Chapter 22: Real Options

I. Introduction to Real Options

A. Basic Idea

=> firms often have the ability to wait to make a capital budgeting decision

=> may have better information later
=> may be able to avoid negative outcomes

=> being able to wait to make a decision is an option.

B. Valuing Real Options

Basic idea: can use any of the option valuation techniques developed for financial options in Ch. 21

Problems:

1) numbers are very difficult to come up with
2) Black-Scholes values European options but most real options can be exercised at any time.

1. Binomial option prices

Information needed:

1) current market prices of securities used to create replicating portfolio
=> need securities with same source of risk as the real option

2) payoffs on the securities and on real option in both possible states

2. Black-Scholes

Information needed:

S = market value of the asset on which have the option
K = exercise price of the option
σ = annual volatility on asset on which have the option
T = years until the option expires
r_f = return on Treasuries that mature when the option expires
Note: used to calculate PV(K)
Div = cash flow give up between now and exercising the option

3. Decision Tree

a. Basic idea: map out future decisions and sources of uncertainty
=> start at end and work back to the present

b. Notes

1) two types of "nodes"
Box = decision node – decide which branch to follow
Circle = information node – resolution of uncertainty not controlled by management
2) can have more than two possible outcomes or decisions at each node
3) discount all cash flows at the required return

Note: in each section, I'll use a different approach than the book since any of the approaches are valid if have the relevant information.

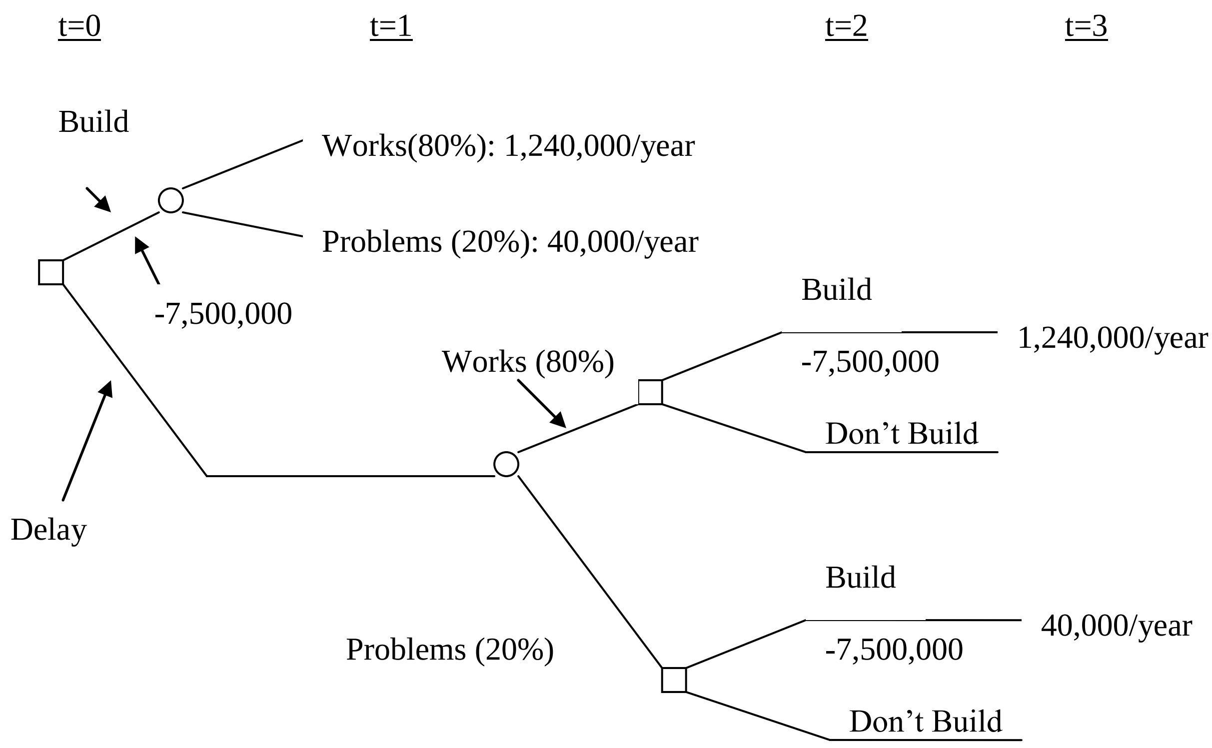
II. The Option to Delay an Investment Opportunity

1. Basic idea: being able to wait to make investment decision (rather than deciding now) is a long call

2. Issues:

1) invest now only if NPV now > value of option to wait
2) option to wait is more valuable the greater the uncertainty about future cash flows
3) div (for Black-Scholes) = loss of value from waiting
- cash flows would have received if invest now
- loss of sales due to competitors acting now
4) book has example with Black-Scholes but can use other methods.

Ex. Your firm is considering investing $7,500,000 in a factory to build home ethanol systems that will allow individuals to create ethanol from grass clippings. There is an 80% chance that the technology will work as planned and expected net cash flows will be $1,240,000 per year and a 20% chance of technical problems that will reduce expected net cash flows to $40,000 per year. Either way, net cash flows would begin a year from today and continue for 20 years (when your patents will expire and new technology will allow personal solar power systems to become viable). Alternatively, in two years, your firm will know whether the technology will work and thus whether net cash flows will be $1,240,000 or $40,000 per year. Should your firm build now or wait two years if the required return on the project is 10% per year?



If delay:

t = 2:

Technology works:

If build: $NPV_{t=2} = -7{,}500{,}000 + \frac{1{,}240{,}000}{.1}\left(1-\left(\frac{1}{1.1}\right)^{18}\right) = 2{,}669{,}751$

If don't build: NPV = 0

Technology doesn't work:

If build: $$NPV_{t=2} = -7{,}500{,}000 + \frac{40{,}000}{.1}\left(1 - \left(\frac{1}{1.1}\right)^{18}\right) = -7{,}171{,}944$$

If don't build: NPV = 0

$E(NPV_{t=2}) = .8(2{,}669{,}751) + .2(0) = 2{,}135{,}801$

t = 0:

$$E(NPV_{t=0}) = \frac{2{,}135{,}801}{(1.1)^2} = 1{,}765{,}125$$

If build now:

t = 0: E(CF) = .8(1,240,000) + .2(40,000) = 1,000,000

$$NPV = -7{,}500{,}000 + \frac{1{,}000{,}000}{.1}\left(1 - \left(\frac{1}{1.1}\right)^{20}\right) = 1{,}013{,}564$$

=> optimal to wait

III. Growth Options

Growth option: firm has an opportunity to undertake an investment in the future

A. Valuing the Growth Potential of a Firm

Notes:
1) growth option is a call => very similar to option to delay.
2) growth options are riskier than existing assets since likely out-of-the-money

B. The Option to Expand

1. Applications

1) investment in project today often opens up additional investment opportunities in future

Ex. opening factory in China establishes relationships so can build a second factory later at a lower cost

2) by making small investment today, find out whether product will be successful

Note: example in book uses decision trees and risk-neutral probabilities, but can use other methods

2. Example: Suppose firm is considering building a new factory at a cost of $250,000. This factory is expected to produce cash flows of $26,000 per year for 25 years starting a year from today. Within two years, if the product is a success, then the plant could be expanded at a cost of $125,000. The expected cash flows from this expansion would be $13,000 per year for 23 years with the 1st cash flow coming one year after the expansion is complete (three years from today). The standard deviation of returns on the expansion of 27% exceeds the standard deviation of returns on the initial factory of 22%. The return on Treasury strips vary by maturity as follows: 1-year = 3.3%, 2-year = 3.5%, 3-year = 3.6%, 25-year = 5%. The required return on this factory and the possible expansion is 9.5% per year. Using the Black-Scholes Option Pricing Model to value the expansion option, should the factory be built?

NPV excluding option to expand = -$4622.98 = 245,377.02 – 250,000

Calculation of PV of inflows:

$$PV_0 = \frac{26{,}000}{.095}\left(1-\left(\frac{1}{1.095}\right)^{25}\right) = 245{,}377.02$$

=> excluding option to expand, not worthwhile

Value of option to expand (Black-Scholes Option Pricing Model):

Variables:

S = present value of cash flows from the expansion
K = cost of expansion
σ = volatility of returns on the expansion over the life of the option
T = number of years during which can expand
r_f = risk-free rate between now and "T"

S:

$$PV_2 = \frac{13{,}000}{.095}\left(1-\left(\frac{1}{1.095}\right)^{23}\right) = 119{,}871.59$$

$$PV_0 = 119{,}871.59\left(\frac{1}{1.095}\right)^{2} = 99{,}974.22$$

T = 2

PV(K) = $\frac{125{,}000}{(1.035)^2} = 116{,}688.84$

σ = .27

$$d_1 = \frac{\ln\left[\frac{S}{PV(K)}\right]}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2} = \frac{\ln\left(\frac{99{,}974.22}{116{,}688.84}\right)}{.27\sqrt{2}} + \frac{.27\sqrt{2}}{2} = -0.21396$$
$$d_2 = d_1 - \sigma\sqrt{T} = -0.21396 - .27\sqrt{2} = -0.59580$$

$N(d_1) = .41529$; $N(d_2) = .27656$

=> value of option to expand = $C = S \times N(d_1) - PV(K) \times N(d_2)$

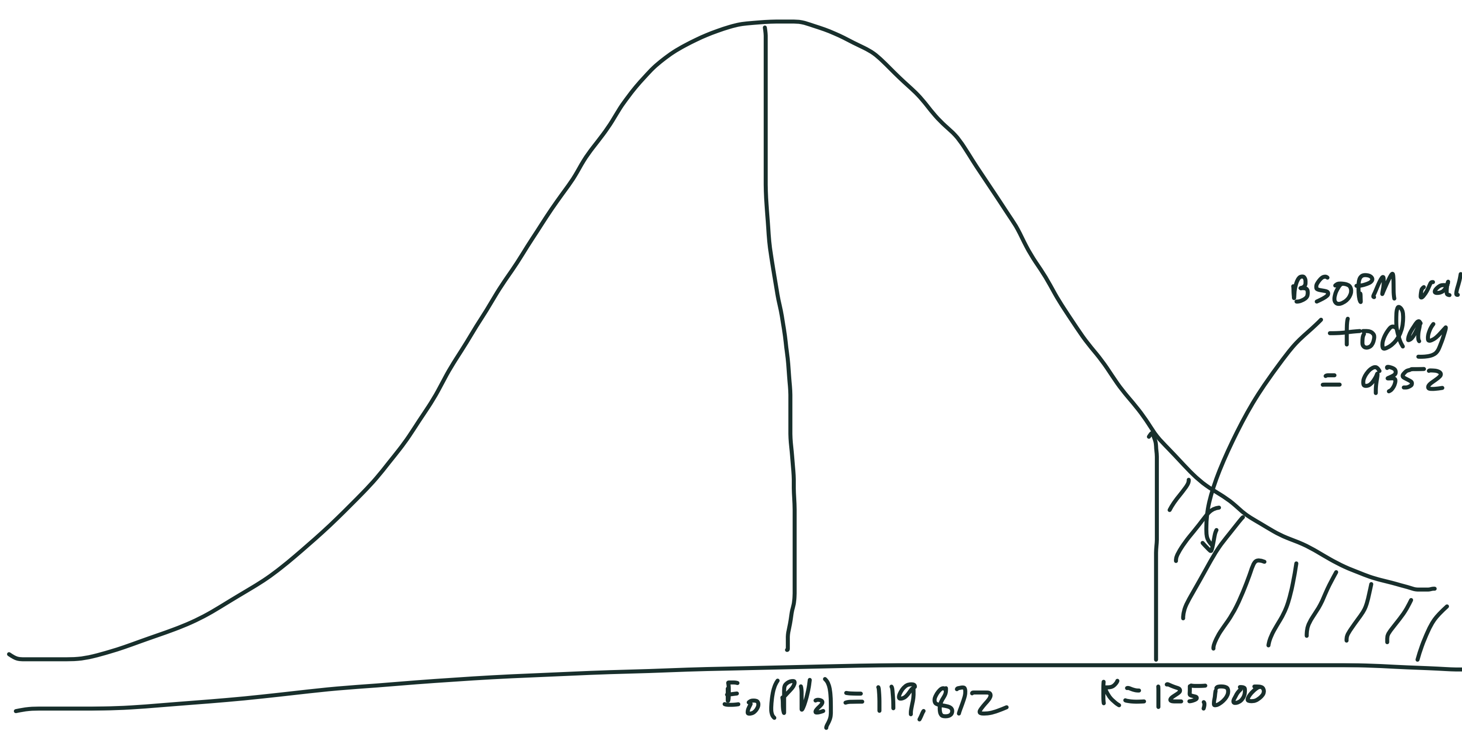
= 99,974.22(.41529) – 116,688.84(.27656) = 9352.32

NPV (including option to expand) = -4622.98 + 9352.32 = -250,000 + 245,377.02 + 9352.32 = 4729.34

=> project is worthwhile

=> intuition not obvious:

=> not worthwhile on own,
=> doesn't look like expansion worthwhile
=> option to expand if better than expected results is valuable
note: only expand if happens to be worthwhile...no downside to possible expansion.



IV. Abandonment Options

=> ability to walk away is essentially a long put and worth something

key => if project fails to live up to expectations, can shut down instead of continuing to operate

=> exercise price equals the cash flows if shut down
Ex. sale of facilities, machinery, etc.

Note: textbook values with a decision tree but can use other methods

=> value of project = NPV (ignoring option to shut down)+ value of shut down option (put)

Ex. Suppose a firm is considering a project costing $100,000 that is expected to provide cash flows of $13,000 per year for 15 years starting a year from today. The required return on the project is 11.25% per year and the standard deviation of returns on the project is 35% over the next three years but only 32% over its 15-year life. If the project fails to live up to expectations, the facility can be sold for $50,000 any time within the next 3 years. The return on Treasury strips vary by year as follows: 1-year = 3.3%, 2-year = 3.7%, 3-year = 4%, 15-year = 5.5%. Should firm undertake project?

PV of inflows:

$$PV_0 = \frac{13{,}000}{.1125}\left(1-\left(\frac{1}{1.1125}\right)^{15}\right) = 92{,}205.36$$

NPV excluding shut down option = -$7794.64 = -100,000 + 92,205.36

Value of option to abandon:

Variables

S = value of asset being abandoned
K = cash flows from selling assets when shut down
σ = volatility of returns over the life of the option on asset shutting down
T = time during which can shut down
r_f = risk-free rate between now and "T"

Note: since cash flows between now and expiration, need to use S^x

T = 3

$$S^x = 92{,}205.36 - \frac{13{,}000}{.1125}\left(1 - \left(\frac{1}{1.1125}\right)^3\right) = 60{,}574.69$$

PV(K) = $\frac{50{,}000}{(1.04)^3}$ = 44,449.82

σ = .35

$$d_1 = \frac{\ln\left[\frac{S}{PV(K)}\right]}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2} = \frac{\ln\left(\frac{60{,}574.69}{44{,}449.82}\right)}{.35\sqrt{3}} + \frac{.35\sqrt{3}}{2} = 0.8137$$

$$d_2 = d_1 - \sigma\sqrt{T} = 0.8137 - .35\sqrt{3} = 0.20746$$

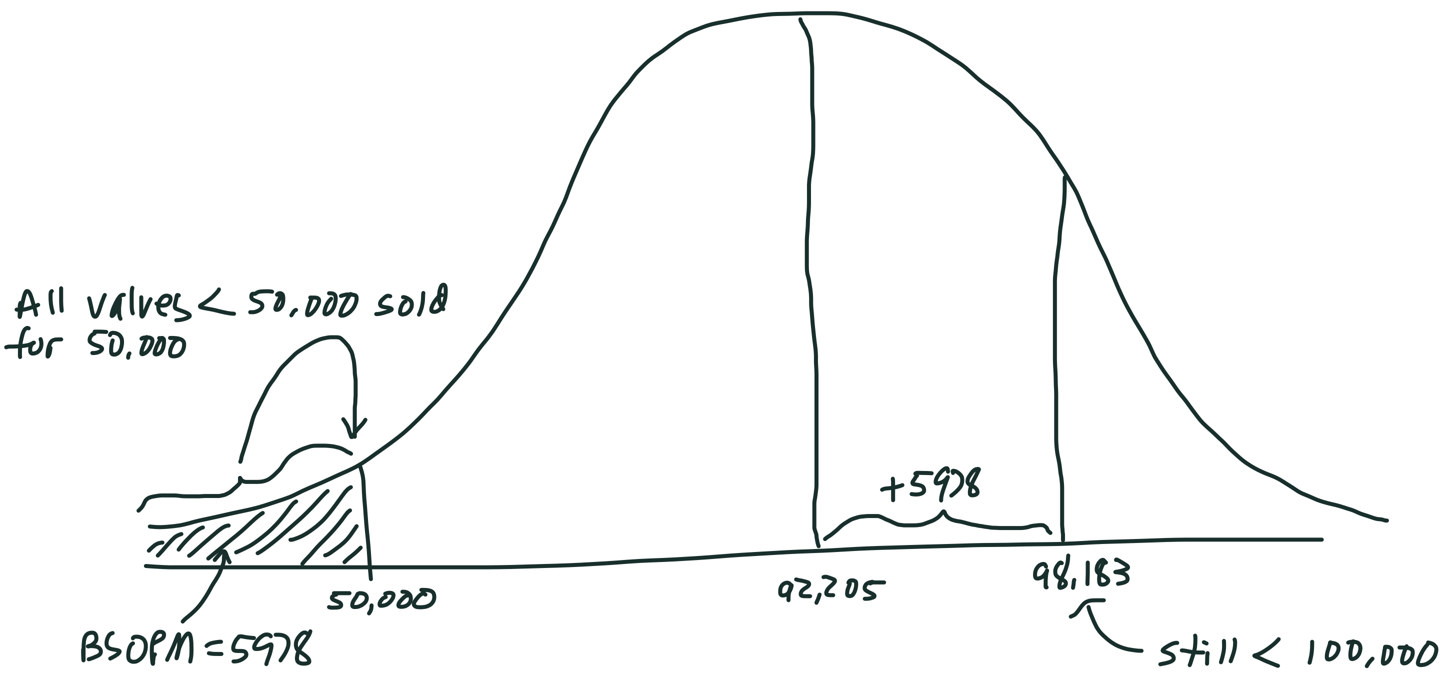
=> $N(d_1)$ = .79209, $N(d_2)$ = .58217

=> $P = PV(K)[1 - N(d_2)] - S[1 - N(d_1)]$ = 5977.89 = 44,449.82(1-.58217) – 60,574.29(1-.79209)

Value of project including option to abandon:

NPV (including the put) = -7794.64 + 5977.89 = -1816.74
= -100,000 + 92,205.36 + 5977.89 = -100,000 + 98,183.25

=> not worthwhile even w/ abandonment option



V. Key Insights from Real Options

1. Investment opportunities with negative NPVs are valuable to the firm as long as it might have a positive NPV in the future if wait

2. Not all positive NPV project should be taken immediately

   => option to delay might be worth more
      => give up the option to wait if invest now

   => uncertainty might be resolved if wait

3. When calculate value of a project, need to include the value of real options associated with the project.