on R&D portfolio allocation

Disregarding consideration of the external capital (Equity), firm management is assumed to be risk neutral; hence, selecting an R&D portfolio is subject to the expected return and amount of internal capital. Therefore, Table 2 shows that, with 5 million of internal capital and lacking any external capital, the optimal utility is 570 units, and the total investment amount equals 4.8 million – Projects A and D are feasible choices.

Table 2. Simulation Results of Financing Decision and Fund Allocation

Scenarios	No external Capital	Benchmark
Internal Capital (in $10,000)	500	500
External Debt (in $10,000)	0	30
External Capital (in $10,000)	0	50
Utility	570	643.28
Expected Revenue (in $10,000)	570	675
Total investment amount (in $10,000)	480	580
Expected total risk	113152	143068
Degree of risk aversion	0	0
Negotiation ability	-	1.1
External shareholder dilution	-	1
Multiplier of bankruptcy risk premium	-	0.5
Basis interest rate (%)	-	3
Borrowing rate (%)	-	5.73
Project portfolio	AD	BD

With access to external capital, the amount of capital is increased; hence, a portfolio consisting of Projects B and D surpasses the portfolio of Projects A and D, and yields 675 as the total utility. Furthermore, the total amount of investment, internal shareholders' utility and revenue to all shareholders for a portfolio consisting of Projects B and D exceeds that of the portfolio of Projects A and D, if we neglect to consider the financing decision.

The simulation also shows that, regarding the expected return of the Project, D>B>C>A; also, Projects D and B require a supplementary budget. To summarize, without external funding, Project A would be the best selection; otherwise, Projects D and B are preferable, due to their higher utility.

Part 2. Impact of altering the scenario

Our model can serve the function of estimating budget utility in a sensitivity analysis. By applying the most likely scenario as the benchmark, the framework can be further extended to calculate the optimum R & D portfolio when different variables are in play. We estimate the following scenarios:

a. Adjustment of the negotiation ability with external shareholders

If the parameter of negotiation ability with external shareholders increases from 1.1 to 1.5 (Table 3, scenario 1(a)), implying an improved access to external funding, Project A can be selected as it increases the expected utility by 33.30%.

Table 3. Simulation Results of Altering the Parameters

Scenario	Benchmark	Scenario 1(a) Adjustment of the negotiation ability with the external shareholders	Scenario1 (b) Adjustment of the negotiation ability with the external shareholders	Scenario 2 (a) Adjustment of the bankruptcy risk premium	Scenario 2 (b) Adjustment of the bankruptcy risk premium	Scenario 3 (a) Change in the degree of risk aversion	Scenario 3 (b) Change in the degree of risk aversion
Internal Capital (in $10,000)	500	500	500	500	500	500	500
External Debt (in $10,000)	30	30	68.44	180	380	0	0
External Capital (in $10,000)	50	250	11.56	50	50	230	50
Utility	643.28	857.5	293.19	645.71	656.97	521.16	102.7
△Utility (%)	-	33.3	-54.42	0.38	2.13	-18.98	-72.19
Expected Revenue (in $10,000)	675	889	675	837	1051	837	378
Total investment amount (in $10,000)	580	780	580	730	930	730	430
Expected total risk	143068	285844	143068	145279	292375	145279	39817
Degree of risk aversion	0	0	0	0	0	0.001	0.005
Negotiation ability	1.1	1.5	0.5	1.1	1.1	1.1	1.1
External shareholder dilution	1	1	0.49	1	1	0.75	1
Multiplier of bankruptcy risk premium	0.5	0.5	0.5	0.1	0.01	0.5	0.5
Basis interest rate (%)	3	3	3	3	3	3	3
Borrowing rate (%)	5.73	5	9.69	6.27	3.69	3	3
Project portfolio	BD	ABD	BD	BCD	ABCD	BCD	CD

Nevertheless, if the negotiation ability with the external shareholders declines from 1.1 to 0.5 (Table 3, scenario 1(b)), compared with the benchmark groups, the internal shareholder utility drops dramatically by 54.42% even as the budget, the total amount of investment and the total revenue stay unchanged.

b. Adjustment of the multiplier of bankruptcy risk premium

Suppose the multiplier of bankruptcy risk premium is drawn down from 0.5 to 0.1 (Table 3, scenario 2(a)); then the borrowing rate could decrease as the banks may require a lower risk premium. With better leverage ability, firms would choose Project C and induce a 0.38% increase in utility. If the multiplier of bankruptcy risk premium falls further to 0.01, eligible firms will borrow more funds and invest in all four projects; in this case the total utility would increase by 2.13%.

c. Change of the degree of risk aversion

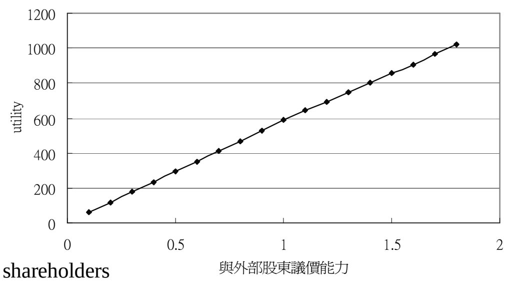
We initially assume that the management of a firm is risk neutral, but it might be risk averse. In practice, different management and firm attributes may exhibit different degrees of risk aversion. The degree of risk aversion is subject to the risk of individual projects and the correlation between the projects. If the degree of risk aversion increases by 0.001, firms prefer to use external capital (Equity) rather than incurring debt, in order to diversify their risk. Hence Projects B, C and D could be selected in an R&D portfolio. An increase of 0.005 in the degree of risk aversion also endorses the above findings and the amount of external funding may also decrease as the firm becomes more reserved; this makes project A preferable to project B.

RESULTS OF SENSITIVITY ANALYSIS

We conjecture that improving the “Negotiation ability with external shareholders” and “Multiplier of bankruptcy risk premium” allows firms to increase their utility through external capital (Equity) and debt financing, and thereby achieve enhanced utility. We now employ a sensitivity analysis to delineate various degrees of “Negotiation ability with external shareholders” and “Multiplier of bankruptcy risk premium” in relation to firms’ utility.

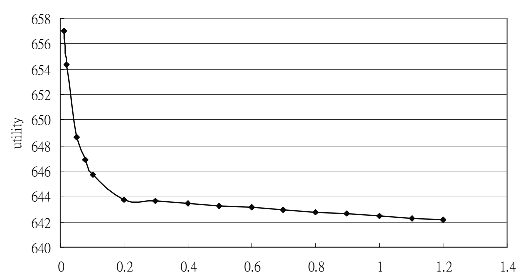
Figure III illustrates the relationship between the “Negotiation ability with external shareholders” and the total internal shareholder utility. It is a positive linear relationship, representing that a 1% increase in negotiation ability can raise total utility by 0.99%. Managers can assess the marginal benefit associated with enhancing the negotiating ability in order to set their own target utility.

Figure IV demonstrates the “Multiplier of bankruptcy risk premium” in relation to firms’ utility. It shows that the relationship follows a convex line near the starting point, and that the total utility decreases as the risk premium increases. The results show that when the multiplier is 0.1, it has a 0.007 elasticity; when the multiplier is 0.2, it has a 0.003 elasticity; and when the multiplier is 0.3, it has a 0.001 elasticity. We can see from the graph that the marginal utility rises significantly when the bankruptcy risk premium multiplier drops below 0.2.



Negotiation ability with external shareholders

Figure III. “Negotiation ability with external shareholders” in relation to firms’ utility



Multiplier of bankruptcy risk premium

Figure IV. “Multiplier of bankruptcy risk premium” in relation to firms’ utility

CONCLUSIONS

The paper postulates a model based on the capital budgeting theory in relation to a firm’s financing decision, to help analyze its optimum capital allocation for R&D projects. It takes a step towards alleviating the difficulty of project budgeting for firm management. We construct a model to show that firms’ financing resources are susceptible to several parameters and their levels. By altering the magnitude of various parameters under different scenarios, a sensitivity analysis can be conducted to estimate the correlation coefficient of each parameter with regards to the condition of a firm’s financing resources. This model is relatively easy to apply and also takes both equity and debt financing into account, unlike previous efforts on this topic. Further, there are no constraints regarding the degree of risk aversion for management.

Throughout the scenario, the analysis takes the condition of financing resources into consideration; in this way, firms are able to extrapolate the budget with the highest utility and thereby choose the most suitable portfolio. We propose applying the most likely condition as the benchmark for the sensitivity analysis, to find the impact of varied parameters on the utility to the firm.

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Appendix: Methodology

This paper aims to shed light on some of the factors involved in a firm's financing decisions. The scope of empirical analysis first includes conducting a utility model with expected returns, degree of risk averseness, amount and cost of debt financing and ratio of cash distribution from internal shareholders, to estimate the utility of a target budget for individual investment projects.

Utility Function

$$\max_{bud_i, F, OE}\left[\sum_{i=1}^{m} bud_i(1+r_i) - A*\sum_{i=1}^{m}\sum_{j=1}^{m} bud_i*\sigma_{ij}*bud_j - F(1+fi)\right]*e \quad ..(1)$$

bud_i: Utility of target budget for project i, i=1~m

r_i: Rate of return of project i

A: Degree of risk averseness of the firm

σ_{ij}: Covariance matrix between each project.

F: Amount of debt financing

fi: Cost of debt financing

e: Ratio of cash distribution from internal shareholders

The total rate of return is the sum of the individual project; the degree of risk averseness and the total amount of debt financing as deductions from the utility. The debt financing cost can be determined by both the market rate and the borrowing rate, and can be expressed as the following equation. The higher the leverage ratio of the firm, the higher the risk premium can be; hence the more costly the borrowing rate asked by the creditor.

$$fi = bi + \frac{F}{IE + OE} * b \quad \ldots (2)$$

fi: Borrowing rate

bi: Market rate

F: Amount of debt financing

IE: Internal capital

OE: External capital (Equity)

b: Multiplier of bankruptcy risk premium

The ratio of cash distribution from internal shareholders is determined by the relative proportion of shares and the ability to negotiate with external shareholders, which can be expressed as follows:

$$c * \frac{IE}{OE + IE} = e \quad \ldots (3)$$

c: Negotiation ability with external shareholders

IE: Internal capital

OE: External capital (Equity)

e: The ratio of cash distribution from internal shareholders

The negotiation ability with external shareholders is determined by the demand and supply of the available capital in the market and the degree of asymmetric information. When there is a great deal of market capital but a shortage of good investment projects, internal shareholders appear to have better bargaining power; thus the ratio of cash distribution from internal shareholders is higher than the internal capital and hence, c is greater than 1.

Above and beyond, the total eligible budget for investment is limited by the amount of debt financing and internal and external capital (Equity). A Limited Equation can be written as follows:

$$st. \quad \sum_{i=1}^{m} bud_i \le F + IE + OE \quad \ldots (4)$$

bud_i: Utility of target budget for project i, i=1~m

F: Amount of debt financing

IE: Internal capital

OE: External capital (Equity)