

TIØ4146 Finance for Science and Technology Students

Chapter 9 - Real Options Analysis (part 2)

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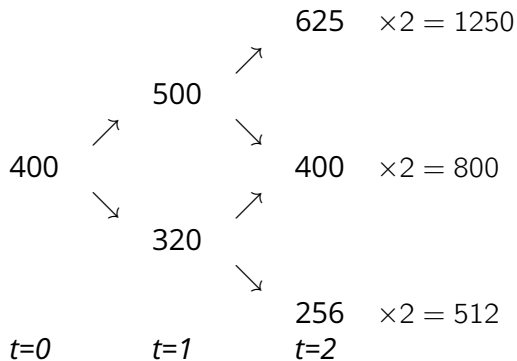
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Follow-up investments

- ▶ Often projects generate follow-up investments which give advantage over competition
- ▶ clear real option value:
 - ▶ re-use gives lower exercise price
 - ▶ market base gives higher payoff
 - ▶ than competitors starting from scratch
- ▶ examples are abundant:
 - ▶ MicroSoft DOS, Windows -95, -NT, -XP, -7, ..
 - ▶ Intel 8086, 80286, 80386, 80486, Pentium, ..

To illustrate, adapt our old example in three ways:

1. Technology project instead of oil well
2. Investment required is 450
3. Project can be repeated on double scale after 2 periods
 - ▶ first project is prerequisite for follow-up e.g. extension of technology
 - ▶ invest $2\times$ exercise price, get $2\times$ market value
 - ▶ risk free rate is 7%
 - ▶ as before exercise price increases with risk free rate:
 - ▶ investment is $2 \times 450 \times 1.07^2 = 1030.4$
4. Further details as before:
 - ▶ real probabilities are .8 and .2 and risk adjusted discount rate 16%



- ▶ Gives initial project negative NPV: $400 - 450 = -50$
- ▶ Follow-up project is loss-making in DCF terms!

$$(.8^2) \times 1250 + (2 \times .8 \times .2) \times 800 + (.2^2) \times 512 = 1076.5$$

$$PV = \frac{1076.5}{1.16^2} = 800 \text{ so the NPV} = 800 - (2 \times 450) = -100$$

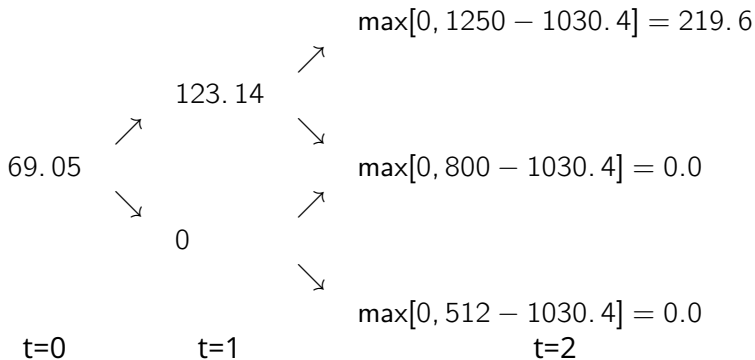
- ▶ Real options analysis gives different picture:
 - ▶ models flexibility to profit from favorable market developments
 - ▶ follow-up investment is an out-of-the-money call option
 - ▶ only exercised if profitable
 - ▶ but out-of-the-money options are valuable
- ▶ The parameters of the binomial process are as before:

$$u = 1.25, \quad d = .8, \quad r = 1.07$$

$$p = \frac{r - d}{u - d} = \frac{1.07 - .8}{1.25 - .8} = .6 \quad (1 - p) = .4$$

The follow-up option matures after 2 periods, at $t = 2$

- ▶ exercise price is $2 \times 450 \times 1.07^2 = 1030.4$



Option value of follow-up project

Value of the option is

- ▶ at $t=1$: $(.6 \times 219.6)/1.07 = 123.14$
- ▶ at $t=0$: $(.6 \times 123.14)/1.07 = 69.05$

The follow-up opportunity is so valuable

- ▶ that it gives the whole project $NPV > 0$
- ▶ $-50 + 69.05 = 19.05$

Makes it a classic among real options

- ▶ particularly valuable in volatile (fast-growing) markets
- ▶ used to be called 'strategic value'
- ▶ can now be priced properly!

Abandonment Option

- ▶ No need to continue loss-making projects
- ▶ assets can be sold, used alternatively
- ▶ (cf. general purpose assets in bankruptcy)
- ▶ gives higher 'bottom' in project value

Abandonment option can be modelled in various ways

- ▶ separate tree for second hand value
 - ▶ lower starting point, less volatile
 - ▶ primary / secondary values cross in down nodes
 - ▶ more profitable to abandon
- ▶ simpler: fixed second hand value

Extend our example with abandonment option

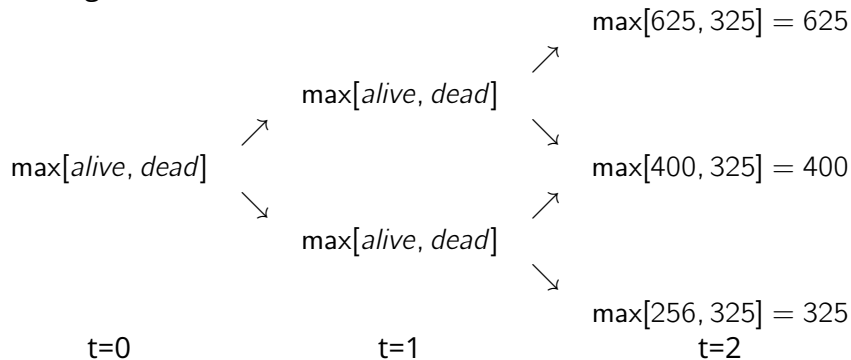
- ▶ possibility to sell project's assets second hand at any time for a fixed price of 325 (formulate an an American put)
- ▶ Valued by including exercise condition:

$$\max[\textit{continue}, \textit{abandon}]$$

in all nodes of the value tree

- ▶ Recall: tree contains project values, not cash flows \Rightarrow exercise condition also in last node

Starting in the end nodes:



Option exercised lower node t=2 ($\text{alive} < \text{dead}$)

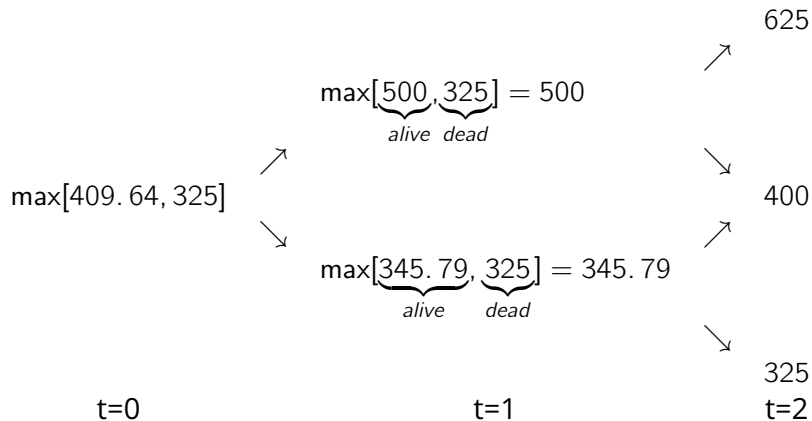
Then we calculate the values alive at $t=1$:
upper node is, of course:

$$\frac{.6 \times 625 + .4 \times 400}{1.07} = 500$$

lower node:

$$\frac{.6 \times 400 + .4 \times 325}{1.07} = 345.79$$

and compare them with the values dead:



t=0 value found by repeating procedure:

$$\frac{.6 \times 500 + .4 \times 345.79}{1.07} = 409.64$$

and checking the t=0 values dead and alive:

$$\max[409.64, 325] = 409.64$$

- ▶ Value without abandonment option is 400
- ▶ flexibility to abandon has value of 9.64

Option value can also be calculated separately:

- ▶ American put with an exercise price of 325
- ▶ exercise condition is $\max[0, 325 - \text{project value}]$

Values at t=2 are:

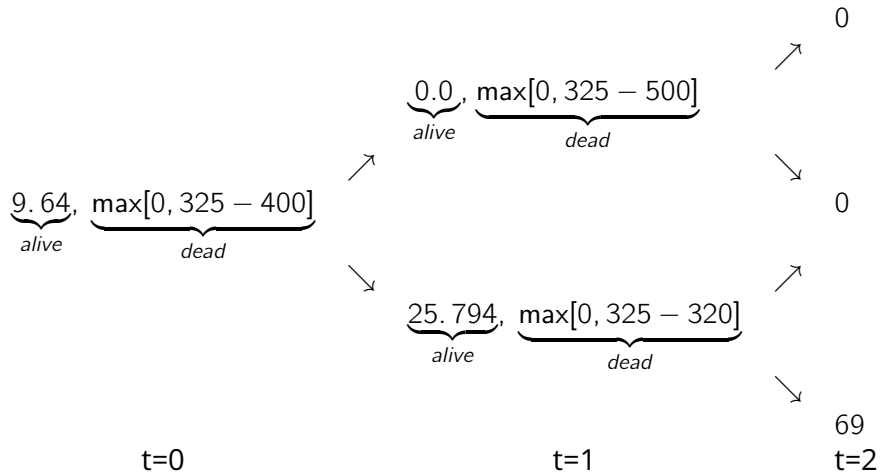
- ▶ $\max[0, 325 - 625] = 0$
- ▶ $\max[0, 325 - 400] = 0$
- ▶ $\max[0, 325 - 256] = 69$

The t=1 value alive is

$$\frac{.6 \times 0 + .4 \times 69}{1.07} = 25.794$$

and the t=0 value alive is

$$\frac{.6 \times 0 + .4 \times 25.794}{1.07} = 9.64$$



Phasing investments

- ▶ Firms may not commit themselves to entire project at once but to successive stages, one at a time. This is very common for certain types of projects.
- ▶ Construction industry:
 - ▶ preparation phase: licenses, groundwork
 - ▶ construction phase: building
 - ▶ finishing stage: fixtures, plumbing, etc.
- ▶ Very pronounced in pharmaceutical research:
 - ▶ basic research: search for potential drugs
 - ▶ pre-clinical tests (on rats)
 - ▶ clinical tests (on humans)
 - ▶ approval and production

Notice: option refers to

- ▶ *decision* to accept project's next phase
- ▶ *not* implementation of already accepted next phase
- ▶ means next phase can be rejected, project abandoned

With a project structured in phases:

- ▶ each phase is call option on the next
- ▶ accepting first phase buys option on second
- ▶ second phase buys option on third, etc.

Means they are compound options:

- ▶ compound options are options on options
- ▶ notice: value of option on 3rd phase included in value of 2nd phase

To illustrate, we adapt, again, our binomial example

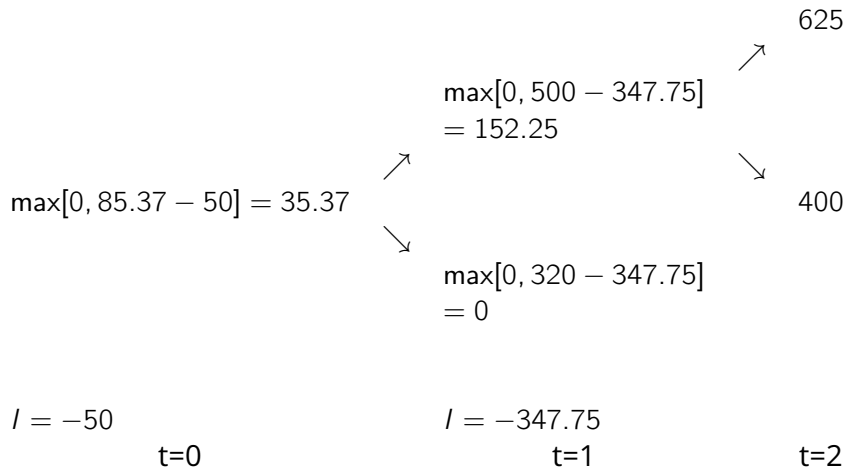
- ▶ project's investment of 375
- ▶ can be made in two stages:
 - ▶ 50 now (preparation phase)
 - ▶ rest in the next period: $1.07 \times 325 = 347.75$

Option modelled by including in $t=1$ nodes:

$$\text{project value} = \max[0, \text{project value} - \text{investment}]$$

Looks obvious in option context, not in practice

Value tree for flexible (phased) project:



t=0 value found with familiar procedure:

$$\frac{.6 \times 152.25 + .4 \times 0}{1.07} = 85.37$$
$$85.37 - 50 = 35.37$$

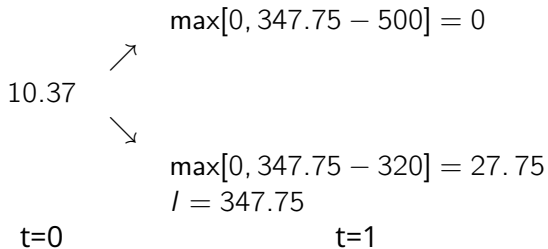
Value of flexibility is 10.37, project's value increase from 25

Option can also be modelled separately

- ▶ Is the option a call or put? How do we formulate the exercise condition?
- ▶ The option is a put
 - ▶ by not investing we 'keep' the investment amount
 - ▶ and give up the project value
- ▶ exercise condition:

$$\max[0, \text{investment} - \text{project value}]$$

Option's value tree becomes



Option value is:

$$\frac{.6 \times 0 + .4 \times 27.75}{1.07} = 10.37$$

Option has counter-intuitive elements:

- ▶ Why only consider investment for next stage?
 - ▶ we know later investments are required
 - ▶ why not include them in exercise decision?

That is what DCF does!

Real option analysis does not ignore later investments

- ▶ included as exercise prices of later options
- ▶ determine value of later options
- ▶ but exercise decision made later
- ▶ at expiration, when more information is available

Why not include previous investments in decision?

- ▶ If the project is abandoned
- ▶ would not they be wasted?

Is 'sunk cost fallacy'

- ▶ if previous investments are irreversible (they usually are)
- ▶ they are wasted already

If much is already invested, will not a small extra investment produce large project?

- ▶ that is precisely what Real Options Analysis models
- ▶ but project should be large in future cash flows, not past investments

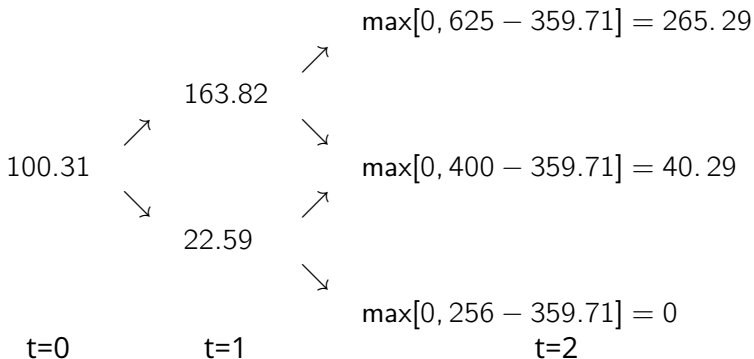
Defaulting a loan

Can easily be included in our binomial example. Assume initial investment of 375 financed with:

- ▶ a zero coupon loan of 300
- ▶ an equity investment of 75
- ▶ nominal interest rate 9.5%
- ▶ matures after 2 periods
- ▶ payment of 359.71 (300×1.095^2)
- ▶ no interest payments in between

Owners have the option to default, and they will do so when

project value < debt obligations



The value of levered equity

Loan is defaulted lower node at $t = 2$

t = 1 values calculated as usual:

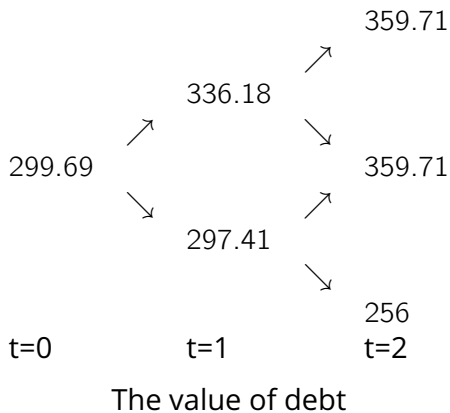
$$\frac{.6 \times 265.29 + .4 \times 40.29}{1.07} = 163.82 \quad \frac{.6 \times 40.29 + .4 \times 0}{1.07} = 22.59$$

so that t = 0 value is

$$\frac{.6 \times 163.82 + .4 \times 22.59}{1.07} = 100.31$$

Project's NPV is $100.31 - 75 = 25.31$ as before (allowing 0.31 rounding)

Value of debt calculated in same way:



- ▶ Payment in lower node $t = 2$ is remaining project value
- ▶ lower than promised payment of 359.71

Total project value remains $100.31 + 299.69 = 400$

- ▶ changing capital structure does not add value
- ▶ divides it differently

We can calculate effective market interest rate for risky loan:

- ▶ calculate expected payoff with real probabilities:

$$.8^2 \times 359.71 + 2 \times .8 \times .2 \times 359.71 + .2^2 \times 256 = 355.56$$

- ▶ then solve $355.56/r^2 = 300$ for r , gives $r=1.089$

Does this mean that option to default has no value?

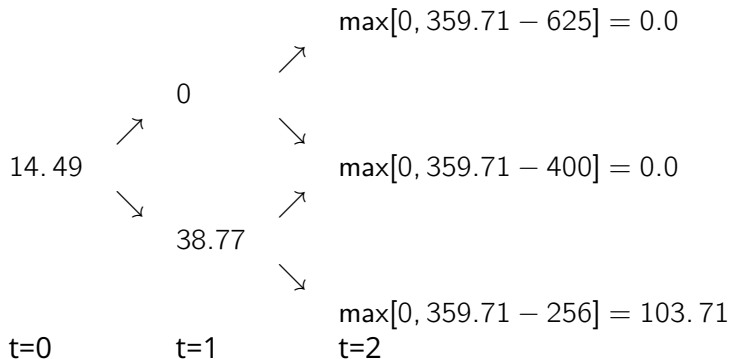
NO! option redistributes value

To illustrate, first calculate value of option to default separately

- ▶ reformulate option as a put
- ▶ owners can 'sell' project to lenders
- ▶ by keeping amount due to the lenders
- ▶ exercise condition is

$$\max[0, \textit{amount due} - \textit{project value}]$$

- ▶ option only exercised in lower node
- ▶ value at exercise is $\max[0, 359.71 - 256] = 103.71$



- ▶ The $t=0$ value is $(.4^2 \times 103.71)/1.07^2 = 14.49$
- ▶ Without default option, loan would be risk free, and thus the value would be $359.71/1.07^2 = 314.18$

General conclusions:

- ▶ difficult to capture dynamic aspects of risk induced by flexibility with discounted cash flow approach
- ▶ discounted cash flow best suited for passive attitude:
 - ▶ accept the cash flows, positive and negative, as given
 - ▶ without exploring the possibilities to change them
- ▶ Adapting approach to include flexibility (decision trees):
 - ▶ makes original discount rate useless
 - ▶ very cumbersome to calculate a new one
- ▶ Verdict on decision trees has to be:
 - ▶ they are outdated
 - ▶ should not be used for investment problems

Real option pricing is the proper approach to valuing flexibility.