Evaluating projects (3)
Today

Evaluating projects

- Real options
- Alternative investment criteria

Reading

- Brealey and Myers, Chapters 5, 10, and 11
Evaluating projects

DCF analysis

\[
\text{NPV} = \text{CF}_0 + \frac{\text{CF}_1}{(1+r)} + \frac{\text{CF}_2}{(1+r)^2} + \frac{\text{CF}_3}{(1+r)^3} + \frac{\text{CF}_4}{(1+r)^4} + \frac{\text{CF}_5}{(1+r)^5} + \ldots
\]

Forecast cashflows
Opportunity costs, inflation, working capital, taxes, depreciation

Discount at the opportunity cost of capital
Rate of return required by investors for projects with similar risk

➤ Static-thinking trap
Decision is made today, then plan is followed

➤ Real options
Recognize that decisions can be revised
Example

Southern Company is evaluating its alternatives for complying with the Clean Air Act. It can: (1) continue to burn HS coal and buy allowances; (2) install scrubbers and sell allowances; (3) switch to LS coal. Phase I of the Clean Air Act takes effect in 1995 and Phase II begins in 2000.
Evaluating projects

Real options

- Option to expand / make follow-up investments
- Option to abandon unprofitable projects
- Option to wait before investing
- Option to change production methods

Key elements

- Information will arrive in the future
- Decisions can be made after receiving this information
Example 1

Your firm has just developed a new handheld PDA, code-named the Model A.

➢ To produce Model A, the firm would need to invest $20 million in new plant and equipment.

➢ The firm would sell Model A for a per unit profit of $200. Sales are expected to be 30,000 in year 1, 40,000 in year 2, and 50,000 in year 3.

➢ Net working capital and taxes are zero, and r = 12%.

➢ Model B will replace Model A in year 4, with the same price and unit costs. Sales are forecasted to be 60,000 in year 4, 80,000 in year 5, and 100,000 in year 6. Model B would require $30 million in new plant and equipment.
PDA, cont.

Should your firm proceed with the Model A?

**Model A**

\[
NPV = -20,000 + \frac{30 \times 200}{1.12} + \frac{40 \times 200}{1.12^2} + \frac{50 \times 200}{1.12^3} = -1,148
\]

**Model B**

\[
NPV_{yr\ 3} = -30,000 + \frac{60 \times 200}{1.12} + \frac{80 \times 200}{1.12^2} + \frac{100 \times 200}{1.12^3} = 7,705
\]

\[
NPV_{Today} = \frac{7,705}{1.12^3} = 5,484
\]

\[
Combined\ NPV = -1,148 + 5,484 = 4,336 \implies Proceed.
\]
PDA, cont.

What if Model B requires an investment of $40 million?

Model A

\[ \text{NPV} = -20,000 + \frac{30 \times 200}{1.12} + \frac{40 \times 200}{1.12^2} + \frac{50 \times 200}{1.12^3} = -1,148 \]

Model B

\[ \text{NPV}_{yr\ 3} = -40,000 + \frac{60 \times 200}{1.12} + \frac{80 \times 200}{1.12^2} + \frac{100 \times 200}{1.12^3} = -2,295 \]

\[ \text{NPV}_{\text{Today}} = -2,295 / 1.12^3 = -1,634 \]

\[ \text{Combined NPV} = -1,148 - 1,634 = -2,782 \Rightarrow \text{Reject?} \]
PDA, cont.

What’s missing?

Information will arrive about Model B’s sales or costs before a decision has to be made.

Sales …

In year 3, sales for Model A are expected to be 50,000. But they might be either 25,000 or 75,000.

If sales are 25,000 in year 3
Forecast for Model B is 30,000, 40,000, 50,000

If sales are 75,000 in year 3
Forecast for Model B is 90,000, 120,000, 150,000
PDA, cont.

Model B decision

➤ If sales in year 3 are 25,000

\[
\text{NPV}_{yr\ 3} = -40,000 + \frac{30 \times 200}{1.12} + \frac{40 \times 200}{1.12^2} + \frac{50 \times 200}{1.12^3} = -21,148
\]

➤ If sales in year 3 are 75,000

\[
\text{NPV}_{yr\ 3} = -40,000 + \frac{90 \times 200}{1.12} + \frac{120 \times 200}{1.12^2} + \frac{150 \times 200}{1.12^3} = 16,556
\]

➤ Continue only if year 3 sales are good

\[
\text{Expected } \text{NPV}_{yr\ 3} = .5 \times 0 + .5 \times 16,556 = 8,278
\]

Abandonment option
PDA, cont.

Should the firm proceed with the Model A?

➢ Model A

NPV = −1,148

➢ Model B

Expected NPV_{yr3} = 8,278

NPV_{Today} = 8,278 / 1.12^3 = 5,892

Combined NPV = −1,148 + 5,892 = $4,744 ⇒ Proceed.
Example 2

You have the opportunity to purchase a copper mine for $400,000. The mine contains 1 million kgs of copper for sure. If you buy the mine, you can extract the copper now or wait one year. Extraction takes one year and costs $2 / kg.

The current price of copper is $2.2 / kg. The price is expected to increase 5% for the next two years.

If the discount rate is 10%, should you buy the mine?
Copper mine, cont.

Copper prices

➢ The current price of copper is $2.2 / kg.

➢ The price is expected to increase 5% next year, but the actual change might be either a 20% drop or a 30% increase. After that, the price will increase by 5% for certain.

\[
P_0 = 2.2 \quad P_1 = 2.86 \quad \text{Exp}[P_1] = 0.5 \times 2.86 + 0.5 \times 1.76 = 2.31
\]

\[
P_1 = 1.76
\]

\[
\text{Exp}[P_2] = 2.31 \times 1.05 = 2.4255
\]
Copper mine, cont.

Static NPV

萃取立即

成本 = $2,000,000
预期收入 = 2.31 × 1 million = $2,310,000

NPV = −400,000 + (2,310,000 − 2,000,000) / 1.1 = −$118,182

萃取一年

成本 = $2,000,000
预期收入 = 2.4255 × 1 million = $2,425,500

NPV = −400,000 + (2,425,500 − 2,000,000) / 1.1^2 = −$48,347
Copper mine, cont.

Where’s the real option?

We are not committed to extracting in one year. We can make the decision once we see copper prices.

Extraction costs = 2.0 / kg.

Copper prices
If $P_1 = 2.86 \Rightarrow P_2 = 2.86 \times 1.05 = $3.003$
If $P_1 = 1.76 \Rightarrow P_2 = 1.76 \times 1.05 = $1.848$

Decision
Extract only if $P_1 = 2.86$
$CF_2 = (3.003 - 2.000) \times 1$ million = $1,003,000$
Copper mine, cont.

Dynamic NPV

Extract in one year

If $P_1 = 1.76 \Rightarrow \text{NPV}_{yr\,1} = 0$

If $P_1 = 2.86 \Rightarrow \text{NPV}_{yr\,1} = \frac{1,003,000}{1.1} = \$911,818$

Expected $\text{NPV}_{yr\,1} = 0.5 \times 0 + 0.5 \times 911,818 = \$455,909$

$\text{NPV}_{today} = -400,000 + \frac{455,909}{1.1} = \$14,463.$
**Copper mine, cont.**

**Decision tree**

- **Extract now**
  - If buy
    - **Wait**
      - $P_1 = 1.76$, $PV = -618$
      - $P_1 = 2.86$, $PV = 382$
    - **Extract**
      - $PV = -526$
      - $PV = 429$
  - **Don’t**
    - $PV = -400$

- **Do not buy**
  - **Extract**
    - $PV = -400$
Copper mine, cont.
Copper mine, cont.

A caution

Should we use the same discount rate for years 1 and 2?

- **During extraction**
  - In year 2, project risk is very low looking forward
  - Profits of $1,003,000 for sure

- **Real option**
  - In year 1, project risk is very high
  - Project has value of either $0 or $911,818 at end of year

**Rule: use a higher discount rate to value the option**
- But how high?
- Black-Scholes option pricing formula
A note on volatility

Copper prices have become more volatile: They are still expected to increase 5% next year, but the actual change might be either a 40% drop or a 50% increase (compared with a change of –20% or 30% before).

How would this affect NPV?

If $P_1 = 3.30 \Rightarrow P_2 = 3.465 \Rightarrow CF_2 = $1,465,000
If $P_1 = 1.32 \Rightarrow P_2 = 1.382 \Rightarrow CF_2 = $0 \quad \text{(why?)}

Expected $NPV_{yr\ 1} = .5 \times 0 + .5 \times (1,465,000 / 1.1) = $665,909

$NPV_{today} = –400,000 + 665,909 / 1.1 = $205,372
Example 3

Boeing is evaluating whether or not to proceed with development of a new regional jet. The firm expects development to take 2 years, cost roughly $750 million, and it hopes to get unit costs down to $36 million. Boeing forecasts that it can sell 30 planes each year at an average price of $41 million.

Where are the real options?

Option to abandon project after 1st or 2nd year of R&D
Option to expand production
Option to shut down production if costs rise or prices fall

What’s wrong with simple NPV?

\[
NPV = -\frac{200}{1+r} - \frac{550}{(1+r)^2} + \frac{150}{(1+r)^3} + \frac{150}{(1+r)^4} + \frac{150}{(1+r)^5} + \ldots
\]
Example 4

Microsoft has just developed the Xbox, and it must now decide whether to proceed with production. If it does, Microsoft would have to invest $700 million in new PP&E immediately. If the Xbox is successful, Microsoft will earn cash profits of $350 million annually. If the Xbox fails, it will lose $200 million annually. The outcomes are equally likely.

Where are the real options?
Real options

Summary

➢ Options are pervasive
  We often have the option to revise our decisions when new information arrives.

➢ Options can have enormous value
  Static NPV analysis that ignores imbedded options can lead to bad decisions.

➢ NPV is still correct when applied correctly

➢ We don’t need to get fancy
  Formal option pricing models, like Black-Scholes, can sometimes be used. But the basic point is much simpler.
Investment criteria

Graham and Harvey (2000)

- Survey of CFOs finds that 75% of firms use NPV ‘always’ or ‘almost always.’

Alternatives

- Payback period
- Accounting rates of return (ROA or ROI)
- Internal rate of return (IRR)
Investment criteria

Properties of NPV

➢ Cashflows
  NPV is based on cashflows and explicitly measures value. It is flexible enough to take into account strategic issues.

➢ Timing and risk
  NPV recognizes that cash received in the future is worth less than cash today, and that risky cashflows are worth less than safe cashflows.

➢ Objective
  NPV is objective. Take all projects with NPV > 0 because these create value.
Alternative 1

Payback period

How long it takes to recover the firm’s original investment (or how long the project takes to pay for itself).

Example

Payback is 3 years for all of the following investments:

<table>
<thead>
<tr>
<th>Project</th>
<th>CF₀</th>
<th>CF₁</th>
<th>CF₂</th>
<th>CF₃</th>
<th>CF₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-100</td>
<td>20</td>
<td>30</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>B</td>
<td>-100</td>
<td>50</td>
<td>30</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>C</td>
<td>-100</td>
<td>50</td>
<td>30</td>
<td>20</td>
<td>600</td>
</tr>
</tbody>
</table>

Issues

Ignores cashflows after the payback period, crude timing adjustment, no risk adjustment.
Alternative 2

Accounting rate of return

Defined in various ways. Accounting profits divided by some measure of investment.

ROA, ROE, ROI: return on assets, equity, or investment

Issues

- Ignores timing
- Accounting earnings ≠ cashflows
- Arbitrary changes in accounting can affect profitability
- Incentive distortions if used for compensation
Example

GM has just designed a new Saturn.

- Sales are expected to be 200,000 cars annually at a price of $18,000. Costs are expected to be $17,000 / car.

- GM expects to invest $400 million in working capital.

- GM must invest $400 million in new equipment and stamping machines. The equipment will be used for the full production cycle of the car, expected to be 4 years, and will have a salvage value of $60 million at the end.

- The tax rate is 40% and r = 10%.
Example, cont.

Book value of assets ($ million)

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beg equip</td>
<td>400</td>
<td>315</td>
<td>230</td>
<td>145</td>
<td>0</td>
</tr>
<tr>
<td>Beg NWC</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>Beg assets</td>
<td>800</td>
<td>715</td>
<td>630</td>
<td>545</td>
<td>0</td>
</tr>
<tr>
<td>Depreciation</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>End equip</td>
<td>400</td>
<td>315</td>
<td>230</td>
<td>145</td>
<td>0</td>
</tr>
<tr>
<td>End NWC</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>End assets</td>
<td>800</td>
<td>715</td>
<td>630</td>
<td>545</td>
<td>0</td>
</tr>
<tr>
<td>Average BV</td>
<td>400</td>
<td>758</td>
<td>673</td>
<td>588</td>
<td>273</td>
</tr>
</tbody>
</table>

Average BV = (Beg BV + End BV) / 2
### Example, cont.

**Income and cashflows ($ million)**

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>3,600</td>
<td>3,600</td>
<td>3,600</td>
<td>3,600</td>
<td></td>
</tr>
<tr>
<td>COGS</td>
<td>3,400</td>
<td>3,400</td>
<td>3,400</td>
<td>3,400</td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>EBIT</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Taxes</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Oper income</td>
<td>69</td>
<td>69</td>
<td>69</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>Cashflow</td>
<td>-800</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>614</td>
</tr>
</tbody>
</table>

Cashflow = Oper income + depr – ΔNWC + equipment
Example, cont.

## ROA / ROI

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oper income</td>
<td>69</td>
<td>69</td>
<td>69</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>Avg assets</td>
<td>400</td>
<td>758</td>
<td>673</td>
<td>588</td>
<td>273</td>
</tr>
<tr>
<td>ROA</td>
<td>9.1%</td>
<td>10.3%</td>
<td>11.7%</td>
<td>25.3%</td>
<td></td>
</tr>
</tbody>
</table>

- \( \text{ROA}_1 = \text{average ROA} = 14.1\% \)
- \( \text{ROA}_2 = \text{avg oper income} / \text{avg assets} = 12.1\% \)
- \( \text{ROA}_3 = \text{avg oper income} / \text{initial investment} = 8.6\% \)
- \( \text{NPV} \approx \$0 \)
Alternative 3

Internal rate of return

IRR is the discount rate that gives NPV = 0. Intuitively, IRR is the return on the project.

Accept projects with an IRR above the discount rate.

Example

Saturn cashflows

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cashflow</td>
<td>-800</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>614</td>
</tr>
</tbody>
</table>

What is the IRR? 10.11%
IRR, cont.

**NPV as a function of r**

**IRR:** $r$ that makes NPV = 0
IRR, cont.

IRR vs. NPV

Generally, if IRR is greater than the hurdle rate, then NPV is positive.

Issues

- Some projects have no IRR
- Multiple IRRs
- Lending or borrowing?
- Mutually exclusive investments
Problem 1: Some projects do not have an IRR

\[ CF_0 = -105,000, \ CF_1 = 250,000, \ CF_2 = -150,000 \]
Problem 2: Some projects have multiple IRRs

\[ CF_0 = -100,000, \ CF_1 = 233,000, \ CF_2 = -135,000 \]
IRR, cont.

Example 2
CF\(_0\) = -20,100, CF\(_1\) = 160,000, CF\(_2\) = -302,900, CF\(_3\) = 166,000

Three IRRs: \(r = 8.6\%, 38.5\%, \text{ and } 449\%\)
Problem 3: The IRR rule must be reversed for a project with an initial cash inflow, \( CF_0 > 0 \).

\[ CF_0 = 100,000, \quad CF_1 = -120,000 \]
Problem 4: Mutually exclusive projects
To choose among mutually exclusive projects, do not compare the IRRs. The project with the higher IRR does NOT have to have the higher NPV.

Two reasons not to use IRR

➢ If the scale of the projects is different
  Project A: \( CF_0 = -1, \ CF_1 = 2 \)
  Project B: \( CF_0 = -10, \ CF_1 = 15 \)

➢ If the timing of the cashflows is different
  Example on next page
IRR, cont.

If you can invest in only one of the following projects, which would you choose?

➤ **Project A**

\[
\begin{align*}
CF_0 &= -10,000 \\
CF_1 &= 10,000 \\
CF_2 &= 1,000 \\
CF_3 &= 1,000
\end{align*}
\]

IRR = 16.0%

➤ **Project B**

\[
\begin{align*}
CF_0 &= -10,000 \\
CF_1 &= 1,000 \\
CF_2 &= 1,000 \\
CF_3 &= 12,000
\end{align*}
\]

IRR = 13.4%
IRR, cont.