RISK AND SENSITIVITY IN CAPITAL BUDGETING

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–"And time yet for a hundred indecisions, And for a hundred visions and revisions, Before the taking of a toast and tea.", - T.S. Eliot

1. TYPES OF RISK IN CAPITAL BUDGETING

A. & B. Technological and Timing Uncertainty:

–Most of this risk can be consider firm idiosyncratic. Thus investors and firms can diversify away this risk.

- The contribution of an individual project's technological uncertainty to total portfolio risk vanishes in the limit in a portfolio. It usually only takes about 20 stocks for the idiosyncratic risk to become 2nd order.
- However, an individual firm while not "valuing" this risk - still would want to estimate the correct cash flows that are associated with the project.
- We shall see the distinction between adjusting cash flows vs. adjusting the discount rate in Section 3 of this note.

C. Uncertain Project Cash Flows

The Basic Problem: EVALUATING NPV

– WHY + NPV?

POSITIVE NPV FROM:

1) a good project, or 2) a bad job of estimating NPV

1. Projected versus Actual Cash Flows

– Estimated cash flows are expectations or averages of possible cash flows, not exact figures.

– EX. LEMONS PROBLEM WITH CARS.

2. Forecasting Risk

– forecasting risk - The danger of making a bad (money losing) decision because of errors in projected cash flows. This risk is reduced if we systematically investigate common problem areas.

D. SOURCES OF PROJECT VALUE. (DISCRETE RISK)

WHAT AFFECTS CASH FLOWS - KEEPS THEM "HIGH"?

- competitive edge
- Often associated with patent rights and technological edges,
- economic axiom that in a competitive market excess profits (the source of positive NPV) are zero.
- monopoly rents - profits above those necessary to keep resources employed in an endeavor that accrue as a result of being the only one able or allowed to do something.

1.2 COMPANY RISK: PORTFOLIO OF PROJECTS

Project that is highly risky may be of low risk to the corporation.

- OIL COMPANY can reduce discovery risk but cannot eliminate price risk.
  - $E(r_i) = \Sigma p_{is} r_{is}$: An individual project's expected return, weighted by the probability of each outcome or state s.
- The mean expected return stays constant across multiple projects: $E(\overline{X}) = E(r_i)$
- The variance of the mean decreases with multiple draws from the same distribution - e.g. oil well drilling risk, possibly new product introductions.

  $VAR(\overline{X}) = \sigma^2 / n$:

- The total risk of the firm can be reduced by two imperfectly correlated projects, X_1 and X_2, however no reward or higher return, will accrue to the firm if the investors could diversify themselves.

- Only if the company is in an unique position to diversify could current owners yield any return above the normal risk adjusted return (by investors demanding less return - paying more).

- Contrast this situation to draws from a distribution over time that are correlated with the market - such as oil prices (although some diversification may be possible from alternative energy sources.) Investors will receive a higher risk adjusted return in this case.

Impact of Total Risk:

– Is there any value to diversification at the firm level? To the extent that bankruptcy risk is non-diversifiable and bankruptcy costs are significant, a decrease in total risk can have value because investors cannot diversify across all firms.

On Sales and customers:	Future Service and reliability.
	Large costs of switching suppliers
	Lost up-front relationship specific costs.
On Bankruptcy Costs:	Higher Supplier Charges / trade credit
	Cutback in R&D, advertising.
On Operating Costs:	Higher Labor Costs / Higher costs
	of investing in long term relationship.
	Debt restrictions and covenants.
On Taxes:	Loss of PV of Tax Credits.

1.3 SYSTEMATIC RISK

Investors only demand a reward for the non-diversifiable risk across companies: "Covariance with the market" for the CAPM.

- Non - systematic risk is not rewarded as investors can buy multiple companies that eliminate this risk.

- Many investments have a high variability of earnings, but a low exposure to market risk. What counts is the strength of the relationship between the firm's earnings and the aggregate earnings on all assets.

- We can measure this response by the normal stock market beta - but also by an accounting beta or a cash flow beta.

These are just like the normal beta except that changes in book earnings or cash flow are used in place of rates of returns. We would predict that firms with high accounting or cash-flow betas should also have high stock betas - and this prediction is borne out.

- (See W. H. Beaver and J. Manegold, 1975, "The Association between Market-Determined and Accounting - Determined Measures of Systematic Risk" Journal of Financial and Quantitative Analysis. Vol. 10: pp. 231-284.)

The next section explores some of these relationships by examining the sources of risk that managers can control: Operating and Financial.

2.0 WHAT CAUSES ASSET RISK?

2.1 Fixed and Variable Costs

A simplifying assumption is to make variable costs a constant amount per unit of output, i.e.,

- variable costs = quantity x cost per unit

  VC = Q x v
- Fixed costs (FC) - Costs that are constant over a period regardless of the level of sales.

Total costs, (TC) - the sum of fixed costs (FC) and variable costs (VC)

TC = FC + VC

TC = FC + (Q x v)

There is almost always some flexibility in production in deciding between fixed and variable costs. Fixed costs, however, generally magnify forecasting errors.

2.2 OPERATING LEVERAGE

A. Operating leverage

The degree to which a project or firm uses Fixed costs in production. Plant and equipment (capital intensive), and noncancellable rentals are typical sources of fixed costs.

B. Implications of Operating Leverage

Since fixed costs do not change with sales, they make good situations better and bad situations worse, i.e., they "lever" results.

C. Measuring Operating Leverage

Degree of operating leverage (DOL) - The degree to which a percentage change in Q (quantity) affects net operating income or operating cash flow.

Percentage change in OCF = DOL x percentage change in Q

$$DOL = 1 + FC/OCF$$

or

$$DOL = 1 + \frac{FC}{Q(P - v) - FC}$$

DOL depends upon the Q you start with in determining OCF above.

Example: Driving Range:

- Variable cost - fixed cost, and OPERATING LEVERAGE.

- Suppose that in this driving range you have an initial capital invested of $45,000. You project that you will make $2.70 after subtracting variable costs per bucket of balls. The capacity of the driving range is 25,000 buckets.

- Your forecast of demand is Q = 20,000 buckets. Ignoring taxes, OCF for the driving range is $9,000 and fixed costs are $45,000.

  DOL = 1 + ($45,000/$9,000) = 6

- If the number of buckets should increase by 5%, OCF should change by (6 x 5%) = 30%. (If linear at 21,000 buckets OCF = -$45,000 + ($2.70 x 21,000) = $11,700, a 30% increase.

D. Integrating Beta and Operating Leverage

We know that **financial leverage,** or the commitment to fixed debt charges, adds to the Asset Beta of a firm and an investors' risk through the formula:

$$B_L = B_{Asset}[1 + (1-t)\frac{D}{E}]$$

- In the same way, Operating leverage - the commitment to fixed operating charges adds to the Asset Beta of a project.

  Noting: Cash Flow = revenue - fixed cost - variable cost where costs are variable if they depend on the rate of output.

The present value can be broken down the same way:

PV(asset) = PV(revenue) - PV(fixed cost) - PV(variable cost).
Or: PV(revenue) = PV(asset) +PV(fixed cost) + PV(variable cost)

Integrating Risk: Applying conservation of risk:

$$B_{revenue} = B_{FC}\frac{PV(FC)}{PV(rev.)} + B_{VC}\frac{PV(VC)}{PV(rev.)} + B_{asset}\frac{PV(asset)}{PV(rev.)}$$

- where FC = fixed cost and VC=variable cost.

- Now, $B_{FC} = 0$ and $B_{VC} = B_{revenue}$ as they should respond to the same underlying variable, the rate of output. Thus:

$$B_{asset} = B_{revenue}\frac{PV(rev.) - PV(\text{var. costs})}{PV(asset)} = B_{revenue}[1+\frac{PV(FC)}{PV(asset)}]$$

- This Formula shows the influence of fixed costs, FC, on the underlying asset beta. In practice, one would have to iterate between finding the PV of the asset and the discount rate - until both were consistent.

2.3 FINANCIAL LEVERAGE + OPERATING LEVERAGE

Just like with operating leverage we can express the response of project cash flows (net income) to a change in operating cash flows (net operating income) or in terms of a quantity sales change.

The degree of financial leverage (DFL) =

DFL = 1 + OCF/(OCF-Interest Exp.)

$$DFL = 1 + \frac{Q(P - v) - FC}{Q(P - v) - FC - Int}$$

Degree of Combined Leverage: DCL

Now, we know that managers can make both financial and operating decisions that affect risk. We want the degree of total or combined leverage (DCL), where VCF = variable cash flows:

$$DCL = 1 + \frac{\text{VCF}}{\text{OCF - Int. Expense}} = 1 + \frac{Q(P - v)}{Q(P - v) - \text{FC - Interest}}$$

– THIS Formula shows that firms with high operating leverage have an incentive to choose to have lower financial leverage in their capital structure than a firm making a similar product with lower operating leverage.

- A recent study in the Journal of Financial and Quantitative Analysis on the impact of operating leverage on financial debt ratios did indeed find this offsetting influence.

3.0 Risk Adjusted Discount Rates

There are two ways to take into account individual project risk.

1. Risk adjusted discount rates, divisional use of the CAPM.

2. Scenario analysis / simulation analysis to identify the sources of the risk.

This section of the note discusses risk adjusted discount rates while Sections 4-5 discuss ways of quantifying the sources of risk.

We can identify situations which make one vs. the other appropriate.

Risk adjusted Discount Rates (Cont.)

- Net Present Value (NPV) handles risk through adjusting the denominator used to discount cash flows. Thus risky cash flows are discounted at a higher discount rate - but **only if** they are systematic.

- A higher discount rate comes from the firm having to offer a higher return to compensate the firm for systematic risk.

- Ideally, we would want to discount each project by the discount rate appropriate for that level of systematic risk. Using one discount rate for all projects incorrectly lumps them together. It is only appropriate when projects exactly match the average risk of the firm.

3.1 Stock or industry betas / Divisional cost of capital:

You may be able to estimate betas from other companies that just operate in the specific line of business you are considering.

- Merrill Lynch, for example publishes a beta book by industry.

- These averages across industry also have the advantage that using them minimizes individual firm forecast error.

- If Digital Equipment for example is contemplating an across the board expansion, using its company beta is appropriate. However if they are proposing to invest in computer controlled machine tools, they would want to use an average of other machine tool companies.

Information on Value of assets:

– Mineral returns or real estate returns are examples of traded assets which have market prices over time. It is possible to calculate rates of return from holding that assets and then calculate a beta.

– Remember that we still have to first have to unleverage the beta from the comparable firm and then releverage it for the amount of financial leverage we have using the formula:

3.2 Adjusting the Discount Rate?

When do you **not** want to adjust the discount rate (or be careful)?

- No changes for diversifiable risk.
- Avoid "fudge" factors to offset for "potential" bad outcomes. Give bad outcomes their due weight in cash flow forecasts, rather that just trying to increase them because of things that can go wrong with the proposed investment. **Adjust cash flow forecasts first.**

For Example:

- An oil company worries about "the risk of a dry hole".
- A pharmaceutical manufacturer worries about the "risk" that a new drug which cures baldness many not be approved by the FDA.
- The owner of a hotel in a politically unstable part of the world worries about the "political risk" of expropriation.

Example: Project: Johnny's Sauce Factory

The project was considered to be of average risk, suitable for discounting at a 10 percent company cost of capital. The investment is expected to last 1 period.

Original forecast:

Possible Cash Flow	Probability	Prob. Weighted Cash Flow
1.2 Million	.25	.3 Mill.
1.0 M	.50	.5
.80 M	.25	.2

Unbiased Cash Flow / disc. rate = 1.0 Million/(1.1)

- Suppose now that the managers realize that there is a 1/6 chance that the project will have a zero cash flow.
- The managers want to adjust the present value by increasing the discount rate.

Johnny's Sauce Factory (Continued)

- However, we should just include in our forecasts of potential cash flows the $0 outcome. As long as our exposure to systematic risk did not change, we should not change our discount factor.
- It is not our exposure to economy wide risk that has changed but rather the possible outcomes. This can include an increased chance of a recession.

Possible Cash Flow	Probability	Prob. Weighted Cash Flow
1.2 Million	.25	.3 Mill.
1.0 Million	.333	.333
.80	.25	.2
0	.167	0

Unbiased Cash Flow / (1+r) = .833 Million/(1.1)

- We avoid the use of a "fudge" factor to increase the discount rate.

3.3 Firm Internal Risk Classes

The firm may also employ several different discount rates internally depending on the "risk class" of the project.

- A replacement decision may be discounted by the risk free rate or a "low risk" rate. A project to expand current operations may be put in a medium risk class and a new product project put in a "high" risk class.

Problems with this approach:

- Differentiation is difficult between systematic and non-systematic risk. Setting up the classification scheme could have people making personal decisions - avoiding examining the differences between projects.
- The rates of return assigned to each risk class should be related to market determined rates of return. It should not be company specific.
- The rates in the risk class should be determined using the closest approximation to a systematic risk based model such as the CAPM -

So, given these objections, why not use a systematic risk based model such as the CAPM from the beginning and use methods of simulating where the risk is coming from to try to measure it.

4.0 IDENTIFYING PROJECT RISK

4.1 SCENARIO ANALYSIS - "WHAT IF" ANALYSIS

4.2 SENSITIVITY ANALYSIS

4.3 SIMULATION ANALYSIS

4.4 DECISION TREE ANALYSIS

4.1 SCENARIO AND OTHER "WHAT IF" ANALYSES

What things are likely to be wrong and what will be their effect if they are?

A. Getting Started

Start with a base case - the expected cash flows - then ask "what if . . ."

Example: Simplified Driving Range

Consider the following revised example of the Driving Range.

- Rentals are expected to be 20,000 buckets a year at $3 per bucket.
- Equipment costs are $20,000, depreciated using straight-line over 5 years and have a zero salvage value.
- Variable costs are 10% of rentals and fixed costs are $45,000 per year.
- Assume no increase in working capital nor any additional capital outlays.
- The required return is 15%, and the tax rate is 15%.

  Revenues =$60,000, Variable costs=$6,000,

  Fixed costs=$45,000, Depreciation = $4,000,

  EBIT = $5,000, Taxes (15%)=750, Net income=$4,250

Thus, cash flow is $5,000 + 4,000 - 750 = $8,250.

At 15%, the five-year annuity factor is 3.352,

- so NPV based upon expected cash flows is:

  Base case NPV = -$20,000 + ($8,250 x 3.352) = $7,654

The Scenarios

The following are different versions of "what if . .".

1. Worst case - Best case scenarios: putting lower and upper bounds on cash flows. Common exercises include poor revenues with high costs, and high revenues with low costs.

If, under most circumstances, the discounted projected cash flows are sufficient to cover the outlay, we can have a high level of confidence that the NPV is positive. Beyond that, it is difficult to interpret the meaning of the scenarios, except as they might point out areas where over-optimistic estimates have crept in.

Scenario	Net income	Cash flow	%Return
Base case	$ 4,250	$ 8,250	30.2%
Worst case	-9,400	-5,400	na%
Best case	17,000	21,000	101.9%

4.2 Sensitivity Analysis

To conduct a sensitivity analysis, hold all projections constant except one, alter that one, and see how sensitive cash flow is to that one when it changes - the point is to get a fix on where forecasting risk may be especially severe.

Common exercises include varying sales, variable costs, and fixed costs.

Then:

- Plot a distribution of the final returns and values from your sensitivity analysis giving you an idea of the risk involved.
- This approach is described in more detail in David Hertz, 1979, "Risk Analysis in Capital Budgeting" Harvard Business Review. pp. 169-181.
- You should present a full picture of the potential distribution of IRR's. If you can give a picture of IRRs like Hertz does.

Critique of this analysis

It uses Internal Rate of Return - IRR. It does not adjust for the following:

- The value to the corporation - Remember the highest IRR is not the highest NPV. Thus you should also get some idea of value contribution.

- Again remember, a large distribution does not mean that these are systematic risks - it just means that there are many possible cash flows to discount, potentially at the same rate.

- The procedure thus does not adjust for risk. Just presenting the ranges may deceive someone into thinking that they are accounting for risk. IRRs make no risk adjustment.

4.3 Simulation Analysis

– Using computers, the interactions of different inputs and likely scenarios may be realized through simulating the different possible cash flows that result.

– This note will not cover simulation analysis. We will make the following limited points:

– The most important step is to provide a distribution that characterizes the uncertainty: such as final prices. This can be a very useful tool if there exists enough data to simulate the distribution. Just choosing a distribution could be very ad hoc.

– If your uncertainty is from commodity prices such as oil, simulation would work well. Oil companies and Aircraft manufacturers use simulation extensively.

LIMITATIONS

– You must use judgment in using the distribution or any probability assumptions. Remember the future may be different from the past. If possible characterized explicitly the factors that influence the distribution. If prices, a supply and demand model entered into the simulation would be important.

– In 1984, there were many groups of researchers including a group from Harvard Business School, that predicted oil prices of $60-$90 a barrel. However, as we now know even for oil, high prices cause demand to decrease and energy supply to increase. Oil was soon trading at around $10 a barrel by January, 1986.

4.4 Decision Tree Analysis

– IMPORTANT TOOL TO VISUALIZE SEQUENTIAL DECISION MAKING.
  - Decision Maker Can Change Probabilities at different points in time.
  - May be easier to visualize and convey your results vs. simulation analysis, for a "messy" problem.

  COMPUTE NPVs associated with various branches. Any dominated branches PRUNE.
  - Biggest problem is assigning the probabilities and demand forecasts. If you do not simplify the problem will get very complicated quickly.
  - Don't let the model get too complicated. Remember you are the decision maker and you should PRUNE, PRUNE, PRUNE.

  Remember: A multiplicity of possible outcomes or a wide range of outcomes does not increase the discount rate used in the analysis. Again, remember only covariances with market based risks matter.

5.0 QUANTIFYING PROJECT RISK:

BREAK-EVEN ANALYSIS.

- OPERATING LEVERAGE & BREAK-EVEN
- SALES & ACCOUNTING BREAK-EVEN
- BREAK EVEN TERMINAL VALUE

Break-even analysis is a widely used technique for analyzing sales volume and profitability. More to the point, it determines the sales volume necessary to cover costs and implicitly asks "Are things likely to go that well?"

5.1 Operating Leverage and Break-Evens

– In general, the lower the fixed costs and the degree of operating leverage, the lower is the break-even point (however you measure it). If a project can be started with low fixed costs and later switched to high fixed costs if it turns out well, this is a valuable option.

For the Following Examples:

- P = price per unit
- v = (variable) cost per unit
- Q = units or quantity
- FC = fixed costs
- D = depreciation & t = tax rate

5.2 Sales Break Even:

What sales level gives $0 net income? (assuming things are the same year to year) This happens when sales equals total costs.

Net income is Sales less total costs less taxes,

- [(Q x P) - (FC + (Q x v) + D)] x (1- t)
- At break-even net income = 0, so,
- O = [(Q x P) - (FC + (Q x v) + D)] x (1- t)

Dividing both sides by (1- t) gives sales equals total costs,

Q x P = FC + (Q x v) + D

Rearranging gives: Q = (FC + D)/(P - v)

EXAMPLE: Accounting Break-Even and NPV

Ignoring taxes for simplification:

1. First calculate Q necessary for accounting break-even. Using the simplified Fairways example -Solve for Q s.t. cover fixed costs.

   Q*(P-v) = (FC + D)

   Q = (FC + D)/(P - v)

   Q = (45,000 + 4,000)/(3 - .30) = 18,148 buckets

   Since operating cash flow = net income + depreciation,

   at Q = 18,148: operating cash flow = $0 + $4,000 = $4,000.

2. At (accounting) break-even Q, the sum of the cash flows, is just equal to the depreciable investment, and the project's payback period is exactly equal to its life.
3. A project that just breaks even on an accounting basis will have a negative NPV at any positive discount rate.

5.3 BREAK-EVEN TERMINAL VALUE

LET H = NPV WITHOUT TERMINAL VALUE

H > 0 TERM. NOT CRITICAL

H < 0 ==>

- $H + TERM^* / (1+r)^n = 0$
- $TERM^* = - H (1+r)^n$

6.0 OPTIONS IN CAPITAL BUDGETING

- Managerial Options and Capital Budgeting

Managerial options - The opportunity to change something, which is valuable.

EXTRA Contingency planning involves determining what will be done if this or that actually happens. This can be explored with "what if" analysis.

- option to expand - ignoring the option to expand can result in underestimating NPV.
- option to abandon - ability to quit a loser is valuable - ignoring the option to abandon can result in underestimating NPV
- option to wait - waiting for favorable conditions or simply for some uncertainty to be resolved, is a valuable option.

Strategic options:

- relate to flexibility that derives from a business strategy or plan.

Several points from Option Theory

- It is valuable to wait to exercise an option. Thus, unless a competitor is going to scoop you and introduce the product, it may pay to wait.
- The cost of waiting, just like a stock option, is the lost profits (dividends) that would be yours from operating the investment.
- The benefits are that you wait until uncertainty is resolved and can then take a better route or investment or equivalently you can decide not to invest at all.
- The more uncertain the outcome, the higher the value of waiting until uncertainty is resolved.

These results hold no matter what the distribution of the asset is.

– Just like in option theory, you have to assume a process that describes how the asset's or investment's returns change over time in order to get an explicit value for this option.

SUMMARY AND CONCLUSIONS

2 Different Types of Risk:

– Idiosyncratic or non-systematic: Risk that is unique to a specific project and can be diversified away.
  - How do we handle UNIQUE risk: Simulations, Scenarios - to get expected cash flows. Know where the risk comes from.
  - However the identification of this type of risk is also very important for contingency planning - both on the financial and operating sides. Have a cover for your "..." so you do not need to cover your "...".

– Systematic or Market Risk: Risk that is handled through the discount rate of the firm that comes from the capital markets.