Real Option Valuation in Investment Planning Models

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Outline

- Planning questions
- Problems with traditional analyses: examples
- Real-option structure
- Assumptions and differences from financial options
- Resolving inconsistencies
- Conclusions

Investment Situation: Automotive Company

- Goal:
  - Decide on coordinated production, distribution capacity and vendor contracts for multiple models in multiple markets (e.g., NA, Eur, LA, Asia)
- Traditional approach
  - Forecast demand for each model/market
  - Forecast costs
  - Obtain piece rates and proposals
  - Construct cash flows and discount

✍ Optimize for a single-point forecast

Planning Questions?

- Start product in production or not? When?
- What to produce in-house or outside?
- How much capacity to install?
- What contracts to make outside?
- External factors: economy, competitors, suppliers, customers, legal, political, environmental
- Where to start?
  - Build a model

Traditional Model Results

- Focus on:
  - Cost orientation (not revenue management)
  - Single program (model, product)
  - NPV
  - Piece rates
- Result: support of traditional, fixed designs, little flexibility, little ability to change, immediate investment or no investment

Trends Limiting Traditional Analysis

- Market changes
  - Former competition:
    - Cost
    - Quality
  - New competition:
    - Customization
    - Responsiveness

Limitations of Traditional Methods for New Trends

- Myopic - ignoring long-term effects
- Often missing time value of cash flow
- Excluding potential synergies
- Ignoring uncertainty effects
- Not capturing option value of delay, scalability, and agility (changing product mix)
- Mis-calculate time-value of cash flow

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  - Value to delay
  - Scalability
  - Reusability
  - Agility
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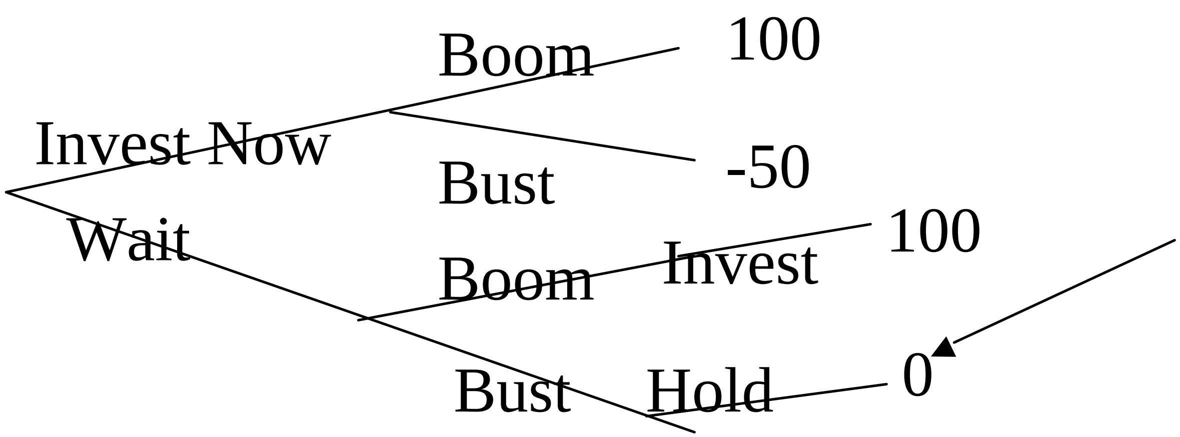
Value to Delay Example

- Suppose a project may earn:
  - $100M if economy booms
  - $-50M if economy busts
- Each (boom or bust) is equally likely
- NPV = $25M (expected) - Start project
- Missing: Can we wait to observe economy?



Here, we don't need to invest in "Bust" - Now we expect $50M

It's worth $25M to wait.

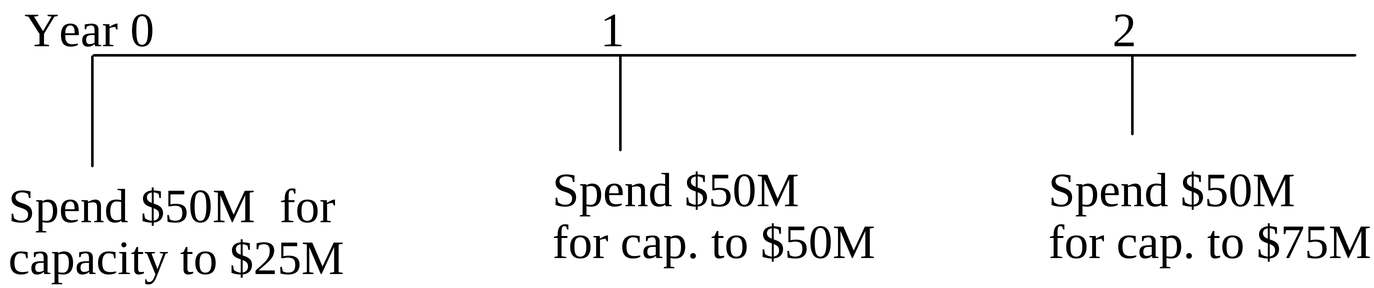
Scale Option Example

- Scalability
- Suppose a five year program
  - Cost of fixed capacity is $100M
  - Cost of scalable capacity is $150M for same capacity
  - Predicted cash flow stream:

Year	1	2	3	4	5
Net	25	50	75	50	25

Scalability Example - cont.

- Assume 15% opportunity cost of capital:
  - NPV(Traditional) = $50M
  - NPV(Scalable)= 0
- Problem: Scalable can be configured over time:



Scalability Result

Cash flow for Scalable:

Year	0	1	2	3	4	5
Net	-50	-25	0	75	50	25

Now, NPV(Scalable)=$75M > NPV(Fixed)

Traditional approach misses scalability advantage.

Reusability Example

- Assume:
  - Same conditions as before for fixed system
  - Two consecutive 5-year programs
  - Suppose for Reusable Manufacturing System (RMS)
    - No scalability
    - Initial cost of $125 M
    - Can reconfigure for second program at cost of $25M

Reusability Example cont.

- Traditional approach
  - Single program evaluation
  - NPV(Fixed) = $50M
  - NPV(RMS) = $25M
  - Choose Fixed
- Problem: Missing the second program

Reusability Two-Program Cash Flows

Fixed cash flow, NPV(Fixed)=$75M

0	1	2	3	4	5
-100	25	50	75	50	-75

6	7	8	9	10
25	50	75	50	25

RMS Cash Flow, NPV(RMS) =$87M

0	1	2	3	4	5
-125	25	50	75	50	0

6	7	8	9	10
25	50	75	50	25

Traditional method misses
two-program advantage

Agility Example: Flexible Capacity Option

Difficulty: Traditional single forecast

Example: Products A, B

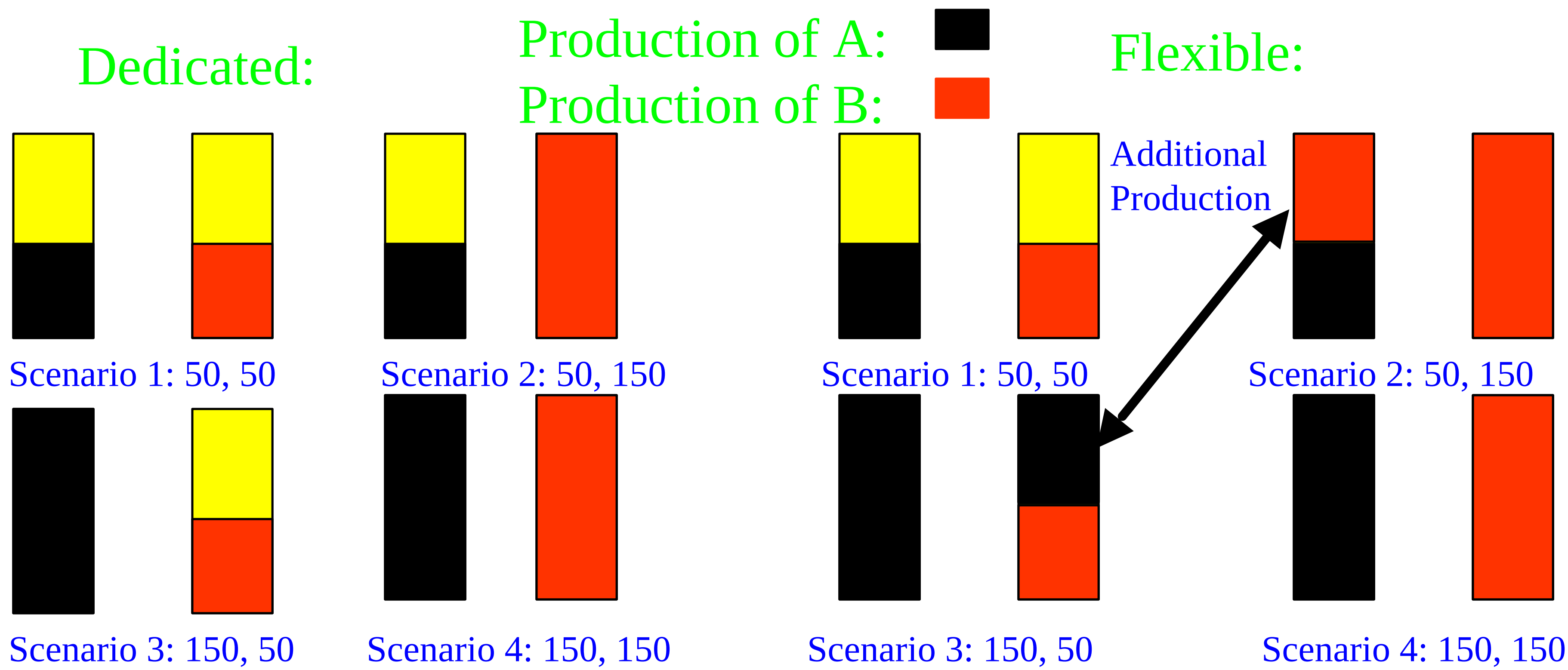
- Forecast demand: 100 for each; Margin: 2
- Dedicated capacity cost: 1
- Flexible capacity cost: 1.1

	Dedicated:	Flexible:
Revenue:	400	400
Cost:	200	220
Profit:	200	180

→ Choose dedicated

Multiple Scenario Effect

Suppose two demand possibilities: 50 or 150 equally likely - *Four scenarios*



Evaluation with Scenarios

- Four scenarios: 50 or 150 on each
- Dedicated
  - Sell (50,50), (50,100), (100,50), (100, 100)
  - Expected revenue: 300
- Flexible
  - Sell (50,50), (50,150), (150,50), (100, 100)
  - Expected revenue: 350

	Dedicated:	Flexible:
Exp. Revenue:	300	350
Cost:	200	220
Profit:	100	130

→ Choose flexible

Summary of Problems

- Missing basic abilities in traditional approaches:
  - Delay option
  - Scaling option
  - Reuse option
  - Agility option
- Option evaluation:
  - Look at all possibilities
  - How to discount?

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Real Options

- Idea: Assets that are not fully used may still have option value (includes contracts, licenses)
- Value may be lost when the option is exercised (e.g., developing a new product, invoking option for second vendor)
- Traditional NPV analyses are flawed by missing the option value
- Missing parts:
  - Value to delay and learn
  - Option to scale and reuse
  - Option to change with demand variation (uncertainty)
  - Not changing discount rates for varying utilizations

Planning Questions?

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- What contracts to make outside?
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Key Steps in Building a Model

- Identify problem
- Determine objectives
- Specify decisions
- Find operating conditions
- Define metrics
  - How to measure objectives?
  - How to quantify requirements, limits?
  - How to include effect of uncertainty?
- Formulate

Utility Function Approach

- Observation:
  - Most decision makers are adverse to risk
- Assume:
  - Outcomes can be described by a utility function
  - Decision makers want to maximize expected utility
- Difficulties:
  - Is the decision maker the sole stakeholder?
  - Whose utility should be used?
  - How to define a utility?
  - How to solve?
- Alternative to decision maker - investor

Measuring Investor Value

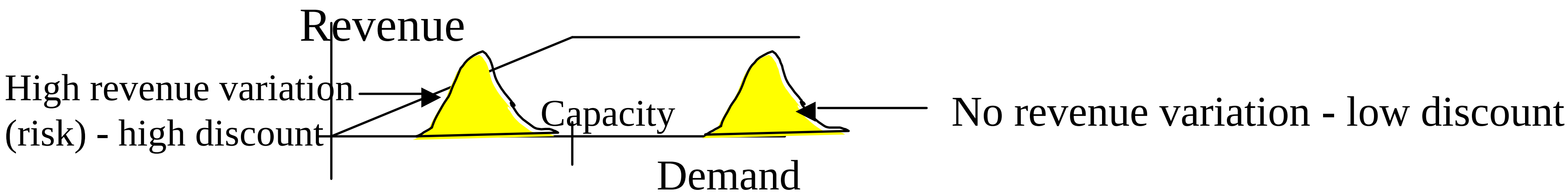
- RISK NEUTRAL?
  - Expected cost objective
  - RESULT: Does not correspond to preference
  - Difficult to assess real value this way
- OBSERVATIONS:
  - Assume investors prefer lower risk
  - Investors can diversify away unique risk
  - Only important risk is market - contribution to portfolio
- CONSEQUENCE: Capital asset pricing model (CAPM)
  - With CAPM, can find a discount rate

Discount Rate Determination

- Traditional approach
  - Discount rate is the same for all decisions in program evaluation
- Problems
  - Program evaluation includes decisions on capacity, distribution channel, vendor contracts
  - These decisions affect correlation to market – hence, change the discount rate
- Need: discount rate to change with decisions as they are determined; How?

Discount Rate Determination

- USE CAP-M? FIND CORRELATION TO THE MARKET?
  - Can measure for known markets (beta values)
  - If capacitated, depends on decisions
    - Constrained resources - capacity
    - Correlations among demands

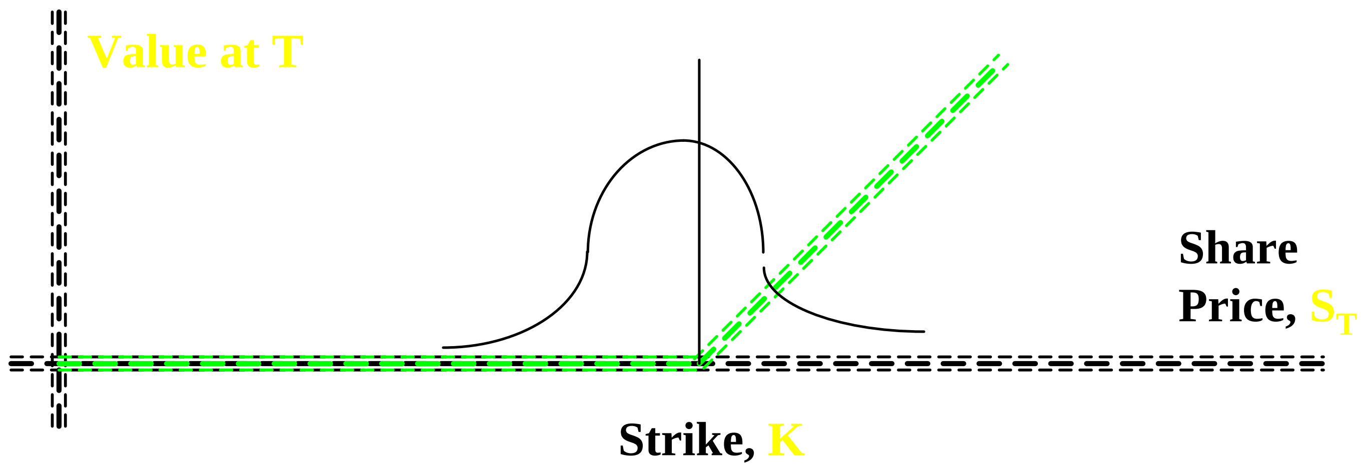


- ALTERNATIVES?
  - Option Theory
    - Allows for non-symmetric risk
    - Explicitly considers constraints -
    - As if selling excess to competitors at a given price

Valuing an Option

- (European) Call Option on Share assuming:
  - Buy at K at time T;Current time: t; Share price: S_t
  - Volatility: ? ; Riskfree rate: r_f; No fees; Price follows Ito process
- Valuing option:
  - Assume risk neutral world (annual return=r_f independent of risk)
  - Find future expected value and discount back by r_f

Call value at t = $C_t = e^{-r_f(T-t)} ? (S_T - K)^+ dF_f(S_T)$



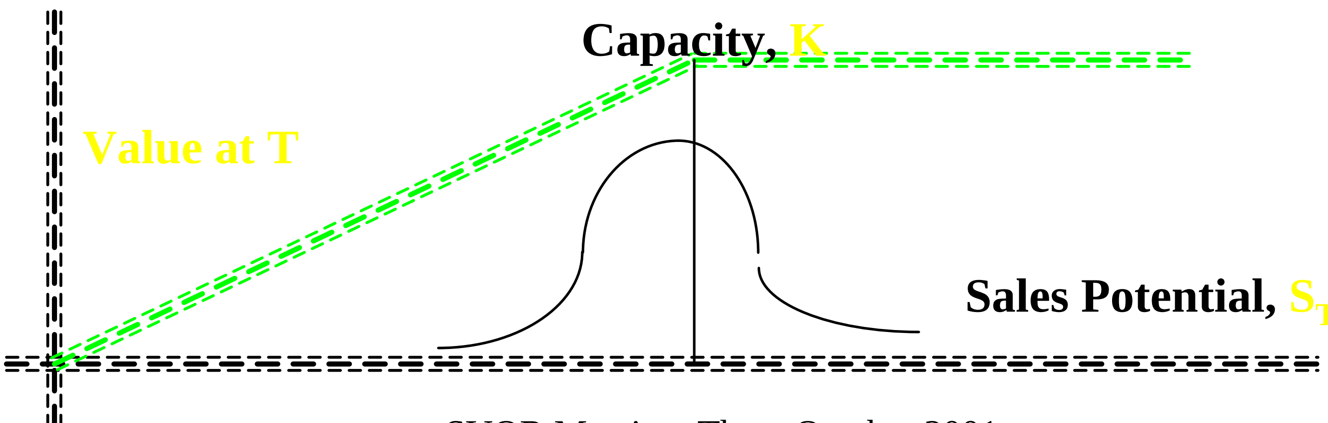
Relation to Real Options

- Example: What is the value of a plant with capacity K?
  - Discounted value of production up to K?
- Problems:
  - Production is limited by demand also (may be > K)
  - How to discount?
- Resolution:
  - Model as an option
  - Assume:
    - Market for demand (substitutes)
    - Forecast follows Ito process
    - No transaction costs

?? Model like share minus call

Using Option Valuation for Capacity

- Goal: Production value with capacity K
  - Compute uncapacitated value based on CAPM:
    - $S_t = e^{-r(T-t)} \int c_T S_T dF(S_T)$
    - where c_T=margin,F is distribution (with risk aversion),
    - r is rate from CAPM (with risk aversion)
  - Assume S_t now grows at riskfree rate, r_f ; evaluate as if risk neutral:
    - Production value = S_t - C_t = $e^{-r_f(T-t)} \int c_T \min(S_T,K) dF_f(S_T)$
    - where F_f is distribution (with risk neutrality)



Generalizations for Other Long-term Decisions

- Model: period t decisions: x_t
- START: Eliminate constraints on production
  - Demand uncertainty remains
  - Can value unconstrained revenue with market rate, r:

$$\mathbf{1/(1+r)^t \; c_t \, x_t}$$

IMPLICATIONS OF RISK NEUTRAL HEDGE:

Can model as if investors are risk neutral

=> value grows at riskfree rate, r_f

Future value: $[1/(1+r)^t \; c_t \, (1+r_f)^t \, x_t]$

BUT: This new quantity is constrained

New Period t Problem: Linear Constraints on Production

- WANT TO FIND (present value):

$$1/(1+r_f)^t \int \text{MAX} [\, c_t x_t (1+r_f)^t/(1+r)^t \mid A_t x_t (1+r_f)^t/(1+r)^t <= b]$$

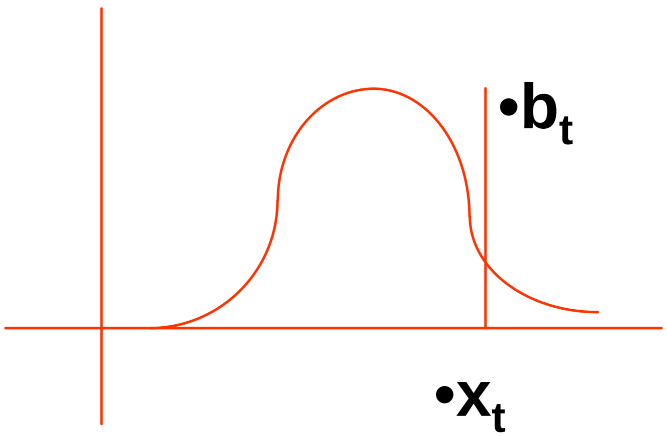
EQUIVALENT TO:

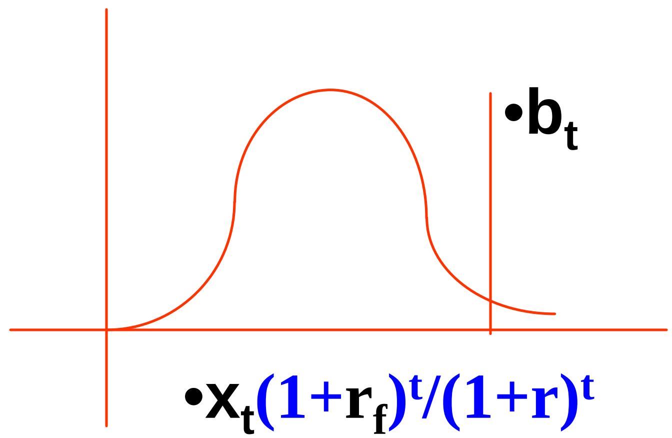
$$1/(1+r)^t \int \text{MAX} [\, c_t x \mid A_t x <= b (1+r)^t/(1+r_f)^t]$$

MEANING: To compensate for lower risk with constraints, constraints expand and risky discount is used

Constraint Modification

- FORMER CONSTRAINTS: $A_t\ x_t <= b_t$
- NOW: $A_t\ x_t\ (1+r_f)^t/(1+r)^t <= b_t$





EXTREME CASES

All slack constraints:

$$1/(1+r)^t \int \text{MAX}\,[\,c_t\,x \mid A_t\,x\ \text{Š}\ b\,(1+r)^t/(1+r_f)^t]$$

becomes equivalent to:

$$1/(1+r)^t \int \text{MAX}\,[\,c_t\,x \mid A_t\,x\ \text{Š}\ b]$$

i.e. same as if unconstrained - risky rate

NO SLACK:

becomes equivalent to:

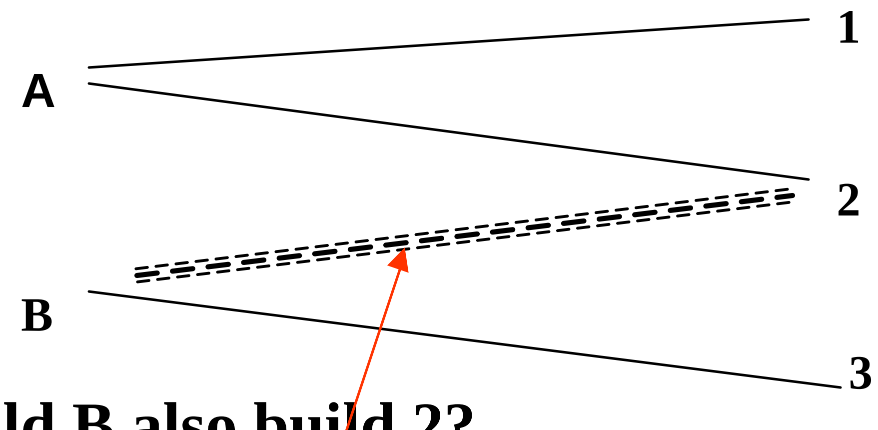
$$1/(1+r)^t \int [c_t\,x = B^{-1}b\,(1+r)^t/(1+r_f)^t] = c_t\,B^{-1}b/(1+r_f)^t$$

i.e. same as if deterministic - riskfree rate

Example: Capacity Planning

- What to produce?
- Where to produce? (When?)
- How much to produce?

EXAMPLE: Models 1,2, 3 ; Plants A,B



Should B also build 2?

Result: Stochastic Linear Programming Model

- Key: Maximize the Added Value with Installed Capacity
  - Must choose best mix of models assigned to plants
  - Maximize Expected Value over s[$?_{i,t}$ e^{-rt}Profit (i) Production(i,t,s) - CapCost(i at j,t)Capacity (i at j,t)]
  - subject to: MaxSales(i,t,s) >= $?_{j}$ Production(i at j,t,s)
  - $?_{i}$ Production(i at j,t,s) <= $e^{(r-rf)t}$ Capacity (i,t)
  - Production(i at j,t,s) <= $e^{(r-rf)t}$ Capacity (i at j,t)
  - Production(i at j,t,s) >= 0
- Need MaxSales(i,t,s) - random
  - Capacity(i at j,0) - Decision in First Stage (now)

NOTE: Linear model that incorporates risk

Result with Option Approach

- Can include risk attitude in linear model
- Simple adjustment for the uncertainty in demand
- Requirement 1: correlation of all demand to market
- Requirement 2: assumptions of market completeness

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Assumptions

- Process of prices or sales forecasts
- No transaction fees
- Complete market (difference from financial options)
  - How to construct a hedge?
  - If NPV>0, inconsistency
  - Process: Trade option and asset to create riskfree security

Creating Best Hedge – and a Confession

- Underlying asset: Max potential sales in market
- Option: Plant with given capacity
- Other marketable securities:
  - Competitors' shares
  - Overall all securities min residual volatility
  - Confession: Due to incompleteness, some volatility remains (otherwise, NPV=0)

Resolution

- Incompleteness gives a range of possible values
- Can adjust capacity limits by varying discount factor with risk neutral assumptions on forecasts
- Can vary constraint multipliers with original forecast distribution
- All optimal policies for the given range are consistent with the market (cannot be beaten all the time)
- Obtain a range of policies – can use other criteria

Result of Residual Risk

- In binomial model, asset price moves from S_t to $uS_t + v_1$ or $dS_t + v_2$ where v_1 and v_2 vary independently and have smallest volatility
- For standard call option,

  $C_t = [(S_t - d S_t + v_1)/(uS_t - dS_t + v_2)] (uS_t - K)$

  $= [(S_t - d S_t + v_1)/p(uS_t - dS_t + v_2)]p (uS_t - K)$

  $= e^{-r(T-t)} (E[(S_t-K)^+])$ where r is in a range determined by [v2,v1]
- Analogous result for capacity valuation: a range of values are consistent

Alternatives and Challenges

- Use equilibrium and utility function approaches
- Caution on complexity of models
- Critical factor: range of outcomes considered
- Other challenges:
  - Effects of pricing decisions
  - Effects of competitors
  - Distribution changes from decisions
  - Extend to financial and real options together: operational and financial hedging

Operational and Financial Hedging uses of Real Options

- Objective: Determine capacity levels in different markets, production in each market, distribution across markets, and use of financial hedging instruments to maximize total global value
- Challenges:
  - Demand and exchange rates may change
  - Correlations among demand and exchange
  - What is enough capacity?
  - What performance metrics to use?

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Summary

- Options apply to many varied decision problems
- Can evaluate planning with proper option evaluation techniques
- Relaxed market assumptions lead to models that determine a range of policies
- Firm or investor utility can choose within range
- Questions? Comments?