Chapter 15

Real Options

Road Map

Part A Introduction to finance.

Part B Valuation of financial assets, given discount rates.

Part C Determination of discount rates.

Part D Introduction to corporate finance.

- Efficient Market Hypothesis (EMH).
- Capital budgeting.
- Real options.
- Financing decisions.

Main Issues

- Strategic Options
- Valuation of Real Options and Capital Budgeting

Contents

1 Strategic Options

In investment decisions, we often face situations involving strategic options. Common and important options in capital investments include:

- The option to wait before investing
- The option to make follow-on investments
- The option to abandon a project
- The option to vary output or production methods.

Two key elements in strategic options and their valuation:

1. New information arrives over time
2. Decisions can be made after receiving new information.

In the previous example of optimal timing with changing demand, the decision is made today based on information today about future cash flows. It does not take into account (1) new information arriving later and (2) flexibility to adjust investment decisions in response to the new information.

In this section, we focus on the impact of strategic options with these two elements on capital investment decisions.

1.1 Value of Strategic Options: An Example

Example 1. UW Inc. is deciding whether or not to buy a copper mine:

- The mine can produce one million kilograms (kg) of copper, but only for one year, and it becomes useless after that.
- It takes one year to extract the copper, and the extraction cost is \$1.8 per kilogram paid up-front, which is increasing at 10% per year.
- The copper price is now $S_0 = \$2$ per kilogram. The next year, it may either increase by the factor $u = 1.3$ to \$2.6, or decrease by the factor $d = 0.8$ to \$1.6 with equal probability, $p = 0.5$.
- All uncertainty about copper price is resolved next year.
- The copper price risk is completely diversifiable so that future cashflows can be discounted at the risk-free rate.
- The risk-free interest rate is 5% and constant over time.

Question: What is the value of this project at $t = 0$?

Valuation Using Naive NPV

We first evaluate this project using the naive NPV criterion.

1. Go ahead with the project (extract) now.

- The expected cashflow next year is

$$\frac{2.6+1.6}{2}=\frac{4.2}{2}=\$2.1 \text{ (per kg.)}.$$

- The NPV (per kg) using static DCF formula gives:

$$NPV_0^{\text{static}}=-1.8+\frac{2.1}{1.05}=\$0.2.$$

2. Wait one year and go ahead with the project (no matter what the price of copper may be).

- In the "up-state", the NPV of the project in year 1 is

$$NPV_{1,\mathrm{up}} = -1.98 + \frac{(2.6)(1.5)}{1.05} = \$0.62.$$

- In the "down-state", the NPV of the project in year 1 is

$$NPV_{1,\mathrm{down}} = -1.98 + \frac{(1.6)(1.05)}{1.05} = -\$0.38.$$

- The NPV now (in year 0) is

$$\begin{aligned} NPV_0 &= \frac{(NPV_{1,\mathrm{up}} + NPV_{1,\mathrm{down}})/2}{1.05} \\ &= \frac{[(0.62 - 0.38)/2]}{1.05} NPV_0^{\mathrm{static}} = \$0.114. \end{aligned}$$

Using naive NPV calculations, we would have concluded:

- Buying the mine has positive NPV.
- We should start extracting copper now.
- The NPV is (0.2)(1,000,000) = \$200,000.

<u>Question:</u> Is this the best we can do?

If we wait, we would not extract copper in the down state:

- At that time, we know for sure that extracting leads to losses,
- And, we have the option not to extract.

Valuation Using Dynamic (Sophisticated) NPV

Let us now redo the calculation, taking into account the flexibility in responding to new information about copper price:

- In the "up-state", NPV of the project is

$$NPV_{1,\text{up}} = -1.98 + \frac{(2.6)(1.05)}{1.05} = \$0.62.$$

- In the "down-state", NPV of the project, if we extract, is

$$NPV_{1,\text{down}} = -1.98 + \frac{(1.6)(1.05)}{1.05} = -\$0.38.$$

- Since it does not pay off to extract in the "down-state", we would not. The NPV now (in year 0) is

$$NPV_0 = \frac{(NPV_{1,\text{up}} + 0)/2}{1.05} = \frac{0.31}{1.05} = \$0.295.$$

We now conclude:

- Buying the mine has positive NPV.
- We should not extract now, but wait for one year:
  - If the copper price goes up, we extract.
  - If the copper price goes down, we do not extract.
- The NPV is (0.295)(1,000,000) = \$295,000.

Lessons from Example 1

- The static naive NPV criterion considers only the possibility of either accepting or rejecting the project at $t = 0$. It *ignores* possibility of postponing this decision to next period, $t = 1$.

- Even if we consider the possibility of waiting using naive NPV calculations, it *ignores* the value of the option to take different actions using new information.

- As long as there is some uncertainty about the future price, the value of the option to postpone the decision to invest is valuable and should be taken into account.

  - In Example 1, the value of the option to postpone the production decision is given by the difference between the static and dynamic NPVs

    $$\text{Value of Waiting} = 0.295 - 0.2 = \$0.095.$$

  - This difference in value comes from the option to take advantage of the additional knowledge learned later, in deciding whether or not to undertake the project.

- NPV rule is still correct when applied correctly.

1.2 Option of Waiting

Example 1. (Continued.) We now use the binomial option pricing approach to value the option to wait in Example 1.

- We want to find a replicating portfolio (a, b) such that

$$S_u a + Rb = C_u$$
$$S_d a + Rb = C_d,$$

which, in our numerical example, is:

$$2.6a + 1.05b = 0.62$$
$$1.6a + 1.05b = 0.$$

- The solution is: $a = 0.62$ and $b = -.945$.
- The current copper price is \$2.0
- The current value of the project, NPV_0, is the value of this replicating portfolio:

$$NPV_0 = aS_0 + b = (0.62)(2.0) - .945$$
$$= \$0.295.$$

This is the same answer that we obtained using the dynamic NPV approach.

- You could get the same answer with *risk-adjusted* probabilities.
- Thus, we see that the option pricing approach applies quite naturally to value investments with embedded options.

1.3 Options to Undertake Follow-up Projects

Example 2. In 1990, MC Inc. considers entering PC business:

- R&D has come up with model-A — a new PC model
- CFs of model-A, if introduced, are as follows

	1990	1991	1992	1993	1994	1995
Investment ($M) (R&D, plant, WC)	-450	-50	-100	-100	125	125
Operating CF ($M)		110	159	259	185	
Net CF	-450	60	59	159	310	125

  NPV at 20% is -$46 million.

- Development and production of model-A would allow MC Inc. to introduce model-B in 1993.
- Expected CFs from model-B are twice that of model-A.
- In expectation, model-B is a loser too.
- But there are scenarios in which model-B really pays off.

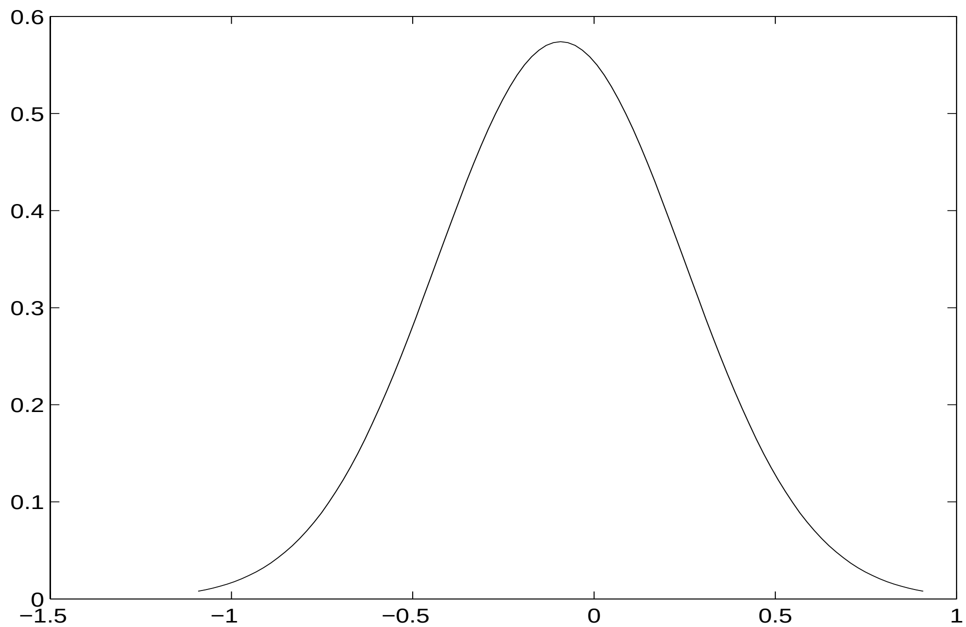
Different Scenarios	PV of model-B ($M)
Benchmark scenario	-92
Initial Investment reduced by 30%	178
Sales increase by 40%	368
Profit margin increases by 50%	302

Question: Should MC Inc. start model-A?

The expected value of model-B is -$92 million. Could this prospect justify the $46 million sacrifice to enter the market with model-A?

Suppose that distribution of possible NPV of model-B in 1993 is as follows:

Probability Distribution of NPV in 1993 for Model-B (in billion dollars)



Note:

- Starting model-B in 1993 is an option.
- So long as MC can abandon the business in 1993, only the right-hand-side of the distribution is relevant.
- The NPV of the right-hand-side is huge even if the chance of ending up there is less then 50%.

Assume:

- Model-B decision has to be made in 1993
- Entry in 1993 with Model-A is prohibitively expensive
- MC has the option to stop in 1993 (possible loss limited)
- Investment needed for model-B is $900M (twice that of A)
- PV of operating profits from model-B is $468 million in 1990
- PV evolves with annual standard deviation of 35%.

The opportunity to invest in model-B is like a 3-year call option on an asset worth $468 million now with exercise price $900 million!

Using Black-Scholes formula:

Value of Call = $55 million.

Total NPV of model-A ($M):

	A	A+B
DCF	-46	-99
Option value	55	
Total value	9	

1.4 Comments on Strategic Options

1. Naive DCF analysis tends to under-estimate the value of strategic options:
   - Timing of projects is an option (American call)
   - Follow-on projects are options (American call)
   - Termination of projects are options (American put)
   - Expansion or contraction of production are options (conversion options).
2. It is difficult to apply DCF for option valuation.
3. Options can be valued (sometimes).

It is important to think of strategic planning as a process of

1. Acquiring and disposing of options
2. Exercising options optimally.

Limitations of option pricing models in project valuation

1. Option pricing models rely on the assumption that the underlying asset (or cash flow) is traded. This assumption often does not hold for real assets (tangible or intangible).

2. Option pricing models rely on specific assumptions about the price process of the underlying asset. For most real assets, we often do not know much about their price process.

3. Results from option pricing models can be very sensitive to the assumptions about the behavior of the underlying driving variables:

   - A constant volatility of the underlying source of risk
     - OK for valuing options with short maturities (most financials)
     - Problematic for valuing projects with CFs over several years.
   - A constant interest rate.

4. etc.

2 Homework

Readings:

- BM Chapter 22.