# Types of Flexibility = Options

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# Theme for this Presentation

- To place Concept of Flexibility in Design into perspective of "Options" in Finance/Economics
- Note that "options" in this context has a specific meaning ≠ "alternative"
- Wide literature on "options" in economics and finance. Topic closely related to flexibility in design – but with important differences!
- In general:

  **Flexibility in design = "real option"**

# Organization

- Formal definition of Options, along with basic types ("calls" and "puts")
- Drivers of Option Value
  - Uncertainty, combined with
  - Asymmetry in Pay-offs
- Decision Analysis Illustrates process



# "Options" Embody Idea of Flexibility

- "Option" : one formal way of defining flexibility
- "Option" has a specific technical definition
- Semantic Caution:
  - The technical meaning of an "option" is… much more specific and limited than … ordinary meaning of "option" in conversation... where "option" = "alternative"
- Pay careful attention to following definition!

## Technical definition: An Option is…

- A right, but not an obligation…
  - "Exercise", that is "use", only if advantageous
  - Asymmetric returns -- "all gain, no pain"
  - Usually acquired at some cost or effort
- to take some action…
  - to change system, buy or sell something, etc,
- now, or in the future...
  - May be indefinite
  - Can be for a limited time only
- for a pre-determined condition("strike" price)
  - Cost of action separate from cost of option



## Illustration of option definition

Spare tire on car is an "option" because it

- provides right, but not an obligation…
  - Operator can use it or not
  - Acquired at some cost – price of tire, loss of space
- to take some action…
  - to change the tire
- now, or in the future...
  - In this case, whenever desired
- for a pre-determined condition ("strike" price)
  - Time, effort of jacking up car, replacing tire, etc.

## Types of Options

- **Two basic types of options**
  - **CALL: right to take advantage of an opportunity (e.g., ability to expand garage if demand is high)**
  - **PUT: right to limit losses of a bad situation (which is what an insurance policy provides)**
- **Options in design can be complicated**
  - **NESTED: one after another successful research => option on development; successful prototyping => option on production**
  - **SIMULTANEOUS: (e.g.: successful fuel cells research => options on hybrid cars and home use)**



## Real Options are Everywhere

- **Examples:**
- **Lease equipment with option to buy**
  - **Action is to buy at end of lease (or to walk away)**
  - **Lease period defined up-front (typically 2-3 years)**
  - **Purchase price defined in lease contract**
- **Flexible manufacturing processes**
  - **Ability to select mode of operation (e.g. thermal power by burning either gas or oil)**
  - **Switching between modes is action**
  - **Continuous opportunity (can switch at any time)**
  - **Switching often has a cost (e.g.: set-up time)**

## Generic Real Options

- Call-like
  - Capture benefits from increases in project value
  - Exercise typically involves putting money into project
  - Exercise when expectations of positive return increase
- Put-like
  - Insure against losses from decreased project value
  - Exercise may involve short-term costs or salvage value
  - Exercise when expectations of losses
- Compound (nested)
  - Projects might contain multiple options
  - Exercise decisions based on overall profit maximization
- In detail…



## Call-Like Real Options

- Waiting to Invest
  - A project might be profitable today, but better tomorrow
  - Leaving investment opportunity open ~ holding a call
  - Deciding factors: uncertainty resolution; foregone profits
  - Choice based on: Max [immediate investment, waiting, 0]
- Expand -- Accelerate effort or level of involvement
  - Allows greater participation in upside
  - Cost of expansion is like strike price
  - Choice based on: Max [status quo, expanded project]
- Restart Temporarily Closed Operations
  - Similar to waiting to invest or expand (a special case)
  - Choice based on: Max [remain closed, re-open]

## Put-Like Real Options

- Abandon
  - Ability to halt investment eliminates further losses
  - might include shut-down costs and salvage values
  - Choice based on: Max [continuing, abandoning]
- Contract -- Decelerate or narrow involvement
  - Reduces participation level and exposure to losses
  - Often incurs short-term scale down costs
  - Choice based on: Max [status quo, contracted]
- Temporarily Shut Down Operations
  - A special case of contraction
  - Eliminates losses, but can incur shut-down costs
  - Choice on: Max [status quo, temporarily shut-down]



## "Real" Options

- "Real" because they refer to projects
  - Contrast with financial options that are contracts
- Real Options are focus of interest for Design
  - They provide flexibility for evolution of system
- Projects often contain option-like flexibilities
  - Rights, not obligations (e.g.: to expand garage)
  - Exercise only if advantageous
- These flexibilities are "real" options
- Let's look at possibilities…

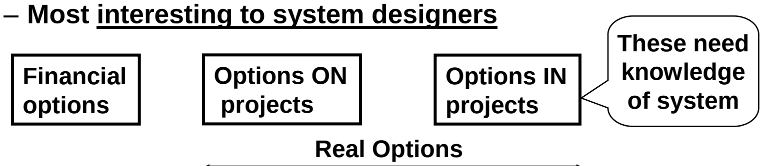
# Compound or Nested Options

- Combinations of Options
  - Many real options exist simultaneously
  - E.g.: those to abandon, contract, or temporarily shut down
  - Complex problem: value of multiple options are often interdependent and in general not additive
  - Use may make others valueless (abandon ends project)
- Switching Between Modes of Operation (example: dual fuel burner case)
  - Flexible systems contain an infinite series of options
  - Allow continual switching between modes of operation
  - If switching modes has a cost, it acts like a strike price
- For compound options, must value as system



# Real Options "IN" and "ON" projects

- Those "real" because, in contrast to financial options, they concern projects, they are "ON" projects
  - E.g.: the option to open a mine (Antamina case)
  - These do not concern themselves with system design
  - Most <u>common in literature</u>
- Those "real" because they concern the design elements of system, they are "IN" projects
  - EX: options for expanding garage
  - These require detailed manipulation inside a system
  - Most <u>interesting to system designers</u>



# Real Options “ON” projects

- These are financial options, but on technical things
- They treat technology as a “black box”
- Example: Antamina mine (see previous discussion)
  - option to open the mine after a two-year exploration period
  - Uncertainty concerns: amount of ore and future price =>uncertainty in revenue and thus in value of mine
  - Option is a Financial Call Option (on Mine as asset)
- Differs from normal Financial Option because
  - Much longer period -- financial option usually < 2 years
  - Special effort needed to model future value of asset, it can’t be projected simply from past data (as otherwise typical)



# Real Options “IN” projects

- These create options by design of technical system
- They require understanding of technology
- Example: Parking Garage
  - Designers can create option for expansion of capacity by way they configure original structure
  - Technical skill needed to create and exercise option
- Differ from other “real” Options because
  - Special effort needed to model feasible flexibility within system itself (e.g.: modeling of technical system)

## Drivers of Option Value

- 2 Major Drivers

- Uncertainty is Principal Driver
  - The greater the uncertainty, the higher the value

- Time is second driver
  - The longer the option is available, the higher the value



## Financial Options

- Focus first on financial options because
  - This is where options and valuation developed
  - Technical terms based on finance
- Financial Options
  - Are tradable assets (see: http://finance.yahoo.com/q/op?s=GOOG )
  - Sold through exchanges similar to stock markets
  - Are on all kinds of goods
    - Stocks, that is, shares in companies
    - Commodities (oil, meat, cotton, electricity...)
    - Foreign exchange, etc., etc.

# Types of Financial Options

- In addition to basic types of options
  - Call: right to BUY asset for a set price
  - Put: right to SELL asset for a set price

- Financial options can get very complicated
  - In addition to Nested and Simultaneous
  - Exotic possibilities ("Asian", "Bermudan", "caput", "collar"….)
  - see en.wikipedia.org/wiki/Exotic_option
  - Not in this course !



# Standard Option Terminology

- S = fluctuating market price of "underlying asset"
- S* = S at the moment owner of option takes advantage of right (when option is "exercised")

- K = Strike price

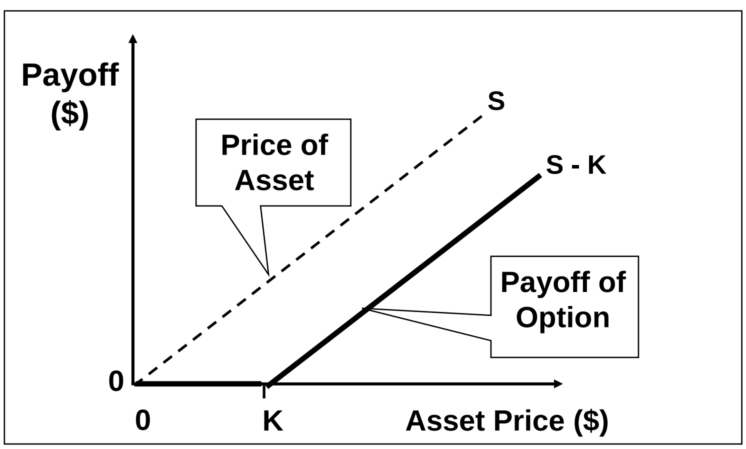
- PAYOFF = owner's net from a having the option, this is consequence we need to understand
- Let's examine what payoff looks like…

# Call Option Payoff

- Call Option gives person right to buy an asset for a predetermined “strike” price, K
- Only rational to exercise right when price of asset is greater than “strike” price:  S > K
- If exercised, option owner pays price of K to get asset worth S*  =>  Payoff = S* - K
- If unexercised, Payoff = 0
- Formally, payoff  = Max of either 0 or S*– K
  = Max [0, S*– K]



# Payoff Diagram for Call Option



# Example of Current Call Option

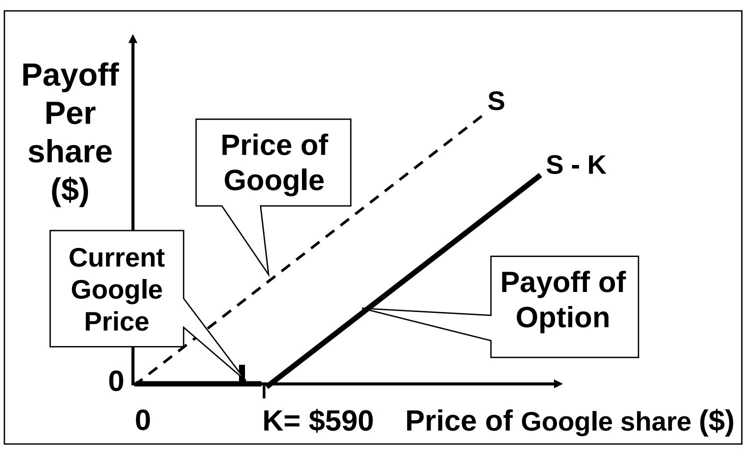
- **Example: A Call Option to**
  - buy 100 shares of Google (shares of Google constitute the "underlying asset")
  - at $590 per share (this is the "strike price")
  - through Jan. 10, 2010

- **On Nov 18, 2009, prices were (yahoo web site)**
  - 1 share of Google = $ 576.50
  - option to buy 1 share = $ 15.40
  - NOTE: option price> immediate value of exercise = $ - 28.90

- **Here's what the payoff diagram looks like…**



# Payoff Diagram for Call Option



## Put Option Payoff

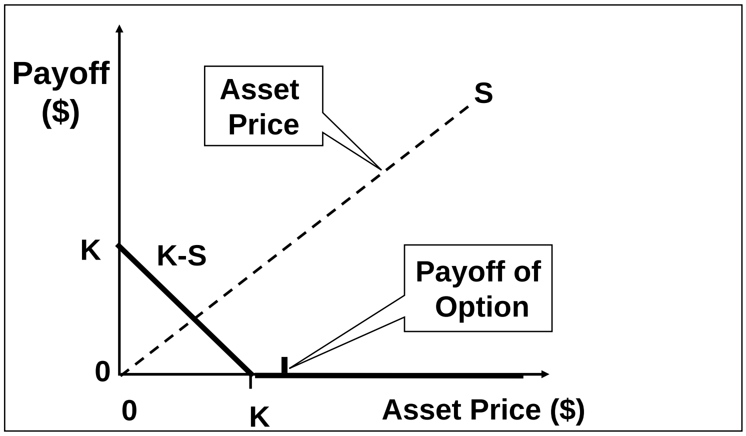
- Put Option gives person right to <u>sell</u> an asset for a predetermined “strike” price, K
- Only rational to exercise right when price of asset is LOWER than “strike” price: S < K
- If exercised, option owner GETS agreed price of K for asset worth S* => Payoff = K - S*
- If unexercised, Payoff = 0
- Net payoff for put = Max [0, K - S*]



## Example Financial Option

- Example: A PUT Option to
  - SELL 100 shares of Google
  - at $590 per share (the “strike” price)
  - Through Jan 10, 2010
- On Nov 15, 2008, prices were (CBOE)
  - 1 share of Google = $ 576.50
  - option to sell 1 share = $ 30.70
  - NOTE: option cost > value of immediate payoff = $ - 17.40

# Payoff Diagram for Put Option






# Asymmetry of Option

- For Call Option, if asset price > strike price… owner then makes profit – that could be unlimited
- Owner not required to exercise option, so… Loss limited to cost of buying option ( $28.90/share in Google example)
- Value of option <u>not symmetric</u>
  - For owner of call option: <u>All gain, No pain</u>
  - Note: This applies once you have option. Usually, you pay for option, so net value of option (after purchase) may have a loss

## Asymmetry is key to option value

# What drives option value?

- How much should you pay for an option?
- Payoff diagrams show for a given strike price
  - Call payoff increases with asset price increases
  - Put payoff increases with asset price <u>decreases</u>
- Payoff does not reflect full value of option
- Why is that?
  - Owner exercises only when advantageous
  - In general, owner can wait for a higher price
  - Value is Max[ immediate exercise, waiting]



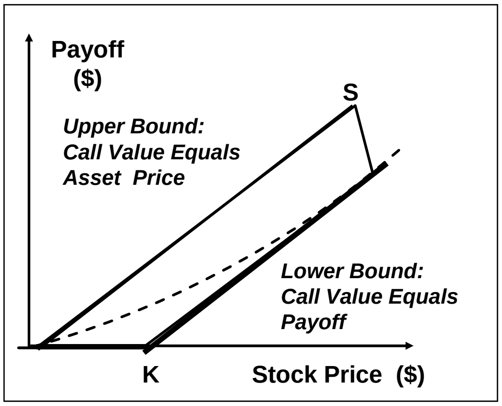
# Boundaries on Price

Some logical boundaries on value of call option that can be exercised any time (American)

Price $\geq$ 0
Otherwise buy option immediately

Price $\leq$ S
Option yields S*- K
Option value < S

Price $\geq$ S - K
Or buy and exercise immediately



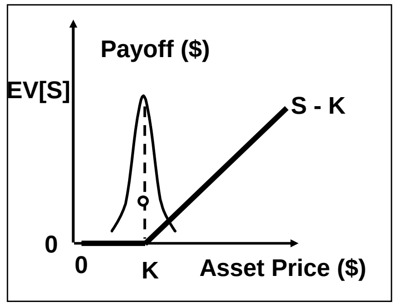
## Why Payoff and Value Differ

- Consider an option whose current asset price equals strike price: (S = K) (it is "at the money")
  Immediate exercise payoff is zero

  However, <u>if you wait</u>:
  Payoff might be higher
  Worst is zero payoff

  Value of waiting not reflected in immediate exercise, to be added

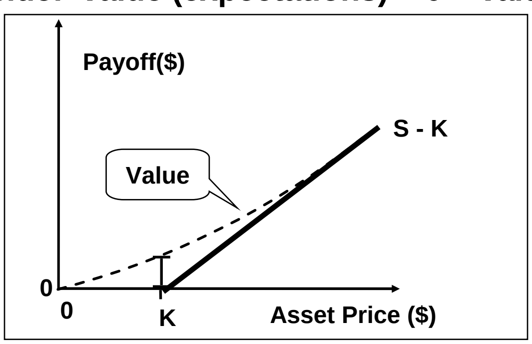
  ∘ = value of option






## Value for All Stock Prices

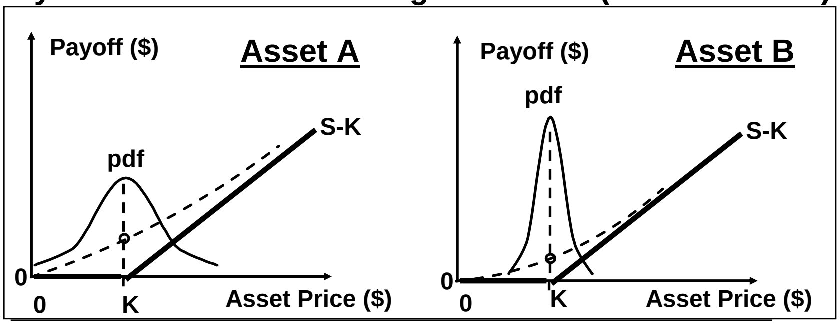
- Value exceeds immediate exercise payoff
- Asymptotically nears immediate payoff for increased S
- If no upside: value (expectations) = 0 = value (option)



# Option Value Increases with Volatility

- Two "at the money" options (S=K) on different assets
  Both have immediate payoff = 0
  Asset A with greater volatility has
  higher P(larger net payoffs) => higher expected value

  Asymmetric value favors high variation (limited losses)






# Life Time of Options

- Two basic types in finance:
- "European" options: oldest type, have fixed date for use ("exercise")
- "American" options: you can use them any time over life – which generally has a definite end date (see Google examples)
- For DESIGN – Options are typically "American" with no end date

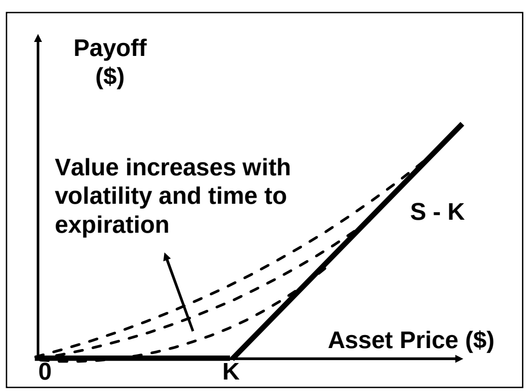
# Impact of Time

- More time to expiration increases value of "American" options
  - Waiting increases chance of value increase
  - Longer- term contains shorter-term options + more time cannot be worse, can only be better
- Compare a 3 and 6 month American call
  - Can exercise 6 month call at same time as 3 month
  - Can wait longer with 6 month
  - Which is more valuable? Must be longer one...
- Time impact not obvious for European options
  - Could miss out on profitable opportunities



# Generalized Value of American Call

- For a set strike price, value increases with
  - Stock price increases
  - Volatility
  - Time
- Increased strike price
  - Reduces likelihood of payoffs
  - Reduces call option value



## Decision Analysis Example: Project R&D Risk

- Start R&D project for $100,000 (0.1M)
- $1,100,000 (1.1 M) to complete development
  - Commercial feasibility determined by initial R&D results
  - Plan to sell (license) technology to highest bidder
- Revenue estimate
  - 50% chance to sell technology for $2,000,000 (2M)
  - 50% chance to sell for $100,000 (0.1M)
- Assume constant 10% discount rate applies
- *Fund project?*

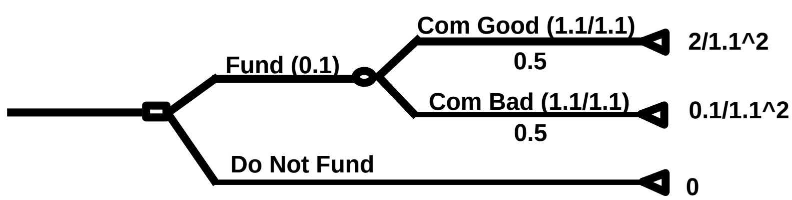


## Traditional NPV Valuation of R&D

| Year | 0 | 1 | 2 |
|---|---|---|---|
| Initial Cost | (0.1) | | |
| Develop-ment | | (1.1) | |
| License Revenues | | | 0.5*2<br>0.5*0.1 |
| Present Value | (0.1) | (1) | 0.868 |

## Tree for NPV Valuation of R&D

- *NPV = - 232*
- *Project should be rejected*





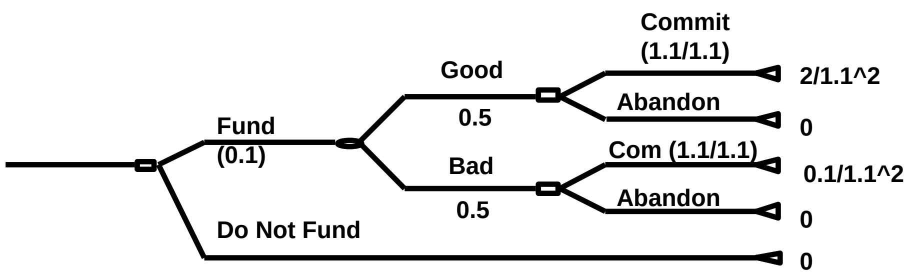

## Flexibility Perspective of R&D

- Develop only if $2M license is expected

| Year | 0 | 1 | 2 |
|---|---|---|---|
| Initial Cost | (0.1) | | |
| Develop-ment | | 0.5*(1.1) | |
| License Revenues | | | 0.5*2<br>0.5*0 |
| Present Value | (0.1) | (0.5) | 0.826 |

# Tree for Flexibility View of R&D

- *NPV = + 226*
- *Should accept project*






# Lessons from R&D Example

- Ability to abandon project has significant value
  - Limits downside; Continue only if advantageous
- NPV misses option value completely
  - Fails to consider effect of intelligent management
- NPV distorts value when there is risk
  - Assumes NPV with expected values = expected NPV
  - "Flaw of the Averages" see article by Savage
  - But: Consequences of scenarios have asymmetries
  - E.g., production costs often not linear with volume
- Decision analysis has the advantage of recognizing value of flexibility

## Summary of Introduction to Options

- Options embody formal concept of flexibility
- Options are not “alternatives”
- 4 step Mantra “right, but not obligation, to act”
- “Calls” for opportunities, “puts” for risks
- Asymmetric returns => source of value
- Many “real” options available to designers
- “Real” Options “ON ” and “IN” systems