Using Management Science to Reduce Enterprise Risks: Defining the Role of Operational and Financial Hedges

John R. Birge
Northwestern University

Is a Sure Thing Always a Good Thing?

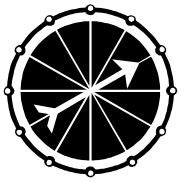
- Traditional view
  - Uncertainty is Risk
  - Risk is Bad
  - ➔Uncertainty is Bad
- True? Always?
- How do we know when and what uncertainties to remove? (what to hedge?)

Themes

- Risk management is big business
- Managing risk is not the same as eliminating risk
- Management science can yield better risk management
- Key tools are stochastic modeling, optimization, and option pricing

Outline

- What is a hedge?
- Who should hedge?
- How can you find a best hedge?
- Where do we go from here?

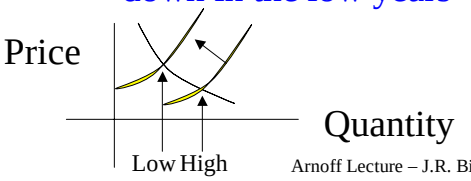


Risk Management and Hedging

- What is a hedge?
  - Action designed to reduce risk of future outcome
  - In finance, perfect hedge leads to no risk (riskfree return)
- Use of hedges
  - Allow pricing of financial derivatives
  - Lead to markets in derivatives
  - Also possible with operations (operational hedges)
    - Quantity - flexible production
    - Timing

Who Should Hedge?

- Farmers?
- Situation:
  - Suppose either high-yield low-yield years for crops
  - Prices up in high years and down in the low years

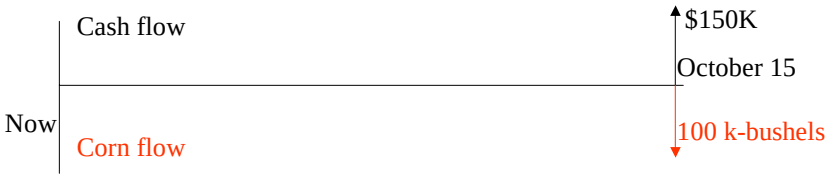


Farmer's Example

- Suppose yield of corn is either 200 k-bushels (high) or 100 k-bushels (low)
- Suppose price with high yield is $1 and price with low yield is $2
- Should the farmer use financial hedge? i.e., sell a future?
  - If so, how much?

Futures Contracts as Hedges

- *Futures contract*: an agreement to buy or sell a fixed quantity at given price at fixed time in future (marked to market every day)
- Example: can agree to sell 100 k-bushels at $1.50/bushel on October 15
- On October 15, we receive $150K and must deliver 100 k-bushels



Futures for the Farmer

- Advantages
  - Can accept the expected price now
  - No risk in the price for the amount we sell
- Potential problems
  - Risk on amount we can produce
  - May have to go into market
- Analysis: Hedge our expected yield (150 k-bushels)

  Guaranteed (all the time) $225K

  High yield – can sell 50 more + $50K (probability ½)

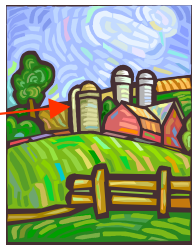
  Low yield – must buy 50 -$100K (probability ½)

  Expectation=225+50/2-100/2= $200k (same as no hedge)

  BUT variance (risk) is up (either $275k or $125 instead of $200k all the time)
- RESULT: should not use futures (alone)

Farmer's Operational Hedge for Risk Management

- What else does the farmer have?
- ***SILO!!***
  - ***Operational hedge***
  - ***Keep corn from high yield to sell at low yield***
- Now, suppose we keep 50 k-bushels in silo from high to low yield years

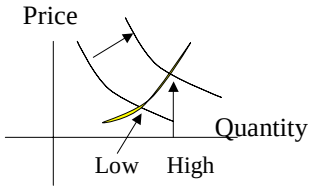


Farmer's Silo Hedge

- Expected returns
  - High-yield years (prob. ½) $150 k
  - Low-yield years (prob. ½) $300 k
  - Expectation: ½(150+300)= $225k
  - Worth $225k-200k =$25k to use the silo
  - Value of the operational hedge (***option value of silo***)
- Combine with future?
  - Now, sell 150 k-bushels for $1.50 in October
  - Now, have the return guaranteed $225K
- Moral: Financial instrument only has value if farmer uses operational hedge

Copper Miner's Example

- Should a copper mine hedge its output with futures?
- What is the nature of copper price differences?
- Demand versus supply curve change means high price-high quantity and low price-low quantity

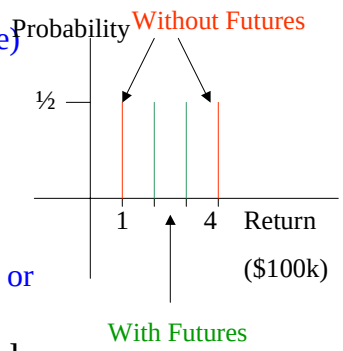


Copper Hedging

- Suppose high demand leads to 200 k-pounds at $2/pound and low demand leads to 100 k-pounds at $1/pound
- Earn $400k (prob. ½) or $100k (prob. ½)
- Expected value of $250k
- Operational hedge? (save 50 k-lbs from high to low years?)
  - High years: earn $300k (prob. ½)
  - Low years: earn $150k (prob. ½)
  - Expectation: $225k ***(lower value!)***

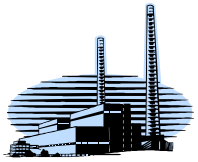
Copper Futures?

- Suppose we sell 200 k-lbs at $1.50 in future
- Result now:
  - Futures return: $300k (all the time)
  - High demand: + $ 0k (with probability ½)
  - Low demand: - $ 100k (with probability ½)
  - Expectation: $250k
  - Risk reduced ($300 or $200 v. $400 or $100)
- Here: financial derivatives give value (how much? present value?)



Manufacturer's Example

- Suppose we can produce in US or Europe
- Demand and currency rates may vary
- Where to put production capacity?
- How much to produce in each country?
- Should we use currency futures (or other options)?



Manufacturer Details

- Suppose high demand in US v. Europe means higher US$ value per Euro
- High US demand 100K, Euro is 50k, and $1/Euro
- Low US demand 50k, Euro is 100k, and $2/Euro
- Sell for 20K E or $ in each region
- Cost is 10K E or $ in each region
- How to hedge? Futures?

Manufacturer and Futures

- Suppose produce and sell in own country
- Use futures to guarantee value in $
- Sell 500M Euros in future for $1.50 (expectation)
  - $750M= (50K sales)(10K E margin)($1.5/E)
- Return:
  - Guaranteed $ 750M
  - High US: $1000M (1/2 prob.)
  - Low US: $1500M (1/2 pr. 500US plus 1B E)

  Expectation: $2000M

Using Operational Hedges in Place of Financial

- Suppose we just produce in Europe when US demand is high and just in Europe when US demand is low
- Result:
  - US Demand high:
    - Sales: $2000M in US + $1000M in Europe
    - Cost: $1500M in Europe
    - Net: $3000-1500=$1500M
  - US Demand low:
    - $1000M in US + $4000M in Europe - $1500M in US
    - Net: $5000- 1500=$3500M
  - Expectation: $2500M!! (>> $2000M with financial hedging)

Lessons from the Manufacturer

- Operational hedges can give a large advantage
- Excess capacity in different markets can be worthwhile
- Analysis of all the possibilities is complicated
- How to measure present value of capacity investment?
- How to find the best hedges overall?

Overall Observations

- Farmer:
  - Financial and operational together
- Miner:
  - Financial alone
- Manufacturer
  - Operational alone
- Unifying framework? Present values of risky returns?

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Unifying Element: Real Options

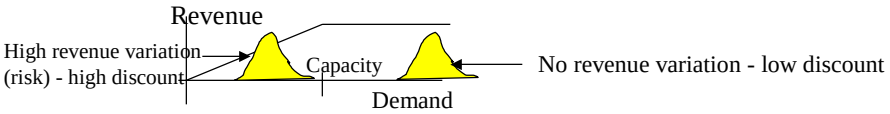
- Real options: real assets that have some (option) value that can be exercised
- Create operational hedges (i.e., manage risks)
- How can we value them?
- What tools do we need?
- Example: *How much is a factory with capacity of 150,000 units worth?*

Key: How to Discount Future Cash Flows?

- Traditional approach
  - Discount rate is the same for all decisions in firm
- Problems
  - Program evaluation includes decisions on capacity, distribution channel, vendor contracts – *all different risks*
  - 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)
  - How to do this for a single plant?
  - Want high discount if slack – low discount if tight

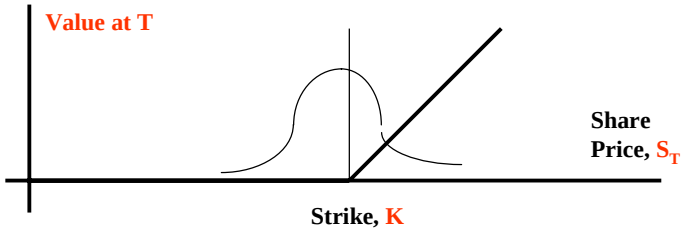


- ALTERNATIVES?
  - Option Theory
    - Allows for non-symmetric risk
    - Explicitly considers constraints -
    - As if selling excess to competitors at a given price

Valuing an Option

- (European) Call Option on Share assuming:
  - Buy at K at time T;Current time: t; Share price: S_t
  - Volatility: σ; Riskfree rate: r_f; No fees; Price follows particular process
  - Can find *perfect hedge*
- 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 = $C_t = e^{-r_f(T-t)}\int(S_T-K)^+ dF_f(S_T)$



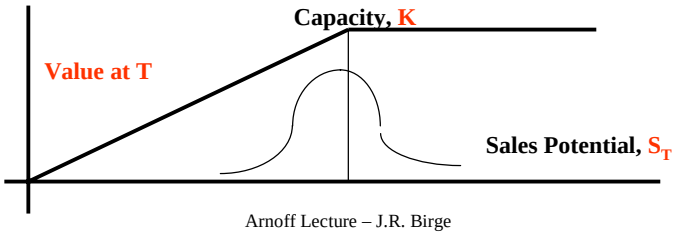
Relation to Real Options

- Example: What is the value of a plant with capacity K?
  - Discounted value of production up to K?
- Solution:
  - Model as an option
  - Assume:
    - Market for demand (substitutes)
    - Forecast follows certain 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 = $S_t - C_t = e^{-rf(T-t)} \int c_T \min(S_T, K) dF_f(S_T)$
    - where F_f is distribution (with risk neutrality)



Results with Real Option Prices

- Can value capacity of the plants in each market
- Now, can use operational choices to determine best mix of financial hedges and production decisions
- Maximize the return (to investors) and minimize the risk

Overall Enterprise Risk Management

- Find the levels of capacity, production, and future contracts to:
  - maximize expected present value of future cash flow
  - subject to:
    - Not exceeding capacity in any markets
    - Transportation and transaction costs
- Real options allows for putting all of these decisions into a stochastic linear program.

Result: Stochastic Linear Programming Model

- Key: Maximize the Added Value of Installed Capacity
  - Must choose best mix of poroducts assigned to plants
  - Maximize Expected Value over s[$\Sigma_{i,t}$ e^{-rt}Profit (i) Production(i,t,s) - CapCost(i at j,t)Capacity (i at j,t)]
  - subject to: MaxSales(i,t,s) >= Σ_j Production(i at j,t,s)
  - Σ_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

NOTE: Linear model that incorporates risk

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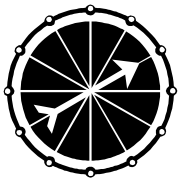
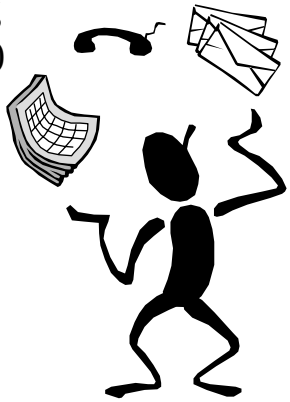


Extensions and Challenges

- Examine assumptions for using real options (complete markets)
- Relax assumptions and have ranges for decisions
- Other challenges:
  - Effects of pricing decisions
  - Effects of competitors
  - Distribution changes from decisions



Conclusions

- Risk managements should involve both financial and operational decisions
- Different circumstances require different approaches
- Real options give a unifying framework
- Results can be optimization models to determine best risk management policy
- Great opportunity to expand management science in enterprise-level management