CHAPTER

7

Risk Analysis, Real Options, and Capital Budgeting

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Key Concepts and Skills

- Understand decision trees
- 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

Chapter Outline

7.4 Decision Trees

7.1 Sensitivity Analysis, Scenario Analysis, and Break-Even Analysis

7.2 Monte Carlo Simulation

7.3 Real Options

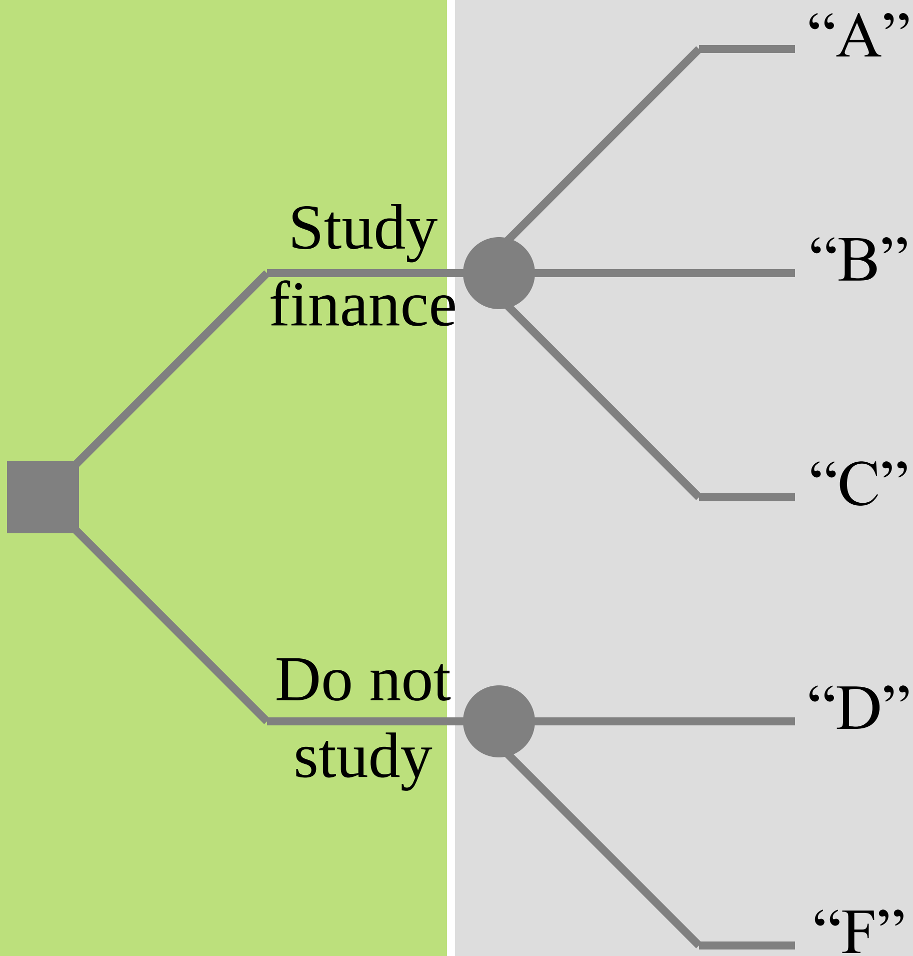
7.4 Decision Trees

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

Example of a Decision Tree

Squares represent decisions to be made.

Circles represent receipt of information, *e.g.*, a test score.



The lines leading away from the squares represent the alternatives.

Example: Stewart Pharmaceuticals

- Stewart Pharmaceuticals Corporation is considering investing in the development of a drug that cures the common cold.
- A corporate planning group, including representatives from production, marketing, and engineering, has recommended that the firm go ahead with the <u>test and development phase</u>.
- This preliminary phase will last one year and cost $1 billion. Furthermore, the group believes that there is a 60% chance that tests will prove successful.
- If the initial tests are *successful*, Stewart Pharmaceuticals can go ahead with full-scale production. This <u>investment phase</u> will cost $1.6 billion. Production will occur over the following 4 years.

NPV Following Successful Test

Investment	Year 1	Years 2-5
Revenues		$7,000
Variable Costs		(3,000)
Fixed Costs		(1,800)
Depreciation		(400)
Pretax profit		$1,800
Tax (34%)		(612)
Net Profit		$1,188
Cash Flow	-$1,600	$1,588

Note that the *NPV* is calculated as of date 1, the date at which the investment of $1,600 million is made. Later we bring this number back to date 0. Assume a cost of capital of 10%.

$$NPV_1 = -\$1,600 + \sum_{t=1}^{4} \frac{\$1,588}{(1.10)^t}$$

$$NPV_1 = \$3,433.75$$

NPV Following Unsuccessful Test

Investment	Year 1	Years 2-5
Revenues		$4,050
Variable Costs		(1,735)
Fixed Costs		(1,800)
Depreciation		(400)
Pretax profit		$115
Tax (34%)		(39.10)
Net Profit		$75.90
Cash Flow	-$1,600	$475.90

Note that the *NPV* is calculated as of date 1, the date at which the investment of $1,600 million is made. Later we bring this number back to date 0. Assume a cost of capital of 10%.

$$NPV_1 = -\$1{,}600 + \sum_{t=1}^{4} \frac{\$475.90}{(1.10)^t}$$

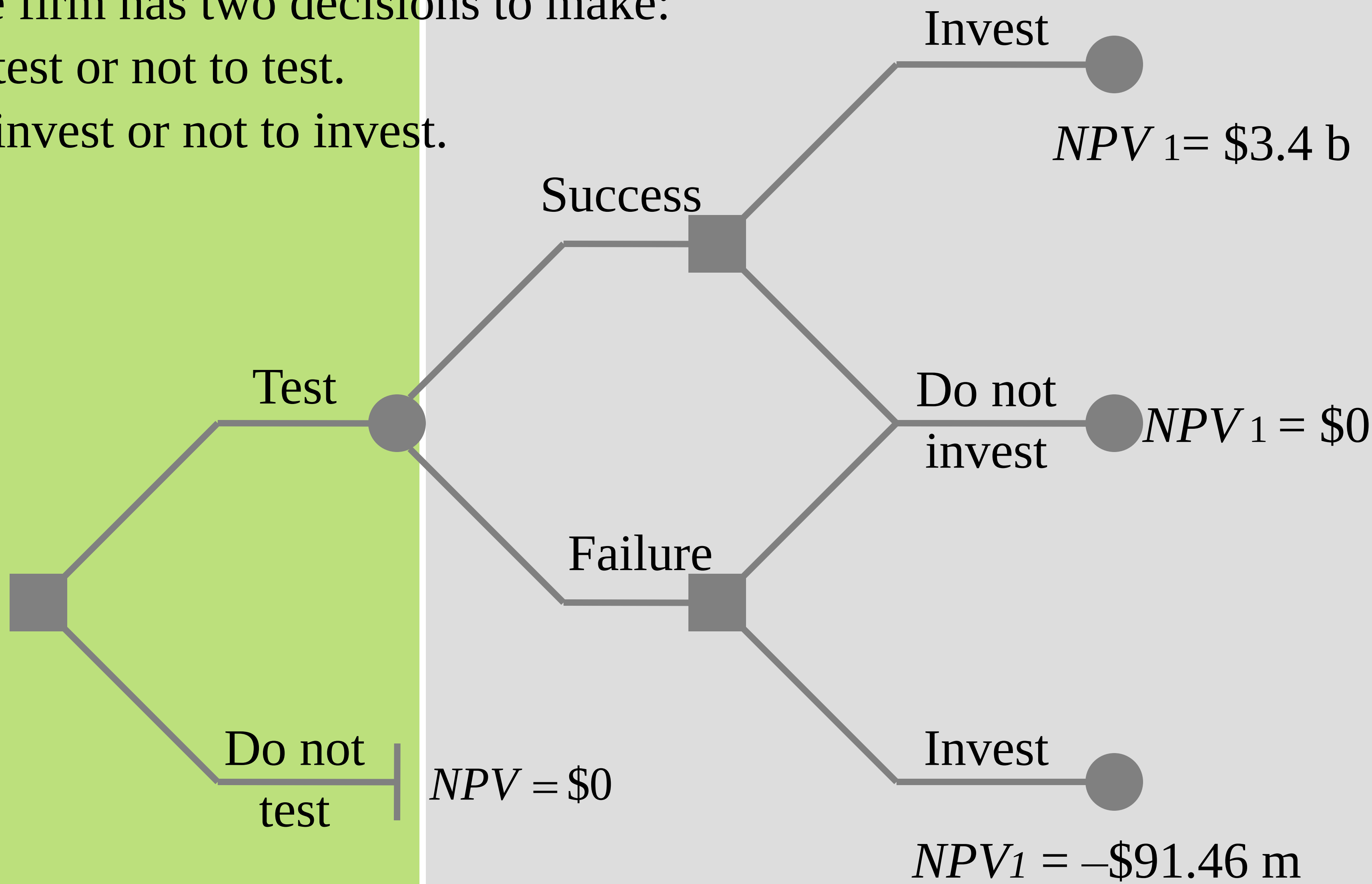
$$NPV_1 = -\$91.461$$

Decision Tree for Stewart

The firm has two decisions to make:

To test or not to test.

To invest or not to invest.



Decision to Test

- Let's move back to the first stage, where the decision boils down to the simple question: should we test?
- The expected payoff evaluated at date 1 is:

$$\begin{array}{c}\text{Expected}\\ \text{payoff}\end{array} = \left(\begin{array}{c}\text{Prob.}\\ \text{sucess}\end{array} \times \begin{array}{c}\text{Payoff}\\ \text{given success}\end{array}\right) + \left(\begin{array}{c}\text{Prob.}\\ \text{failure}\end{array} \times \begin{array}{c}\text{Payoff}\\ \text{given failure}\end{array}\right)$$

$$\begin{array}{c}\text{Expected}\\ \text{payoff}\end{array} = (.60 \times \$3{,}433.75) + (.40 \times \$0) = \$2{,}060.25$$

The NPV evaluated at date 0 is:

$$NPV = -\$1{,}000 + \frac{\$2{,}060.25}{1.10} = \$872.95$$

So, we should test.

7.1 Sensitivity, Scenario, and Break-Even

- Each allows us to look behind the NPV number to see how firm our estimates are.
  - Sensitivity analysis is also known as “what if” analysis; we examine how sensitive the NPV calculation is to a change in the underlying assumption
  - Helps us focus on the variables that have the largest impacts on NPV, and allocate additional resources to refine the forecasts
  - Indicates if the NPV should be trusted
- When working with spreadsheets, try to build your model so that you can adjust the key variable in one cell and have the NPV calculations linked to that cell.

Sensitivity Analysis: Stewart Pharmaceuticals

Investment	Year 1	Years 2-5
Revenues		$6,000
Variable Costs		(3,000)
Fixed Costs		(1,800)
Depreciation		(400)
Pretax profit		$800
Tax (34%)		(272)
Net Profit		$528
Cash Flow	-$1,600	$928

$$NPV = -\$1{,}600 + \sum_{t=1}^{4} \frac{\$\ 928}{(1.10)^t} = \$1{,}341.64$$

Note that the *NPV* is calculated as of date 1, the date at which the investment of $1,600 million is made. Later we bring this number back to date 0.

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Sensitivity Analysis: Stewart

- We can see that NPV is very sensitive to changes in revenues. In the Stewart Pharmaceuticals example, a 14% drop in revenue leads to a 61% drop in NPV.

$$\%\Delta\text{Rev} = \frac{\$6{,}000 - \$7{,}000}{\$7{,}000} = -14.29\%$$

$$\%\Delta NPV = \frac{\$1{,}341.64 - \$3{,}433.75}{\$3{,}433.75} = -60.93\%$$

For every 1% drop in revenue, we can expect roughly a 4.26% drop in NPV1:

$$4.26 = \frac{-60.93\%}{-14.29\%}$$

Scenario Analysis: Stewart

- A variation of sensitivity analysis is the scenario analysis.
- For example, the following three scenarios could apply to Stewart Pharmaceuticals:
    1. The next years each have heavy cold seasons, and sales exceed expectations, but labor costs skyrocket.
    2. The next years are normal, and sales meet expectations.
    3. The next years each have lighter than normal cold seasons, so sales fail to meet expectations.
- Other scenarios could apply to FDA approval.
- For each scenario, calculate the NPV.

Break-Even Analysis

- 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 net income = 0
  - – Cash break-even: sales volume at which operating cash flow = 0
  - – **Financial break-even**: sales volume at which net present value = 0

Break-Even Analysis: Stewart

- Another way to examine variability in our forecasts is the break-even analysis.
- In the Stewart Pharmaceuticals example, we could be concerned with break-even revenue, break-even sales volume, or break-even price.
- To find either, we start with the **break-even operating cash flow (**OCF_{BE}**)**.
  - An application of the EAC concept where all NON-operating CFs are included in the calculation of the EAC, i.e., OCF_{BE} !

Break-Even Analysis: Stewart

- The project requires an investment of $1,600.
- In order to cover our cost of capital (break even), the project needs to generate a cash flow of $504.75 each year for four years.
- This is the project's break-even operating cash flow, OCF_{BE}.

N	4
I/Y	10
PV	1,600
PMT	– 504.75
FV	0

Break-Even Revenue: Stewart

Work backwards from OCF_{BE} to Break-Even Revenue

Revenue		+ VC	\$5,358.71
Variable cost			\$3,000
Fixed cost			\$1,800
Depreciation		+D	\$400
EBIT		+FC	\$158.71
Tax (34%)	$\frac{\$104.75}{0.66}$		\$53.96
Net Income			\$104.75
	OCF = \$104.75 + \$400		\$504.75

Break-Even Analysis: P_{BE}

- Now that we have break-even revenue of \$5,358.71 million, we can calculate break-even price.
- The original plan was to generate revenues of \$7 billion by selling the cold cure at \$10 per dose and selling 700 million doses per year,
- We can reach break-even revenue with a price of only:

$$\$5{,}358.71 \text{ million} = 700 \text{ million} \times P_{BE}$$

$$P_{BE} = \frac{\$5{,}358.71}{700} = \$7.66 \,/\, \text{dose}$$

Break-Even Analysis: Dorm Beds

- Recall the “Dorm beds” example from the previous chapter.
- We could be concerned with break-even revenue, break-even sales volume or break-even price.

Dorm Beds Example

Consider a project to supply the University of Missouri with 10,000 dormitory beds annually for each of the next 3 years.

Your firm has half of the woodworking equipment to get the project started; it was bought years ago for $200,000: is fully depreciated and has a market value of $60,000. The remaining $100,000 worth of equipment will have to be purchased.

The engineering department estimates you will need an initial net working capital investment of $10,000.

Dorm Beds Example

- The project will last for 3 years. Annual fixed costs will be $25,000 and variable costs should be $90 per bed.
- The initial fixed investment will be depreciated straight line to zero over 3 years. It also estimates a (pre-tax) salvage value of $10,000 (for all of the equipment).
- The marketing department estimates that the selling price will be $200 per bed.
- You require an 8% return and face a marginal tax rate of 34%.

Dorm Beds Break-Even Analysis

- In this example, we should be concerned with break-even price.
- Let’s start by finding the revenue that gives us a zero NPV.
- To find the break-even revenue, let’s start by finding the break-even operating cash flow (OCF_{BE}) and work backwards through the income statement.

Dorm Beds CF_0

What is the CF in year zero, CF_0, for this project?

Cost of New Equipment $100,000

Net Working Capital Investment $10,000

Opportunity Cost of Old Equipment <u>$39,600</u> = $60,000 × (1-.34)

$149,600

Note that these are all NON-operating CFs concerning this project, and they are used in determining the break-even operating cash flow, OCF_{BE}, via the EAC procedures in the next two slides!

Dorm Beds Break-Even Analysis

The PV of the cost of this project is the sum of $149,600 today less the PV of $16,600 salvage value and return of NWC in Year 3.

CF0	−149,600	I	8
CF1	$0	NPV	– 136,422.38
F1	2		
CF2	$16,600		
F2	1		

Break-Even Analysis: OCF_{BE}

First, set your calculator to 1 payment per year.

Then find the operating cash flow the project must produce each year to break even:

N	3
I/Y	8
PV	− 136,422.38
PMT	52,936.46
FV	0

Break-Even Revenue

Work backwards from OCF_{BE} to Break-Even Revenue

Revenue	$10{,}000 \times \$P_{BE} =$	\$988,035.04
Variable cost	$10{,}000 \times \$90 =$	\$900,000
Fixed cost		\$25,000
Depreciation	$100{,}000 \div 3 =$	<u>\$33,333</u>
EBIT	$\dfrac{\$19{,}603.13}{0.66}$	\$29,701.71
Tax (34%)		<u>\$10,098.58</u>
Net Income		\$19,603.13

$OCF =$ \$19,603.13 + \$33,333   \$52,936.46

Break-Even Analysis

- Now that we have break-even revenue we can calculate break-even price

If we sell 10,000 beds, we can reach break-even revenue with a price of only:

$$P_{BE} \times 10{,}000 = \$988{,}035.34$$

$$P_{BE} = \$98.80$$

Common Mistake in Break-Even

- What's wrong with this line of reasoning?
- With a price of \$200 per bed, we can reach break-even revenue with a sales volume of only:

$$\text{Break-even sales volume} = \frac{\$988{,}035.04}{\$200} = 4{,}941 \text{ beds}$$

As a check, you can plug 4,941 beds into the problem and see if the result is a zero NPV.

Don't Forget that Variable Cost Varies

Revenue	$Q_{BE} \times \$200 = \$88{,}035.04 + Q_{BE} \times \$110$	
Variable cost	$Q_{BE} \times \$90 =$	$?
Fixed cost		$25,000
Depreciation	$100{,}000 \div 3 =$	<u>$33,333.33</u>
EBIT	$\dfrac{\$19{,}603.13}{0.66}$	$29,701.71
Tax (34%)		<u>$10,098.58</u>
Net Income		$19,603.13
	$OCF = \$19{,}603.13 + \$33{,}333$	$52,936.46

Break-Even Analysis

- With a contribution margin of $110 per bed, we can reach break-even revenue with a sales volume of only:

$$Q_{BE} = \frac{\$88{,}035.04}{\$110} = 801 \text{ beds}$$

- If we sell 10,000 beds, we can reach break-even gross profit with a contribution margin of only $8.80:

$$CM_{BE} \times 10{,}000 = \$88{,}035.04$$

$$CM_{BE} = \$8.80$$

- If variable cost = $90, then P_{BE} = $98.80

Summary – Breakeven Analysis

- Procedures for PV Breakeven Analysis:
  - Compute the true cost, at time 0, of the project.
  - Compute the break-even annual operating cash flows, OCF_{BE} (i.e., EAC), that generate the same present value as the present value of the true cost, i.e., NPV=0, that are computed based on non-operating cash flows of the project!
  - Compute the break-even revenue level.
  - Compute the break-even price or sales quantity level that produces a zero net present value for the project.

7.2 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 evaluate gambling strategies.

Monte Carlo Simulation

- Imagine a serious blackjack player who wants to know if she should take the third card whenever her first two cards total sixteen.
  - She could play thousands of hands for real money to find out.
  - This could be hazardous to her wealth.
  - Or, she could play thousands of practice hands.
- Monte Carlo simulation of capital budgeting projects is in this spirit.

Monte Carlo Simulation

- Monte Carlo simulation of capital budgeting projects is often viewed as a step beyond either sensitivity analysis or scenario analysis.
- Interactions between the variables are explicitly specified in Monte Carlo simulation; so, at least theoretically, this methodology provides a more complete analysis.
- While the pharmaceutical industry has pioneered applications of this methodology, its use in other industries is far from widespread.

Monte Carlo Simulation

- Step 1: Specify the Basic Model
- Step 2: Specify a Distribution for Each Variable in the Model
- Step 3: The Computer Draws One Outcome
- Step 4: Repeat the Procedure
- Step 5: Calculate NPV

7.3 Real Options

- One of the fundamental insights of modern finance theory is that options have value.
  – An option is valuable because it gives the holders the RIGHT, NOT obligation, to do something at their advantage.
  – The price of an option is non-negative
- The phrase "We are out of options" is surely a sign of trouble.
- Because corporations make decisions in a dynamic environment, they have options that should be considered in project valuation.

Real Options

- The Option to Expand
  - Has value if demand turns out to be higher than expected
- The Option to Abandon
  - Has value if demand turns out to be lower than expected
- The Option to Delay
  - Has value if the underlying variables are changing with a favorable trend

Discounted CF and Options

- We can calculate the market value of a project as the sum of the NPV of the project without options, NPV, and the value of the managerial options embedded in the project, Opt.

$$M = NPV + Opt$$

A good example would be comparing the desirability of a specialized machine versus a more versatile machine. If they both cost about the same and last the same amount of time, the more versatile machine is more valuable because it comes with options.

The Option to Abandon: Example

- Suppose we are drilling an oil well. The drilling rig costs $300 today, and in one year the well is either a success or a failure.
- The outcomes are equally likely. The discount rate is 10%.
- The *PV* of the successful payoff at time one is $575.
- The *PV* of the unsuccessful payoff at time one is $0.

The Option to Abandon: Example

Traditional NPV analysis would indicate rejection of the project.

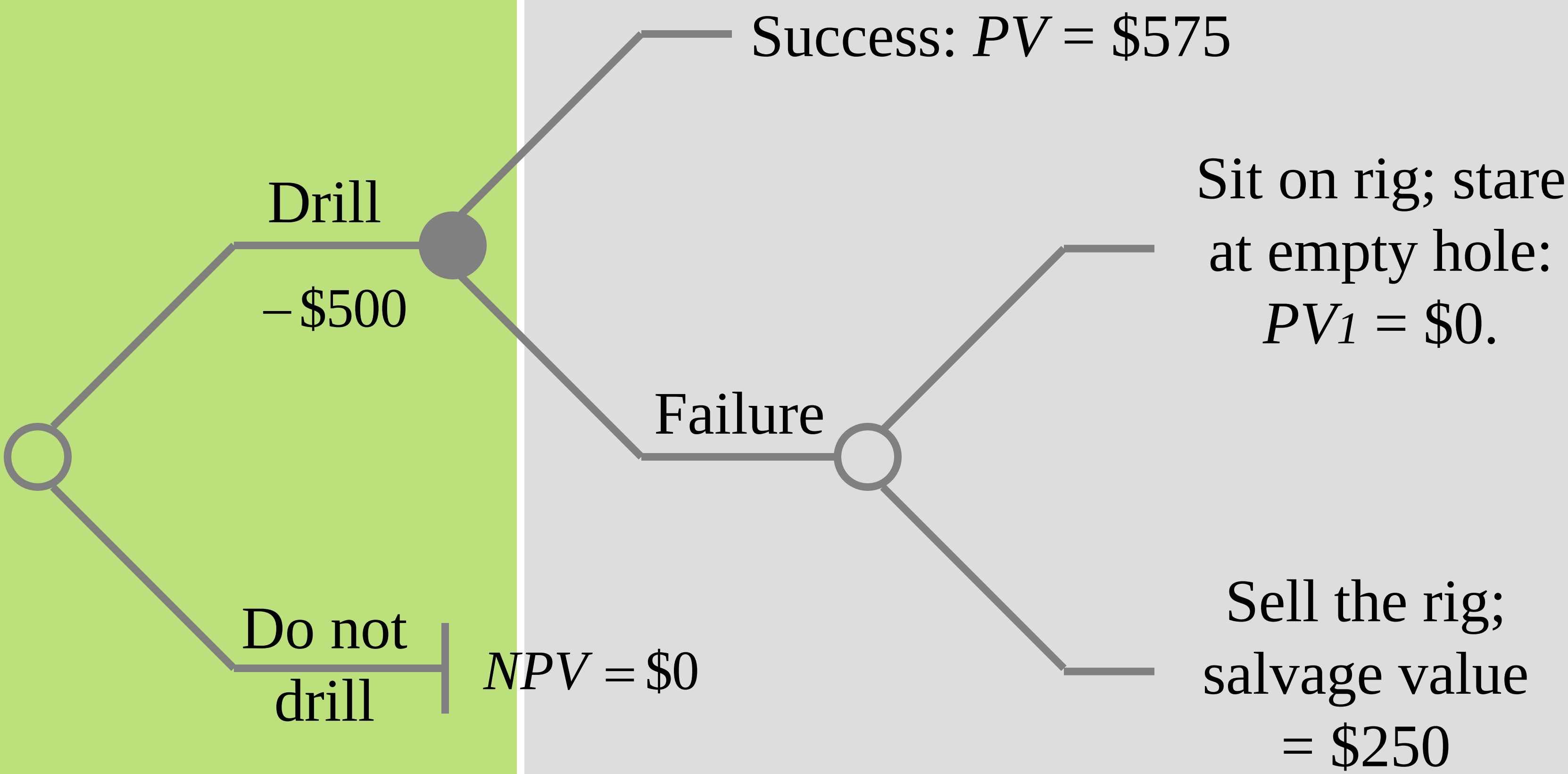
$$\text{Expected Payoff} = \text{Prob. Success} \times \text{Successful Payoff} + \text{Prob. Failure} \times \text{Failure Payoff}$$

$$\text{Expected Payoff} = (0.50 \times \$575) + (0.50 \times \$0) = \$287.50$$

$$NPV = -\$300 + \frac{\$287.50}{1.10} = -\$38.64$$

The Option to Abandon: Example

Traditional NPV analysis overlooks the option to abandon.



The firm has two decisions to make: drill or not, abandon or stay.

The Option to Abandon: Example

- When we include the value of the option to abandon, the drilling project should proceed:

$$\begin{matrix}\text{Expected} \\ \text{Payoff}\end{matrix} = \begin{matrix}\text{Prob.} \\ \text{Success}\end{matrix} \times \begin{matrix}\text{Successful} \\ \text{Payoff}\end{matrix} + \begin{matrix}\text{Prob.} \\ \text{Failure}\end{matrix} \times \begin{matrix}\text{Failure} \\ \text{Payoff}\end{matrix}$$

$$\begin{matrix}\text{Expected} \\ \text{Payoff}\end{matrix} = (0.50 \times \$575) + (0.50 \times \$250) = \$412.50$$

$$M = -\$300 + \frac{\$412.50}{1.10} = \$75.00$$

Valuing the Option to Abandon

- Recall that we can calculate the market value of a project as the sum of the NPV of the project without options and the value of the managerial options implicit in the project.

$$M = NPV + Opt$$

$$\$75.00 = –\$38.64 + Opt$$

$$\$75.00 + \$38.64 = Opt$$

$$Opt = \$113.64$$

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 2—this schedule yields the highest NPV when judged today.

The Option to Delay: Example

- In this example, the value of the option to delay the launching of the project by 2 years is

Opt = \$6,529 - \$5,000 = \$1,529

What is the value of the option to delay the launching of the project by 4 years?

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?