Pricing as a means of co-ordinating supply chain decisions

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SCM

- Supply chain - collection of distinct entities jointly responsible for delivery of product or service to *final* customer
- Distinct entities
  - Independent management
  - Different objectives
- What does the "management" in SCM mean?
  - Co-operation and shared objectives: can this be formalized as a joint objective (e.g. using game theoretic ideas)?
  - Co-ordination : IT integration and technology, shared systems [technologies across systems, such as RFID]
  - Joint planning : investments, asset creation

Prices

- Prices (in "final" markets):

  Traditional signals for

  producers -> quantities to produce

  consumers -> quantities to consume

  result in market clearing

  In today’s world – dynamic pricing →revenue management
- Prices in intermediate markets are negotiated

  - Cost based

  - Transfer pricing concepts

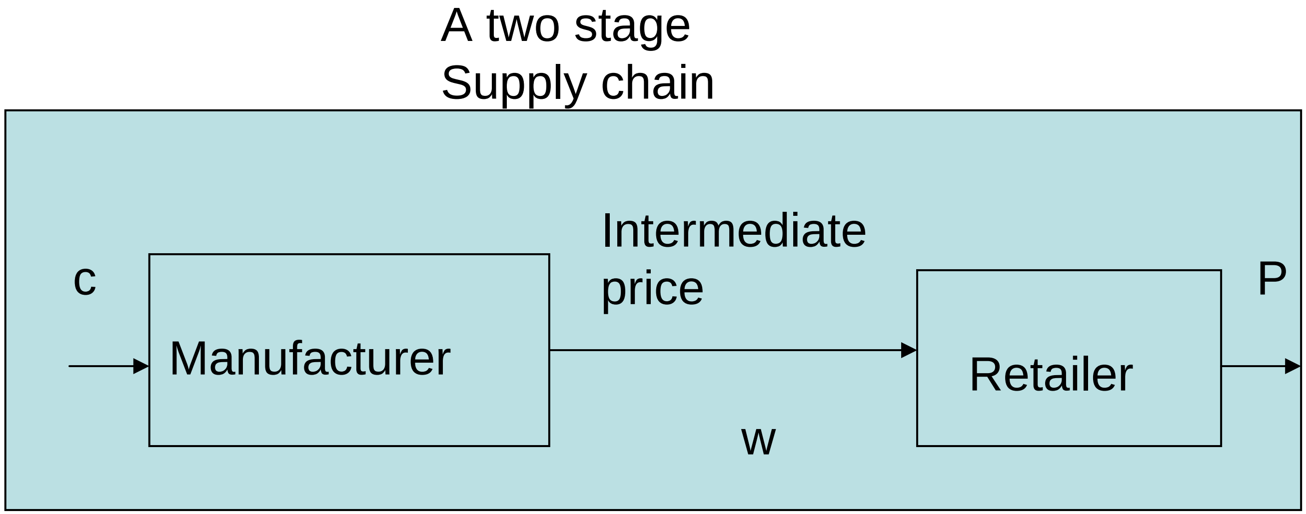
  - Shadow prices
- Prices for services

Prices in supply chains

- Impact of prices in interfaces of a vertically dis-integrated chain of entities
- Leads to ***double marginalization***
- Resulting prices are higher and profits are lower than in the integrated case

Double marginalization operates at different levels in various types of markets (price dependent demand, uncertain demand, competing suppliers/customers, etc.)

Double marginalization



- Ideally, supply chain should jointly take decisions on maximum realizable margin p – c and *then* distribute profits
- Instead, manufacturer takes decisions based on margin w – c and retailer based on margin p – w, in some order
- Usually turn out to be suboptimal, often detrimental to both

Simple illustration

- Demand curve : $Q = 100 - p$
- If zero marginal costs, producer selling directly gives a revenue maximal solution $p^* = 50$, $Q^* = 50$ and total revenue 2500
- With an intermediary (say, wholesaler), to whom the sale is made at price w, the margin is split as (p-w) for the wholesaler and w for the producer. What are the prices that will emerge rationally?

$p^* = (100 + w)/2$, and $Q^* = 50-(w/2)$ [w=0 gives the original price]

Producer sets $w^*= 50$ and total supply chain revenue will be 1875

If producer gives a concession for offering the product at marginal cost, revenue can go up by 600 and intermediary profit also goes up (by a small amount).

Double marginalization for the stochastic demand case

- Basis : Newsvendor model for single stage
  - General form : Q* = F’(c/p) i.e. Probability of stockout = c/p
- Price of Anarchy (PoA)
  - From transportation networks with multiple users

    (Papadimitriou, Koutsoupias and others; 2000):

    Ratio of the performance of the worst Nash equilibrium of the decentralized case to the performance of the centralized case
  - For supply chains with multiple players
    - Perakis and Roels 2007
    - Chan and Simchi Levi 2004

Related work

Lariviere, Cachon, Porteus, Anupindi / Bassok etc.

Bilevel programming : Leader follower models

e.g. for manufacturer as a leader:

$\text{Max}_w \ (w-c)Q$

$$\text{s.t. } Q = \text{argmax}_x \ p\, E \min(x,D) - wx$$
$$p\, E \min(x,Q) - wQ >= 0$$

- The value of the optimum solution to the lower level problem as a function of the parameter set by the leader could be
  - A non-differentiable (but continuous) function, eg. when follower's problem is an LP
  - Non convex (numerous examples)
- Numerical search required for most formulations

Structural results (Perakis and Roels)

Two variants:

Leader offers a wholesale price w

Follower accepts the contract, if beneficial

Manufacturer selects inventory level

- Pull supply chains
  - Demand realized, orders placed by retailer, unmet demand from manufacturer lost
  - Perform better when the upstream player is the leader
- Push supply chains
  - Order placed by retailer, demand realized and unmet demand lost
  - Perform better when the downstream player is the leader
- Results available for multi-stage and assembly systems

Summary of some results

- Price-only contracts do not achieve supply chain optimality – *Lariviere*
  - Optimal order quantities less in decentralized case
  - PoA = *4/3* for some cases (procurement with option contracts) – *Chan and Simchi Levi*
  - PoA = $(p/c)^{(p/p-c)} - (p/c)$ for push supply chains (manufacturer as leader) – *Perakis and Roels*
  - PoA = *e-1* for pull supply chains (retailer as leader) – *P and R*
  - There are demand distributions where these inefficiencies are indeed realized
- Pull systems generally more efficient

Extensions : G.Singla, IIT Bombay

Variant 1 : Demand that depends on price,

e.g. Base demand = b(Price – K) : $b < 0$, $K > 0$

Variant 2: Two period decision with a festival period and remaining period

- In many products, large proportion of sales occur in one time window (Diwali, monsoon, etc.)
- Discount w_R offered in second period based on unsold items in the first period
- Buy back/discount contracts address the DM problem

Analytical and numerical results for optimal w_R for manufacturer and order quantities N_1 and N_2 for retailer

- Key quantities are

  A = the expected overstock at the end of the first period

  Ratios (w/p) and (w_R/p)

- Optimal quantities as a function of this are piecewise well-behaved in intervals defined by A and the two ratios

Summary :

Multi-dimensional contracts as a way out

- Buy-back contracts, salvage possibilities
- Discounts on subsequent purchase
- Revenue sharing

All these share the quantity risk in a more even manner and so promote “correct” inventory investments for supply chain optimality

Extent of risk/profit sharing depends on supply chain muscle vis a vis partners. Interestingly, exerting too much muscle may be counterproductive.

Another dimension in logistics contracts is asset risk. Pricing of penalties is an important aspect.

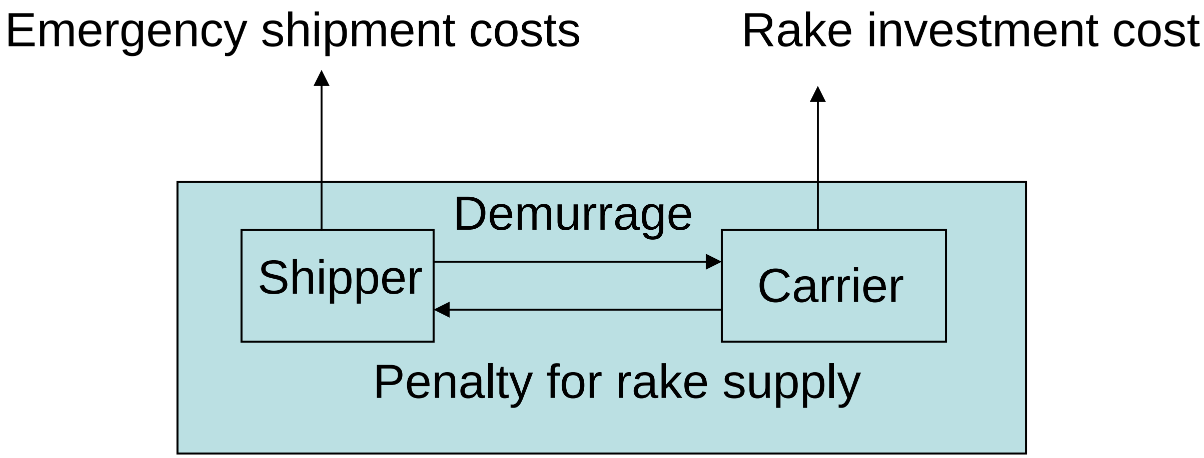
Penalty contracts

- In inventory models, shortage/penalty cost or cost of under-stocking is taken as a given
- We give a supply chain view of how such costs are important in optimal resource allocation
- Unlike holding costs, shortage costs are subjective and akin to opportunity costs
- In supply chains, shortage costs reflect alternate investments (inventories or assets) to attain a desired service level
- Cost parameter for one player are transmitted as prices for another player

Sinha, IIT Bombay – penalties and demurrages in logistics contracts

- Setting – closed circuit operations of vehicles (e.g. railway rakes) with uncertain demand (e.g. Poisson with known rate) of commodity (e.g. cement)
- Asset cost (wagon delays) vis a vis penalty costs for shipment delays, quantified as costs of emergency shipments
- Main result
  - There is a set of values of demurrage parameter (d) and penalty parameter for late supply (p) that
    - Reduces supply chain costs
    - Is no worse for either player (shipper or carrier)
  - Benefits because of better balance of asset investments (wagons versus item inventories)

Schematic view



- Penalties and demurrages are internal costs/prices
- Should be designed to minimize external costs
- Protect each others investment (inventories and assets)

Price parameters in logistics contracts – Sinha (cont'd)

- Region of viable contract parameters polyhedral in nature
- Completely characterized in this setting
- Has nice perturbation properties, i.e. some set of contract parameters remain supply chain optimal for small changes in operating conditions
- Form a basis for two sided logistics contracts (current railway contracts have only one sided penalties, for demurrage, thereby distorting supply chain optimality)

Conclusions

- Pricing in interactions internal to a supply chain affect overall supply chain performance
- Pricing is an important part of contract design
  - Agency for contract design?
  - Negotiated pricing?
- Supply chain pricing captures interactions between
  - pure market driven efficiencies (competition, as captured by Nash-Cournot equilibrium); and
  - firm level strategy/planning (optimization)