Principles of Corporate Finance

Chapter 11. Project Analysis

Ciclo Profissional 2º Semestre / 2009

Graduação em Ciências Econômicas
Topics covered

1. The capital investment process
2. How to handle uncertainty on projects’ evaluation
   ▶ Sensitivity analysis
   ▶ Scenario analysis
   ▶ Break-even analysis
3. Monte Carlo simulation
4. Real options and decision trees
The capital investment process

1. List of investments projects planned for the coming year
   - Projects may come up from several divisions (furniture, marketing, etc) and several level of management
   - Establish consensus forecasts of economic indicators (inflation and growth in GNP) and of particular items important for the firm

2. Capital budget is approved by top managers and the board of directors
   - Top managers cannot control the details of cash flows forecast and middle management may have an optimistic bias
   - To offset such bias, one could think that a solution is to artificially increase the cost of capital under which projects should have positive NPV
   - In practice, the proportion of proposed projects having positive NPVs at the corporate hurdle rate is independent of the hurdle rate

3. Post audits: a review of the project to see how closely it met forecasts, to identify problems and find solutions
Sensitivity analysis: an example

- Otobai is considering the introduction of an electrically powered scooter for city use.
- Staff members have prepared the cash-flow forecasts.

<table>
<thead>
<tr>
<th></th>
<th>Year 0</th>
<th>Years 1-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Investment</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>2 Revenue</td>
<td></td>
<td>37.5</td>
</tr>
<tr>
<td>3 Variable cost</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>4 Fixed cost</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>5 Depreciation</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>6 Pretax profit</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>7 Tax</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>8 Net profit</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Operating cash flow</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Net cash flow</td>
<td>−15</td>
<td>3</td>
</tr>
</tbody>
</table>
Sensitivity analysis: an example

- Assuming that the opportunity cost is 10%, we get the following NPV

\[
NPV = -15 + \sum_{t=1}^{15} \frac{3}{(1 + 0.10)^t} = +¥3.43 \text{ billion}
\]

- Before concluding, one should identify the key variables that determine the cash flows
  - Revenue is the product of *unit sales* and *price per unit*
  - Unit sales is the product of *new product’s share of market* and *size of scooter market*
  - Unidentified variables may also be relevant: patent problems, investment on service station to recharge the scooter batteries
Sensitivity analysis: an example

- Once relevant variables are identified one can proceed to a sensitivity analysis by computing what happens to the NPV if one at a time we replace the forecasted values of each variable by their optimistic and pessimistic values.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
<th>NPV, ¥ billions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pessimistic</td>
<td>Expected</td>
</tr>
<tr>
<td>Market size, million</td>
<td>0.9</td>
<td>1</td>
</tr>
<tr>
<td>Market share</td>
<td>0.04</td>
<td>0.10</td>
</tr>
<tr>
<td>Unit price, yen</td>
<td>350,000</td>
<td>375,000</td>
</tr>
<tr>
<td>Unit variable cost, yen</td>
<td>360,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Fixed cost, ¥ billions</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

- The most dangerous variables are market share and unit variable cost.
Consider that a pessimistic value for unit variable cost partly reflects the worry that a particular machine will not work as designed.

The operation will have to be performed by other methods at an extra cost of ¥20,000.

The chance that this will occur is 10%, but if it does occur the after-tax cash-flow is reduced by

\[
\text{Reduction} = \text{Unit sales} \times \text{additional cost} \times (1 - \text{tax rate})
\]
\[
= 100,000 \times 20,000 \times 0.50 = ¥1 \text{ billion}
\]

It would reduce the NPV of the project by

\[
\sum_{t=1}^{10} \frac{1}{(1 + 0.10)^t} = ¥6.14 \text{ billion}
\]

leading to a negative NPV.
One should examine if a relatively small change in the scooter’s design would remove the need for the new machine.

Imagine a situation where a ¥10 million pretest of the machine will reveal whether it will work.

- It clearly pays to invest ¥10 million to avoid a 10% probability of a ¥6.14 billion fall in NPV.

\[ -10 + 0.10 \times 6,140 = +¥604 \text{ million} \]
Limits to sensitivity analysis

- What exactly does optimistic or pessimistic mean?
- One could define pessimistic value of variable, the value such that there is only 10% chance that the actual value will prove to be worse.
- However, it is difficult to define what is the true probabilities of possible outcomes.
- Another problem is that variables are likely to be interrelated.
  - It does not make sense to look at the effect in isolation of an increase of market size since an increase of market size may imply simultaneously an increase of the demand and the unit prices.
Scenario analysis

- A solution to circumvent the problem of interrelation of variables is to look for *consistent* combinations of variables.
- One may consider alternative plausible scenarios.
- Estimate the direct effect on all variables of some events:
  - Sharp rise in world oil prices
  - Encourage the use of electrically powered transportation
  - Prompt a world recession, stimulate inflation and reduce market size
Scenario analysis: an example

<table>
<thead>
<tr>
<th></th>
<th>Cash Flows, Years 1-10, ¥ billions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base Case</td>
</tr>
<tr>
<td>1 Revenue</td>
<td>37.5</td>
</tr>
<tr>
<td>2 Variable cost</td>
<td>30</td>
</tr>
<tr>
<td>3 Fixed cost</td>
<td>3</td>
</tr>
<tr>
<td>4 Depreciation</td>
<td>1.5</td>
</tr>
<tr>
<td>5 Pretax profit</td>
<td>3</td>
</tr>
<tr>
<td>6 Tax</td>
<td>1.5</td>
</tr>
<tr>
<td>7 Net profit</td>
<td>1.5</td>
</tr>
<tr>
<td>8 Net cash flow</td>
<td>3</td>
</tr>
<tr>
<td>PV of cash flows</td>
<td>18.4</td>
</tr>
<tr>
<td>NPV</td>
<td>3.4</td>
</tr>
</tbody>
</table>

**Assumptions**

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>High Oil Prices and Recession Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market size, million</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Market share</td>
<td>0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>Unit price, yen</td>
<td>375,000</td>
<td>431,300</td>
</tr>
<tr>
<td>Unit variable cost, yen</td>
<td>300,000</td>
<td>345,000</td>
</tr>
<tr>
<td>Fixed cost, ¥ billions</td>
<td>3</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Break-even analysis

- Sensitivity or scenario analysis evaluates how serious it would be if sales or costs turned out to be worse than forecasted.
- Alternatively, one can ask how bad sales can get before the project begins to lose money.
- This analysis is called **break-even analysis**.

<table>
<thead>
<tr>
<th>Unit Sales, Thousands</th>
<th>Revenues, Years 1-10</th>
<th>Investment</th>
<th>Year 0</th>
<th>Years 1-10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Variable</td>
<td>Fixed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Costs</td>
<td>Costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Taxes</td>
<td>PV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inflows</td>
<td>Outflows</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>100</td>
<td>37.5</td>
<td>15</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>200</td>
<td>75.0</td>
<td>15</td>
<td>60</td>
<td>3</td>
</tr>
</tbody>
</table>
Break-even analysis

- The intersection of the two lines is the break-even point, i.e., the point at which the project has zero NPV.
- As long as sales are greater than 85,000 the project has a positive NPV.
Managers frequently calculate the break-even points in terms of accounting profits rather than present values.

In accounting terms, we deduct depreciation of ¥1.5 billion each year to cover the cost of the initial investment.

<table>
<thead>
<tr>
<th>Unit Sales, Thousands</th>
<th>Revenues Years 1-10</th>
<th>Variable Costs</th>
<th>Fixed Costs</th>
<th>Depreciation</th>
<th>Taxes</th>
<th>Total Costs</th>
<th>Profit after Tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1.5</td>
<td>–2.25</td>
<td>2.25</td>
<td>–2.25</td>
</tr>
<tr>
<td>100</td>
<td>37.5</td>
<td>30</td>
<td>3</td>
<td>1.5</td>
<td>1.5</td>
<td>36.0</td>
<td>1.5</td>
</tr>
<tr>
<td>200</td>
<td>75.0</td>
<td>60</td>
<td>3</td>
<td>1.5</td>
<td>5.25</td>
<td>69.75</td>
<td>5.25</td>
</tr>
</tbody>
</table>
Accounting break-even

Accounting revenues
and costs,
billions of yen

Break-even point:
Profit = 0

Revenues

Costs
(including depreciation
and taxes)

Scooter sales,
thousands

60
20
0
200
Accounting break-even

- The break-even analysis based on accounting profits suggests a break-even of 60,000 scooters.
- Selling 60,000 scooters a year will generate sufficient revenues to pay operating costs and to recover initial outlay of ¥15 million.
- But they will not be sufficient to repay the opportunity cost of capital of the initial outlay.
- In particular, the accounting break-even analysis does not consider the time value of money.
Operating leverage

- Assume that Otobai now considers a different production technology with
  - lower variable costs of only ¥120,00 per unit (versus ¥300,000 per unit)
  - higher fixed costs of ¥19 billion
- Total forecasted production costs are lower

\[ 12 + 19 = ¥31 \text{ billion} < ¥33 \text{ billion} \]

- Profitability improves and the NPV increases to ¥9.6 billion
Operating leverage

<table>
<thead>
<tr>
<th></th>
<th>Year 0</th>
<th>Years 1–10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>1. Revenue</td>
<td></td>
<td>37.5</td>
</tr>
<tr>
<td>2. Variable cost</td>
<td></td>
<td>12.0</td>
</tr>
<tr>
<td>3. Fixed cost</td>
<td></td>
<td>19.0</td>
</tr>
<tr>
<td>4. Depreciation</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>5. Pretax profit (1 – 2 – 3 – 4)</td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>6. Tax</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>7. Net profit (5 – 6)</td>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td>8. Operating cash flow (4 + 7)</td>
<td></td>
<td>4.0</td>
</tr>
<tr>
<td>Net cash flow</td>
<td>−15</td>
<td>+4.0</td>
</tr>
</tbody>
</table>

\[ NPV = -15 + \sum_{t=1}^{10} \frac{4.0}{(1.1)^t} = +¥9.6 \text{ billion} \]

- Before making the final decision one may want to evaluate the project sensitivity
Operating leverage

- Break-even sales have increased to 88,000 (that’s bad)
- The project is much more exposed to changes in market size, market share, or unit price
Monte Carlo simulation

- Sensitivity analysis allows you to consider the effect of changing one variable at a time.
- Scenario analysis allows you to consider the effect of a limited number of plausible combinations of variables.
- **Monte Carlo simulation** is a tool for considering *all* possible combinations.
Monte Carlo simulation

1. Model the project
2. Specify probabilities for forecast errors
3. Select numbers for forecast errors and calculate cash flows
Modeling the project

- **Cash flow**

\[
\text{cash flow} = (\text{revenues} - \text{costs} - \text{depreciation}) \times (1 - \text{tax rate}) + \text{depreciation}
\]

- **Revenues**

\[
\text{revenues} = \text{market size} \times \text{market share} \times \text{unit price}
\]

- **Costs**

\[
\text{costs} = (\text{market size} \times \text{market share} \times \text{variable unit cost}) + \text{fixed cost}
\]
Specifying the probabilities

- For example, consider the market size variable.
- The marketing department has estimated a market size of 1 million scooters in the first year.
- Actually we have:

  \[ \text{market size} = \text{expected market size} \times (1 + \text{forecasted error}) \]

- We have to forecast the error’s distribution.
Simulate the cash flows and calculate the NPV

- The computer *samples* from the distribution of the forecasted errors
- It calculates the resulting cash flows for each period
- It records the results for each sample
- After many iterations we begin to get accurate estimates of the probability distributions of the project cash flows
- *Accurate* only in the extent that the model and the probability distribution of forecasted errors are accurate
- GIGO principle: *garbage in, garbage out*
Monte Carlo simulation
Real options and decision trees

- Until now we implicitly assumed that managers hold assets passively
- In reality, a manager may decide
  - to expand the project if things go well
  - to modify the project
  - to cut back and abandon the project if it goes badly
- Projects that can easily be modified are more valuable than those that do not
- The more uncertain the outlook, the more valuable this flexibility becomes
- Options to modify projects are known as **real options**
- Real options can be described using a **decision tree**
The option to expand

- FedEx needs to move a massive amount of goods each day
- FedEx ordered 15 of Boeing’s 777 freighters to be delivered between 2009 and 2011
- If business continues to expand, FedEx will need more aircraft
- Rather than placing additional firm orders today, FedEx secured a place in Boeing’s production line by acquiring options to buy a further 15 aircrafts at a predetermined price
- These options do not commit FedEx to expand but give it the flexibility to do so
The option to expand

2006: Acquire option on future delivery

Observe growth in demand for airfreight

Low demand

High demand

Exercise delivery option

Don't take delivery
The option to expand

- Many other investments take on added value because of the further options they provide
  - Starting with a pilot program to figure out possible problems and to test the market. The company evaluates the pilot and decides whether to expand to full-scale
  - When designing a factory, the company can provide extra land or floor space to reduce the future cost of a second production line
- Such options to expand do not show up in the assets that the company lists in its balance sheet
- However, investors are very aware of their existence and the market value of the firm is higher than the value of its physical assets now in place
The option to abandon

- Once a project is no longer profitable, the company will cut its losses and exercise its option to abandon the project.
- Some assets are easier to bail out than others:
  - Tangible assets are usually easier to sell than intangible ones.
  - Active secondhand markets really exist only for standardized items.
  - Real estate, airplanes, trucks, and certain machine tools are likely to be relatively easy to sell.
  - Knowledge accumulated by a software company’s research and development program would probably not have significant value.
  - Some assets you have to pay to get rid of them: old mattresses, nuclear power plants.
The option to abandon: an example

- Wankel-engine has to choose between two technologies for production of an outboard engine
  - Technology A uses a computer-controlled machinery custom-designed to produce the complex shapes required for the engine in high volumes and at low cost. But if the outboard does not sell, the equipment will be worthless
  - Technology B uses standard machine tools. Labor costs are much higher, but the machinery can be sold for $10 million if the engine does not sell
- Technology A looks better in a DCF analysis
- Technology B allows for more flexibility if we are unsure about whether the new outboard will have success
The option to abandon: an example

If we are obliged to continue in production regardless of how profitable the project turns out to be, then technology A is clearly the superior choice.

However, choosing the technology B, if the outboard is not a success in the market, we are better off selling the plant and equipment for $10 million than continuing with a project that has a present value of $8 million.

Technology B provides an insurance policy: if the outboard’s sales are disappointing, we can abandon the project and recover $10 million.

We can represent these alternatives in a decision tree.
Decision tree of the option to abandon

- **Demand revealed**
  - **Technology A**
    - **Sluggish** $8.5 million
    - **Buoyant** $18.5 million
  - **Technology B**
    - **Buoyant** $18 million
    - **Abandon** $10 million
  - **Demand revealed**
    - **Sluggish** $8 million
    - **Abandon** $10 million
Production options

- When undertaking new investments, a firm may think about the possibility that a later stage it may wish to modify the project by modifying
  - the input: switching between burning oil and burning natural gas
  - the output: switching between scooters with two tires and three tires
- These opportunities are known as *production opportunities*
Timing options

- A project with positive NPV may be even more valuable if undertaken in the future.

- Timing decisions are straightforward under certainty:
  - Fix a date $t$ and calculate the net future value at date $t$ of the project if undertaken at date $t$.
  - Compute the net present value of investment if undertaken at date $t$:
    \[
    \frac{\text{net future value at date } t}{(1 + r)^t}
    \]
  - Choose the date $t$ maximizing the net present value.

- The timing option is much more complicated under uncertainty:
  - Perhaps “It is better to strike while the iron is hot even if there is a chance it will become hotter.”
  - On the other hand, one may wait a bit to obtain more information and avoid a mistake.
  - When the NPV is only marginally positive, managers often choose not to invest today since there is much to be learned by delay.
Timing options under certainty: an example

- You own a large tract of timber
- Lumber prices will rise as we wait and trees will keep growing

<table>
<thead>
<tr>
<th>Year of Harvest</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net future value ($ thousands)</td>
<td>50</td>
<td>64.4</td>
<td>77.5</td>
<td>89.4</td>
<td>100</td>
<td>109.4</td>
</tr>
<tr>
<td>Change in value from previous year (%)</td>
<td>+28.8</td>
<td>+20.3</td>
<td>+15.4</td>
<td>+11.9</td>
<td>+9.4</td>
<td></td>
</tr>
</tbody>
</table>

- The longer we wait, the more money we will make
Timing options under certainty: an example

- However, we should not forget the opportunity cost
- What matters is the value of the project \textit{today}
- Assume that the appropriate discount rate is 10%

<table>
<thead>
<tr>
<th>Year of Harvest</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net present value ($ thousands)</td>
<td>50</td>
<td>58.5</td>
<td>64.0</td>
<td>67.2</td>
<td>68.3</td>
<td>67.9</td>
</tr>
</tbody>
</table>

- The optimal point to harvest is year 4
- Observe that after year 4, the gain in value is lower than the cost of capital
Decision trees: an example

- Magna Charter is a corporation providing flying service for the southeastern U.S.
- The founder thinks there will be a demand for businesses that cannot justify a full-time company plane
- The venture is not sure
  - There is a 40% chance that demand in the first year will be low
  - If it is low, there is a 60% that it will remain low in subsequent years
  - If the initial demand is high, there is a 80% chance that it will remain high
Decision trees: an example

- The problem is to decide what kind of plane to buy
  - Turboprop
  - Piston-engine
- A turboprop costs $550,000 while a piston-engine costs $250,000 but has less capacity and customer appeal
- The piston-engine is an old design and likely to depreciate rapidly
  - The founder estimates that a secondhand piston aircraft will be available for $150,000
- A possible project is to start with one piston plane and buy another if demand is still high
- See the decision tree where expected cash flows are certainty-equivalents and have to be discounted with the risk-free rate of interest of 10%
Backward argument

- In year 1, the only decision that the manager needs to make is whether to expand if purchase of a piston-engine plane is succeeded by high demand.
- If the manager expands, the net present value at year 1 is

\[
NPV_1(\text{expand}) = -150 + \frac{C_2(\text{expand})}{(1 + 0.10)}
\]

where

\[
C_2(\text{expand}) = (0.8 \times 800) + (0.20 \times 100) = +660
\]

implying that \( NPV_1(\text{expand}) = \$450,000 \)
Backward induction

- If the manager does not expand, the net present value at year 1 is

\[
\text{NPV}_1(\text{no expand}) = 0 + \frac{C_2(\text{no expand})}{(1 + 0.10)}
\]

where

\[
C_2(\text{no expand}) = (0.8 \times 410) + (0.20 \times 180) = +364
\]

implying that \(\text{NPV}_1(\text{expand}) = \$331,000\)

- Expansion pays if market demand is high
Today’s decision

- Assume that the manager’s decision is to buy the piston-engine plane at year 0
- If there is high demand, the manager can expect to receive in year 1

\[ C_1(\text{high}) = 100 + 450 = $550,000 \]

- If there is low demand, the manager can expect to receive in year 1

\[ C_1(\text{low}) = 50 + \frac{(0.40 \times 220) + (0.60 \times 100)}{1 + 0.10} = $185,000 \]

- The NPV of the investment in the piston-engine plane is therefore

\[ \text{NPV}_0(\text{piston}) = -250 + \frac{(0.60 \times 550) + (0.40 \times 185)}{1 + 0.10} = $117,000 \]
Today’s decision

- If the manager buys the turboprop, there is no future decisions to analyze
- The NPV of the investment in the turboprop is

\[ \text{NPV}_0 \text{(turbo)} = -550 + \frac{C_1 \text{(turbo)}}{1 + 0.10} + \frac{C_2 \text{(turbo)}}{(1 + 0.10)^2} \]

- The expected cash flow in year 1 is

\[ C_1 \text{(turbo)} = 0.60 \times 150 + 0.40 \times 30 = 102 \]

- The expected cash flow in year 2 is

\[ C_2 \text{(turbo)} = 0.60 [0.80 \times 960 + 0.20 \times 220] + 0.40 [0.40 \times 930 + 0.60 \times 140] = 670 \]

- Therefore, the NPV of the investment in the turboprop is

\[ \text{NPV}_0 \text{(turbo)} = -550 + \frac{102}{1 + 0.10} + \frac{670}{(1 + 0.10)^2} = 96,000 \]
Conclusion

- The piston-engine plane is the better bet
- However, the choice would be different if we forgot to take account of the option to expand
- The NPV of the investment in the piston-engine would be

\[
NPV_0(\text{piston}) = -250 + \frac{C_1(\text{piston})}{1 + 0.10} + \frac{C_2(\text{piston})}{(1 + 0.10)^2}
\]

- The expected cash flow in year 1 would be

\[
C_1(\text{piston}) = 0.60 \times 100 + 0.40 \times 50
\]

- The expected cash flow in year 2 is

\[
C_2(\text{piston}) = 0.60 [0.80 \times 410 + 0.20 \times 180] \\
+ 0.40 [0.40 \times 220 + 0.60 \times 100]
\]

- Therefore, the NPV of the investment in the piston-engine would be

\[
NPV_0(\text{piston}) = $52,000
\]
The value of the option to expand is therefore

\[ 117 - 52 = +65 \]  or  \[ $65,000 \]