Managing risk in the supply chain

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Agenda

- Sources of and tools for supply chain management risk
- Recent research on supply chain risk management
  - Risk neutral decision makers
  - Risk averse decision makers
- More discussion

Sources of supply chain management risk

- Demand risk
- Supply risk
- Price risk
- Quality risk
- Strategic risk
- Environmental risk
- Unknown risks

Tools for managing risk in the supply chain

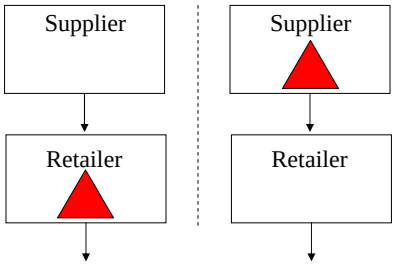
- Location pooling
- Lead time pooling
- Product pooling
- Delayed differentiation
- Capacity pooling / flexible manufacturing
- Dynamic pricing / capacity controls
- Assemble-to-order
- Outsourcing / offsourcing
- CPFR, VMI
- Contracts (buy-backs, quantity flexibility, etc.)
- Markets/exchanges/auctions
- Financial engineering:
  - Deviation measures, real options, portfolio optimization, etc.

Literature – Managing risk in a risk neutral world

- Quality risk:
  - Baiman, Netessine and Kunreuther (2004), Baiman and Netessine (2004)
- Delivery lead time risk:
  - Cachon and Zhang (2004a,b)
- Supplier quality/performance:
  - Debo (2004)
- Forecast quality:
  - Lariviere (2004)
- Forecast sharing:
  - Anand and Goyal (2004)
- Spot price volatility:
  - Wu, Kleindorfer and Zhang (2002); Wu and Kleindorfer (2004)

Allocation of inventory risk

Push
"Sell to the newsvendor"



Pull
"Buy from a newsvendor"

- Everyone in the supply chain can be better off by switching from one extreme risk allocation to the other (i.e., from push to pull or from pull to push)
- Smart allocation of risk can reduce the need for complex contracts.

Is supply chain risk reduction always Pareto improving?

- Iyer and Bergen (1997):
  - Quick response does not always benefit the supplier.
- Anupindi and Bassok (1999):
  - Location pooling at the retail level does not always benefit the supplier.
- Lee and Whang (2002):
  - A secondary market does not always benefit the supplier.
- Dong and Rudi (2004):
  - Inventory transshipment among retailers does not always benefit the supplier.

Is supply chain risk reduction beneficial in a competitive setting?

- Roller and Tombak (1993):
  - Manufacturing flexibility can be harmful.
- Carr, Duenyas, Lovejoy (1999):
  - Less demand or supply risk can be harmful.
- Anand and Girotra (2004):
  - Delayed differentiation can be harmful.
- But...
- Cachon and Harker (2002):
  - Capacity pooling with a contract manufacturer benefits competing firms because price competition is reduced.

Approaches to Risk Management

- **Economics literature**
  - Von Neumann-Morgenstern utilities
    - Expected utility $E\{U(\Pi)\}$
- **Finance literature**
  - Capital Asset Pricing Model (CAPM)
    - Markowitz Mean-Variance tradeoff $E\{\Pi\}$-$k\mathrm{Var}\{\Pi\}$
    - Portfolio Approach

Linking Economics with Finance

- When
  - The utility function is quadratic

  OR
  - The utility is CARA* $[U(\Pi)=-\exp(-r\,\Pi)]$ and Π is normally distributed
- Then
  - Expected utility maximization is equivalent to mean-variance objective maximization

*CARA: Constant Absolute Risk Averse

Supply Chain Management

- **Academia:**
  - Traditional models focus on maximizing **expected profit**
- **Practice:**
  - Significant increase in the level of risk faced by many companies
    - Examples: Cisco, Apple, Sony…

Literature – Managing risk in a risk averse world

- **Single Period**
  - Lau (80): Tradeoff between profit mean and standard deviation
  - Eeckhoudt, Gollier and Schlesinger (95): Exponential utility function
  - Chen and Federgruen (00): Mean-variance tradeoff
  - Schweitzer and Cachon (00): Empirical work
- **Multi Period**
  - Bourakiz and Sobel (92): Exponential utility function, base-stock is optimal
- **Infinite Horizon**
  - Bourakiz and Sobel (92): Exponential utility function, base-stock is optimal
  - Chen and Federgruen (00): Mean-variance tradeoff for inventory level or customer waiting time

Risk Measures

- Mean-Variance Limitation
  - Equally penalizes desirable upside and undesirable downside outcomes
- Other Risk Measures
  - Utility functions
  - VaR
  - CVaR

Risk Measure: utility function

$$\begin{array}{ll} \max & E(u(f(\mu, \tilde{\mathbf{d}}))) \\ \text{subject to} & \mu \in \Pi, \end{array}$$

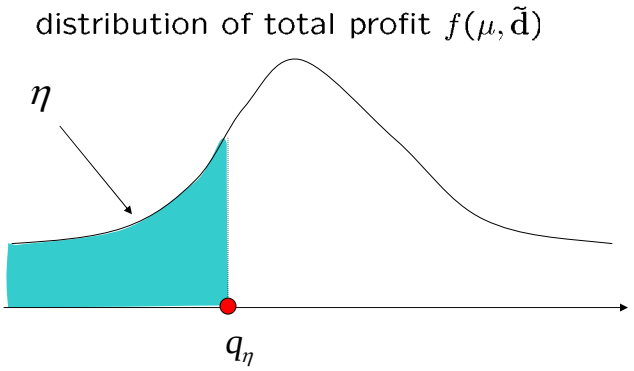
where u is a concave and increasing utility function. Special case includes

$$u_b(w) = b(1 - e^{-w/b}).$$

Notice that

$$\lim_{b \to \infty} u_b(w) = w.$$

Risk Measure: Value at Risk

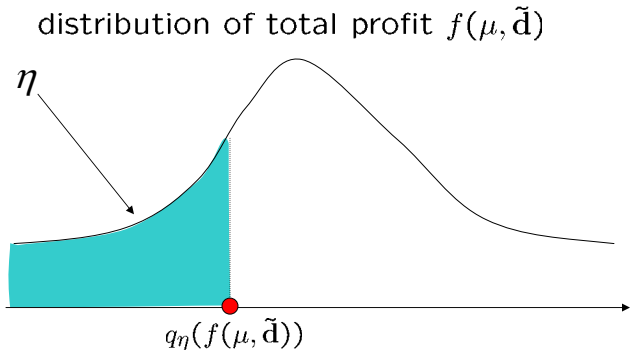


$$\mathrm{Prob}(f(\mu, \tilde{d}) < q_\eta) = \eta$$

Problems with Value at Risk

- Does not preserve subadditivity
  - A portfolio with two instruments may have a larger VaR than the sum of the VaRs of the two instruments
- The VaR risk measure is indifferent to the extent of which the profit falls below the q_η

Risk Measure: Conditional Value at Risk



$$\text{CVaR}_\eta(f(\mu, \tilde{d})) = E[f(\mu, \tilde{d}) \mid f(\mu, \tilde{d}) \leq q_\eta(f(\mu, \tilde{d}))]$$

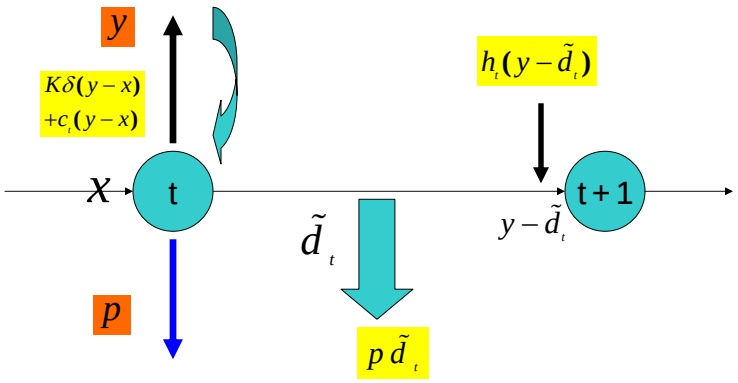
Multi-period Inventory Model

- Single product, periodic review
- Finite horizon: T
- Fixed ordering cost: K
- Variable ordering cost: c_t
- Zero lead time
- Convex inventory and backorder cost: $h_t(x)$
- Demand function:

$$d_t = -\alpha_t p + \beta_t$$

- Objective: Maximize expected utility or conditional value at risk of the total discounted profit

Multi-period model: sequence of events



Finite Horizon Model: Main Results

Chen, Sim, Simchi-Levi and Sun (2004)

		Fixed Price		Price Control	
		K=0	K>0	K=0	K>0
Exact	Risk Neutral Model	**Base stock**	**(s,S)**	**Base stock list price**	**(s,S,A,p)**
	Exponential Utility	**Base stock**	**(s,S)**	**Base stock**	**(s,S,A,p)**
	Increasing & Concave Utility or CVaR	Wealth dependent **Base stock**	**?**	Wealth dependent **Base stock**	**?**
Heuristics	CVaR	**Bass stock**	**(s,S)**	**Base stock**	**(s,S,A,p)**

Questions

- Is there a disconnect between academic research and industry needs?
- What is an appropriate risk measure?
- What are appropriate risk models?
  - Models that combine operational and financial hedging strategies
- Is there anything we can learn from other industries?
- Teaching cases?
- Methods to deal with “unknown unknown”...