Chapter 7

Risk Analysis, Real Options, and Capital Budgeting

风险分析、实物期权和资本预算

Key Concepts and Skills

- Understand and be able to apply scenario and sensitivity analysis
- Understand the various forms of break-even analysis
- Understand Monte Carlo simulation
- Understand the importance of real options in capital budgeting
- Understand decision trees

Uncertainty in Project Analysis

- Factors may affect your assessment of value
  - Revenues may be over-estimated
  - Actual costs may be higher than estimated
  - Tax rates may go up
- How would you respond to this uncertainty?
  - Will wait for the uncertainty to be resolved?
  - Will not take the investment?
  - Ignore it?

Evaluating NPV Estimates

- The future cash inflows for a NPV computation is just an estimate

- A positive NPV is a good start – now we need to take a closer look:
  - Forecasting risk – how sensitive is our NPV to changes in the cash flow estimates; the more sensitive, the greater the forecasting risk

How To Handle Uncertainty

- **Sensitivity Analysis**（敏感分析） – What happens if certain variables are forecasted incorrectly?
- **Scenario Analysis** （场景分析） – What happens if a logical set of variables are forecasted incorrectly?
- **Simulation Analysis** （蒙特卡罗模拟）– Alternative results when a large number of different scenarios are proposed.
- **Break Even Analysis** （盈亏平衡）– What is the minimum level of sales (prices, costs) which still allows the project a non-negative NPV

Scenario Analysis

- What happens to the NPV under different cash flow scenarios?
- At the very least, look at:
  - Best case – high revenues, low costs
  - Worst case – low revenues, high costs
  - Then measure the range of possible outcomes
- Best case and worst case are not necessarily probable, but they can still be possible

New Project Example

- Consider the following project:

- The initial cost is $200,000, and the project has a 5-year life. There is no salvage. Depreciation is straight-line, the required return is 12%, and the tax rate is 34%.

Scenario Analysis

	Base	Lower	Upper
Unit Sales	6000	5500	6500
Price per unit	80	75	85
VC per unit	60	62	58
FC per year	50000	55000	45000
Sales	480000	412500	552500
VC	360000	341000	377000
FC	50000	55000	45000
Depreciation	40000	40000	40000
EBIT	30000	-23500	90500
Taxes	10200	-7990	30770
NI	19800	-15510	59730
OCF	59800	24490	99730

Scenario Analysis

Year	Base	Lower	Upper
0	-200000	-200000	-200000
1	59800	24490	99730
2	59800	24490	99730
3	59800	24490	99730
4	59800	24490	99730
5	59800	24490	99730
NPV	15565.62	-111719.03	159504.33

Summary of Example Scenario Analysis

Scenario	Net Income	Cash Flow	NPV	IRR
Base case	19,800	59,800	15,567	15.1%
Worst Case	-15,510	24,490	-111,719	-14.4%
Best Case	59,730	99,730	159,504	40.9%

Sensitivity Analysis

- What happens to NPV when we change one variable at a time?
- This is a subset of scenario analysis where we are looking at the effect of specific variables on NPV
- The greater the volatility in NPV in relation to a specific variable, the larger the forecasting risk associated with that variable, and the more attention we want to pay to its estimation

Sensitivity Analysis

	Base	Lower	Upper
Unit Sales	6000	5500	6500
Price per unit	80	80	80
VC per unit	60	60	60
FC per year	50000	50000	50000
Sales	480000	440000	520000
VC	360000	330000	390000
FC	50000	50000	50000
Depreciation	40000	40000	40000
EBIT	30000	20000	40000
Taxes	10200	6800	13600
NI	19800	13200	26400
OCF	59800	53200	66400

Sensitivity Analysis

Year	Base	Lower	Upper
0	-200,000	-200,000	-200,000
1	59800	53200	66400
2	59800	53200	66400
3	59800	53200	66400
4	59800	53200	66400
5	59800	53200	66400
NPV	$15,565.62	-$8,225.91	$39,357.14

Summary of Sensitivity Analysis

Scenario	Unit Sales	Cash Flow	NPV	IRR
Base case	6,000	59,800	15,566	15.1%
Worst case	5,500	53,200	-8,226	10.3%
Best case	6,500	66,400	39,357	19.7%

Simulation Analysis

- Simulation is really just an expanded sensitivity and scenario analysis
- Monte Carlo simulation can estimate thousands of possible outcomes based on conditional probability distributions and constraints for each of the variables

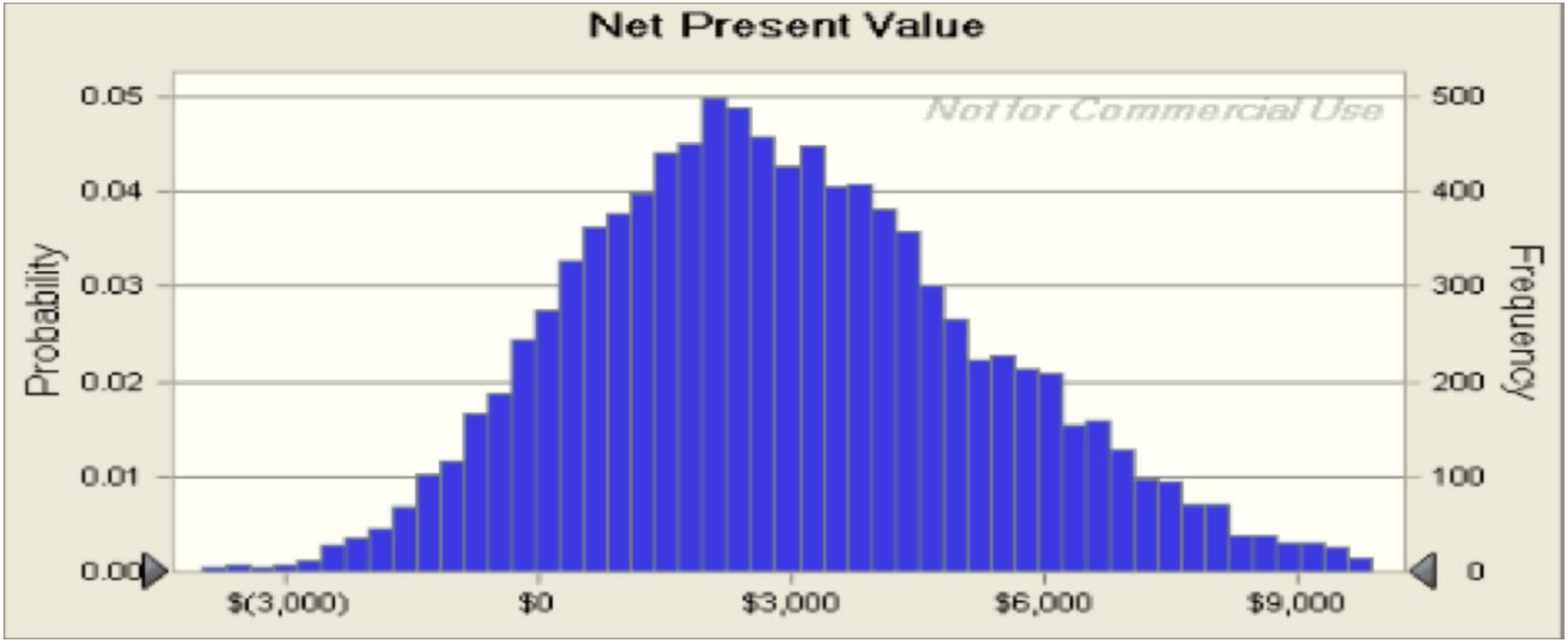
Monte Carlo Simulation

- Monte Carlo simulation is a further attempt to model real-world uncertainty.
- This approach takes its name from the famous European casino, because it analyzes projects the way one might analyze gambling strategies.

Monte Carlo Simulation

- Imagine a serious blackjack player who wants to know if he should take the third card whenever his first two cards total sixteen.
  - He could play thousands of hands for real money to find out.
  - This could be hazardous to his wealth.
  - Or he could play thousands of practice hands to find out.
- Monte Carlo simulation of capital budgeting projects is in this spirit
- The output is a probability distribution for NPV with an estimate of the probability of obtaining a positive net present value

Simulation Analysis



Simulation Analysis

- Assume that you are the manager is given the results of the simulation. The average and median NPV are close to $2.9 billion. However, there is a 12% probability that the project could have a negative NPV? How would you use this information?

- I would accept the investment since the average NPV is positive.
- I would reject the investment, because 12% is higher than my threshold value for losing on a project.

Making a Decision

- If the majority of your scenarios have positive NPVs, then you can feel reasonably comfortable about accepting the project
- If you have a crucial variable that leads to a negative NPV with a small change in the estimates, then you may want to forego the project

Break-Even Analysis （盈亏平衡分析）

- A common tool for analyzing the relationship between sales volume and profitability
- There are three common break-even measures:
  - Accounting break-even:

    sales volume at which NI = 0
  - Cash break-even:

    sales volume at which OCF = 0
  - Financial break-even:

    sales volume at which NPV = 0

Costs

- There are two types of costs that are important in breakeven analysis: variable and fixed
  - Total variable costs = quantity * cost per unit
  - Fixed costs are constant, regardless of output, over some time period
  - Total costs = fixed + variable = FC + v*Q

Example: Costs

- Example:
  - Your firm pays $3,000 per month in fixed costs. You also pay $15 per unit to produce your product.

    - What is your total cost if you produce 1,000 units?

    - What if you produce 5,000 units?

Average vs. Marginal Cost

- Average Cost
  - TC / # of units
  - Will decrease as # of units increases
- Marginal Cost
  - The cost to produce one more unit
  - Same as variable cost per unit

Average vs. Marginal Cost

Example: What is the average cost and marginal cost under each situation in the previous example?

Produce 1,000 units:
Average = 18,000 / 1000 = $18
Marginal = $16

Produce 5,000 units:
Average = 78,000 / 5000 = $15.60
Marginal = $16

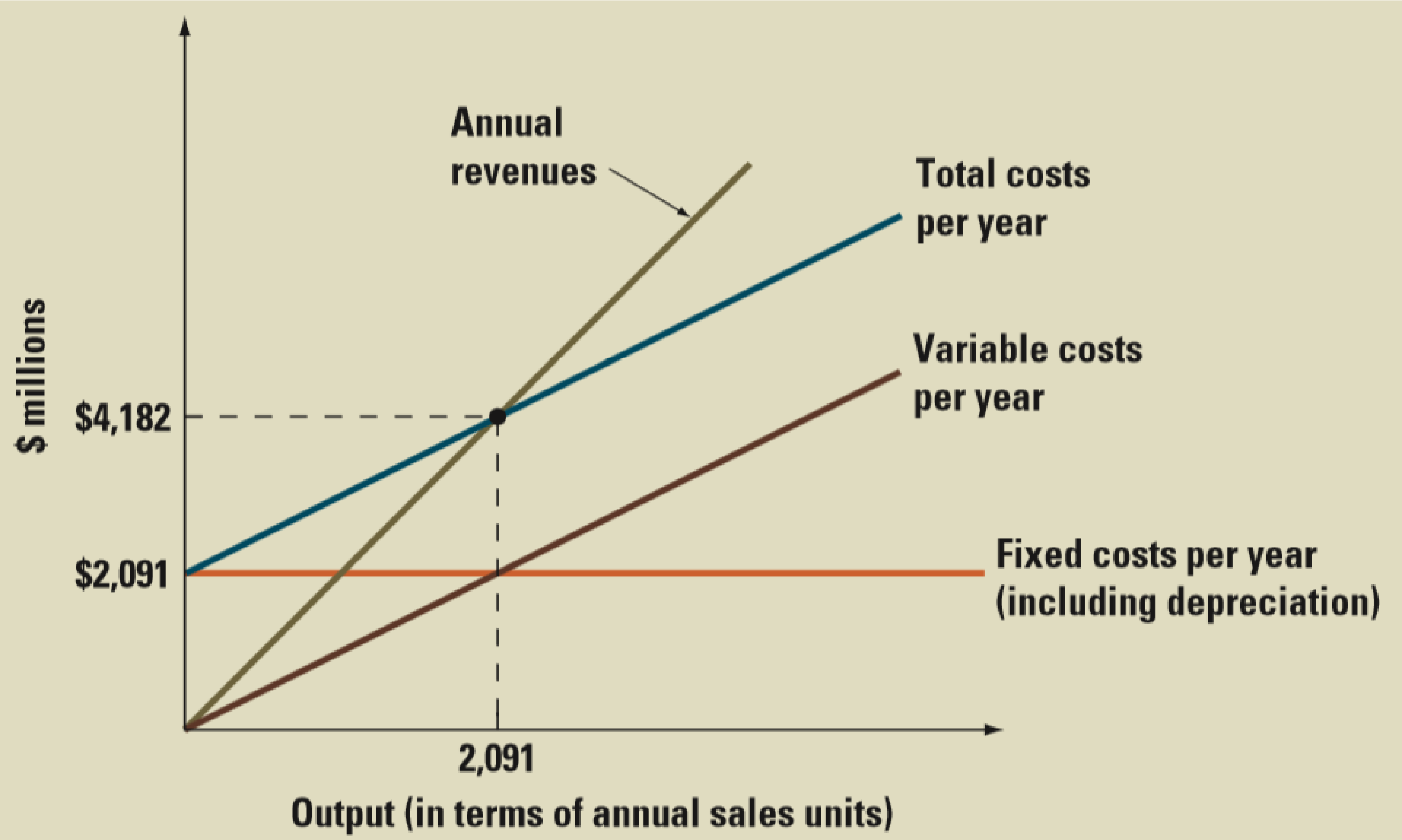
Three Types of Break-Even Analysis

1. Accounting Break-even
   Where NI = 0
   Q = (FC + D)/(P – v)
2. Cash Break-even
   Where OCF = 0
   OCF = [(P – v)Q – FC – D](1 – T) + D
   Q = FC /(P – v)   (ignoring taxes)
3. Financial Break-even
   Where NPV = 0

Accounting Break-Even

- The quantity that leads to a zero net income.
- $NI = (Sales – VC – FC – D)(1 – T) = 0$
- $QP – vQ – FC – D = 0$
- $Q(P – v) = FC + D$
- $Q = (FC + D) / (P – v)$

Accounting B-E Example



Using Accounting Break-Even

- Accounting break-even is often used as an early stage screening number
- If a project cannot break-even on an accounting basis, then it is not going to be a worthwhile project
- Accounting break-even gives managers an indication of how a project will impact accounting profit

Accounting Break-Even and Cash Flow

- We are more interested in cash flow than we are in accounting numbers
- If a firm just breaks even on an accounting basis, cash flow = depreciation
- If a firm just breaks even on an accounting basis, NPV will generally be < $0

Accounting B-E Example

Consider the following project:

- A new product requires an initial investment of $5 million and will be depreciated to an expected salvage of zero over 5 years
- The price of the new product is expected to be $25,000, and the variable cost per unit is $15,000
- The fixed cost is $1 million

Accounting B-E Example

What is the accounting break-even point each year?

Depreciation = 5,000,000 / 5 = 1,000,000

Q = (1,000,000 + 1,000,000)/(25,000 – 15,000)

= 200 units

Sales Volume and Operating Cash Flow

What is the operating cash flow at the accounting break-even point (ignoring taxes)?

OCF = (S – VC – FC - D) (1-t)+ D

OCF = (200*25,000 – 200*15,000 – 1,000,000 -1,000,000) + 1,000,000
= $1,000,000

Cash Break-Even

What is the cash break-even quantity? (ignoring taxes)

$$OCF = [(P-v)Q - FC - D] + D = (P-v)Q - FC$$

$$Q = (OCF + FC) / (P - v)$$

$$Q = (0 + 1{,}000{,}000) / (25{,}000 - 15{,}000)$$
$$= 100 \text{ units}$$

Financial Break-Even

Consider the previous example and...

- Assume a required return of 18%
- Accounting break-even = 200
- Cash break-even = 100

What is the financial break-even point?

Financial Break-Even

What OCF (or payment) makes NPV = 0?

N = 5; PV = 5,000,000; I/Y = 18; CPT PMT = 1,598,889 = OCF

Q = (1,000,000 + 1,598,889) / (25,000 – 15,000) = 260 units

The question now becomes: Can we sell at least 260 units per year?

Real Options 实物期权

- One of the fundamental insights of modern finance theory is that options have value.
- NPV analysis, as well as all the other approaches in Chapter 5, ignores the adjustments that a firm can make after a project is accepted.
- Because corporations make decisions in a dynamic environment, they have options that should be considered in project valuation.

Real Options 实物期权

- The Option to Expand 拓展期权
  - Has value if demand turns out to be higher than expected
- The Option to Abandon 放弃期权
  - Has value if demand turns out to be lower than expected
- The Option to Delay 择机期权
  - Has value if the underlying variables are changing with a favorable trend

The Option to Expand

- New tech to build ice hotel
- An initial investment of a single ice hotel is \$12 million. Annual cash flow in the future will be \$2 million. And the cash flows would be perpetual.
- 20 percent was an appropriate discount rate
- NPV = -\$12,000,000 + \$2,000,000/.20 = -\$2 Million
- Reject the ice hotel?

The Option to Expand

- What if the cash flow estimate of \$2 million per year actually reflected the belief that there was a 50 percent probability that annual cash flows will be \$3 million and a 50 percent probability that annual cash flows will be \$1 million.

Optimistic forecast: $-\$12 \text{ million} + \$3 \text{ million}/.20 = \$3 \text{ million}$

Pessimistic forecast: $-\$12 \text{ million} + \$1 \text{ million}/.20 = -\$7 \text{ million}$

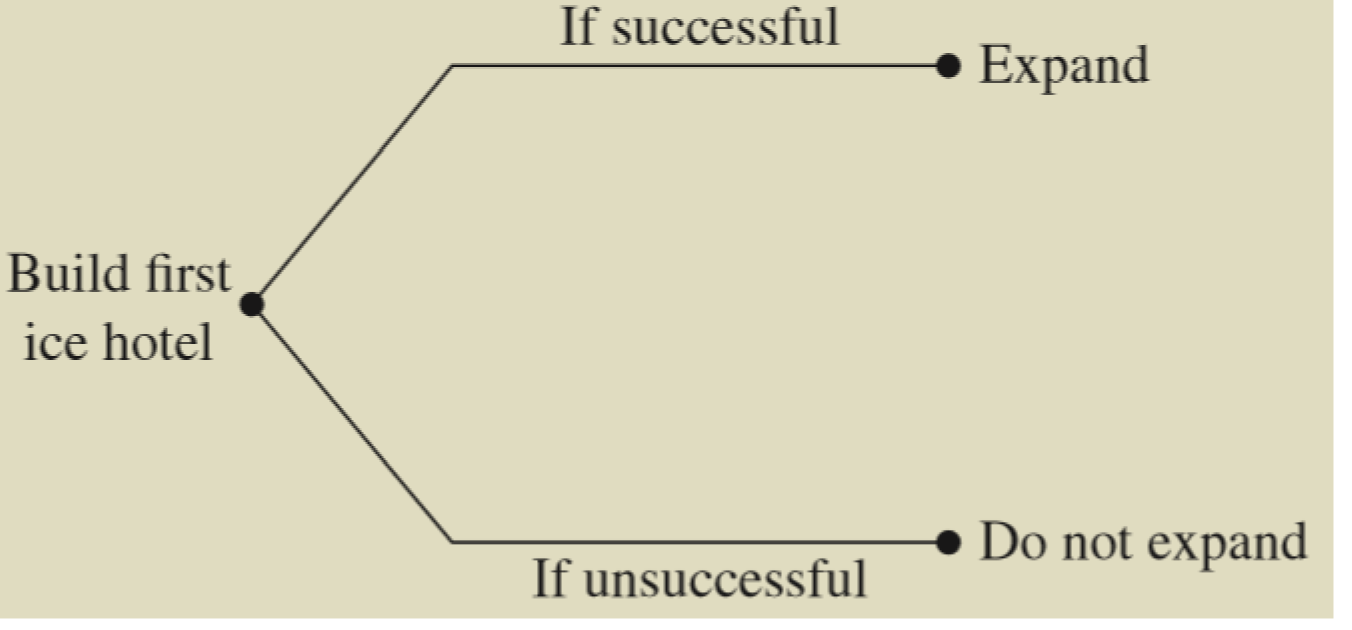
- An average of the two forecasts yields an NPV for the project of:

$$50\% \times \$3 \text{ million} + 50\% \times (-\$7 \text{ million}) = -\$2 \text{ million}$$

- However, if the optimistic forecast turns out to be correct, we would want to expand. If there are 10 locations in the world that can support an ice hotel, the true NPV of the venture would be:

$$50\% \times 10 \times \$3 \text{ million} + 50\% \times (-\$7 \text{ million}) = \$11.5 \text{ million}$$

The Option to Expand



The Option to Abandon

- What if there is a 50 percent probability that annual cash flows will be \$6 million and a 50 percent probability that annual cash flows will be -\$2 million.

Optimistic forecast: $-\$12 \text{ million} + \$6 \text{ million}/.2 = \$18 \text{ million}$
Pessimistic forecast: $-\$12 \text{ million} - \$2 \text{ million}/.2 = -\$22 \text{ million}$

- An average of the two forecasts yields an NPV for the project of:

$$50\% \times \$18 \text{ million} + 50\% \times (-\$22 \text{ million}) = -\$2 \text{ million}$$

- However, as of Year 1, the entrepreneur will know which forecast has come true. If cash flows equal those under the optimistic forecast, he will keep the project alive. If, however, cash flows equal those under the pessimistic forecast, he will abandon the hotel.

$$50\% \times \$18 \text{ million} + 50\% \times (-\$12 \text{ million} - \$2 \text{ million}/1.20) = \$2.17 \text{ million}$$

The Option to Delay: Example

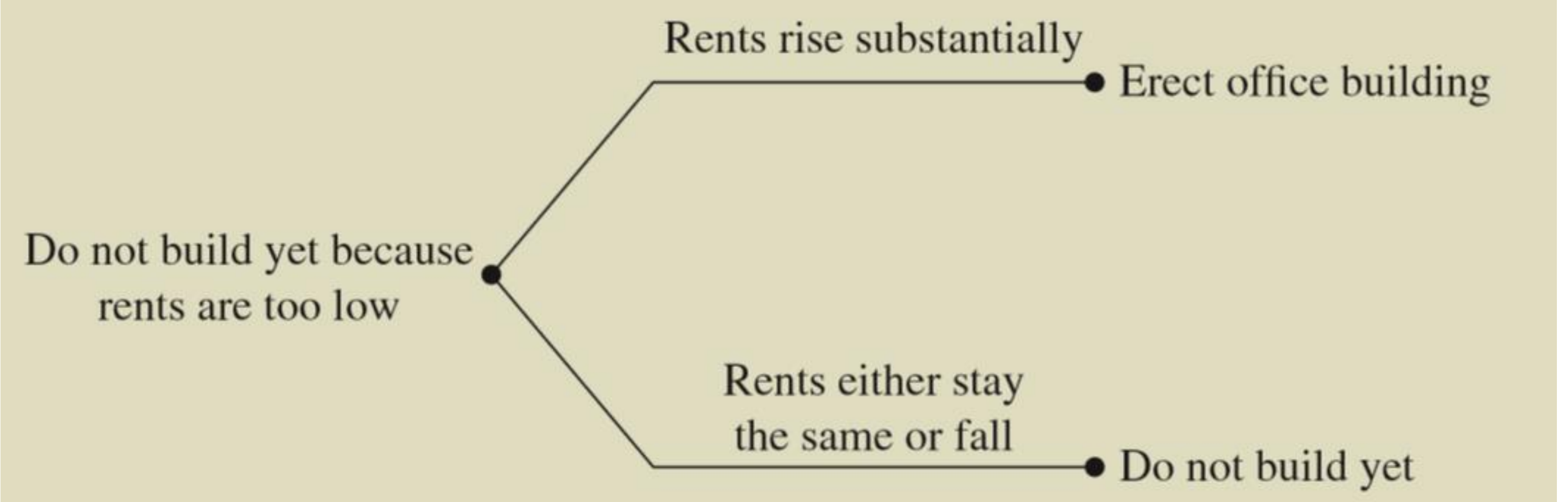
Year	*Cost*	*PV*	*NPV $_t$*	*NPV $_0$*
0	\$ 20,000	\$ 25,000	\$5,000	\$5,000
1	\$ 18,000	\$ 25,000	\$7,000	\$6,364
2	\$ 17,100	\$ 25,000	\$7,900	\$6,529
3	\$ 16,929	\$ 25,000	\$8,071	\$6,064
4	\$ 16,760	\$ 25,000	\$8,240	\$5,628

$$\$6{,}529 = \frac{\$7{,}900}{(1.10)^2}$$

- Consider the above project, which can be undertaken in any of the next 4 years. The discount rate is 10 percent. The present value of the benefits at the time the project is launched remains constant at \$25,000, but since costs are declining, the NPV at the time of launch steadily rises.
- The best time to launch the project is in year ?

The Option to Delay: Example

- One often finds urban land that has been vacant for many years. Why would anyone pay a positive price for land that has no source of revenue?



Vacant land may have value today because the owner can erect a profitable office building if rents rise.

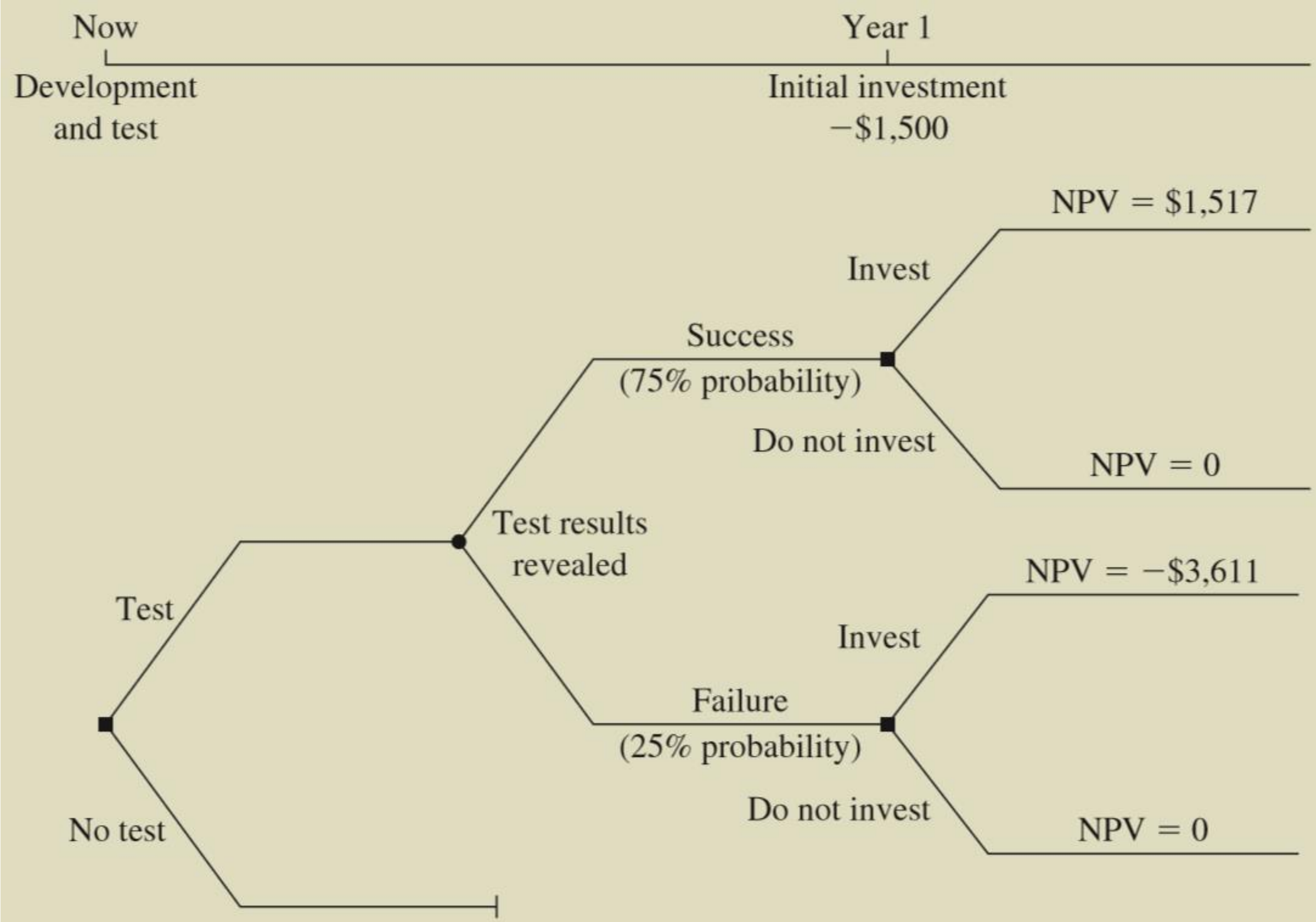
Decision Trees 决策树

- Allow us to graphically represent the alternatives available to us in each period and the likely consequences of our actions
- This graphical representation helps to identify the best course of action.

Decision Trees

- Solar Electronics Corporation’s (SEC’s) solar-powered jet engine project
- First, SEC develops some prototypes and conduct marketing test of the engine. This preliminary phase would take a year and cost $100 million.
- Second, if the test are successful, SEC begins full-scale production.

Decision Trees



Squares represent decision points. Circle represents receipt of information.
SEC must make two decisions:

1. Whether to develop and test the engine.
2. Whether to invest for full-scale production.

Decision Trees

The expected payoff evaluated at Date 1 (in millions) is:

$$\begin{aligned}
\begin{matrix}\text{Expected}\\ \text{payoff}\end{matrix} &= \left(\begin{matrix}\text{Probability}\\ \text{of}\\ \text{success}\end{matrix} \times \begin{matrix}\text{Payoff}\\ \text{if success-}\\ \text{ful}\end{matrix}\right) + \left(\begin{matrix}\text{Probability}\\ \text{of}\\ \text{failure}\end{matrix} \times \begin{matrix}\text{Payoff}\\ \text{if}\\ \text{failure}\end{matrix}\right) \\
&= (.75 \times \$1{,}517) + (.25 \times \$0) \\
&= \$1{,}138
\end{aligned}$$

The NPV of testing computed at Date 0 (in millions) is:

$$\begin{aligned}
\text{NPV} &= -\$100 + \frac{\$1{,}138}{1.15} \\
&= \$890
\end{aligned}$$

Because the NPV is positive, the firm should test the market for solar-powered jet engines.

Quick Quiz

- What are sensitivity analysis, scenario analysis, break-even analysis, and simulation?
- Why are these analyses important, and how should they be used?
- How do real options affect the value of capital projects?
- What information does a decision tree provide?