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
  - Strategic risk
- Supply risk
  - Environmental risk
- Price risk
  - Unknown risks
- 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 / offsubscing
- 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:

- Delivery lead time risk:
  - Cachon and Zhang (2004a,b)

- Supplier quality/performance:
  - Debo (2004)

- Forecast quality:

- Forecast sharing:

- 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 $E\{\Pi\} - kVar\{\Pi\}$
    - Portfolio Approach

Linking Economics with Finance

- **When**
  - The utility function is quadratic
  - OR
  - The utility is CARA* $[U(\Pi)=-exp(-r \Pi)]$ and $\Pi$ is normally distributed

- **Then**
  - Expected utility maximization is equivalent to mean-variance objective maximization

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*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

\[
\max_{\mu \in \Pi} \mathbb{E}(u(f(\mu, \bar{d})))
\]

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

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 $q_\eta$
Risk Measure: Conditional Value at Risk

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

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


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<thead>
<tr>
<th>Model</th>
<th>Exact</th>
<th>Fixed Price</th>
<th>Price Control</th>
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<tbody>
<tr>
<td>Risk Neutral Model</td>
<td>Base stock</td>
<td>(s,S)</td>
<td>Base stock list price</td>
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<td>Exponential Utility</td>
<td>Base stock</td>
<td>(s,S)</td>
<td>Base stock</td>
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<tr>
<td>Increasing &amp; Concave Utility or CVaR</td>
<td>Wealth dependent</td>
<td>?</td>
<td>Wealth dependent</td>
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<td>Heuristics</td>
<td>CVaR</td>
<td>Bass stock</td>
<td>(s,S)</td>
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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”...