Supply Chain Coordination

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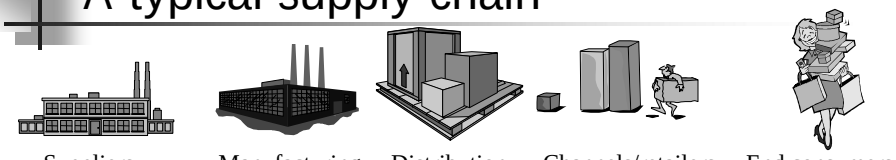
A typical supply chain



Suppliers Manufacturing Distribution Channels/retailers End consumers

Materials, products, services, information, money

Supply chain activities

- Design
- Manufacturing
- Procurement
- Planning and forecasting
- Order fulfillment
- Distribution

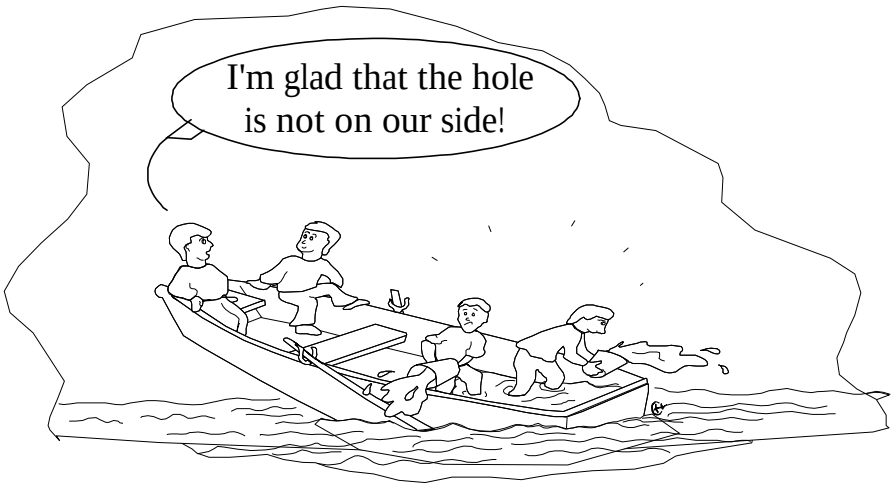
Supply chains are…

Decentralized, but interconnected
Complex tradeoffs, conflicting objectives

Conflicting objectives

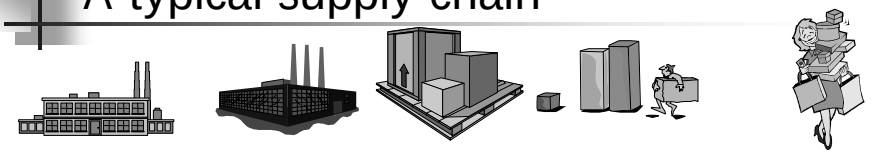
- Conflicting objectives in the supply chain
- Conflicting objectives even within a single firm
  - Marketing/Sales: more FGI inventory, fast delivery, many package types, special wishes/promotions
  - Production: bigger batch size, longer lead times, stable production plan
  - Distribution: full truckload, low depot costs, low distribution costs, small # of SKUs, stable distribution plan

Losing Sight of the Common Objective



Source: Mumin Kurtulus

A typical supply chain



Suppliers | Manufacturing | Distribution | Channels/retailers | End consumers

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Supply chain activities

- Design
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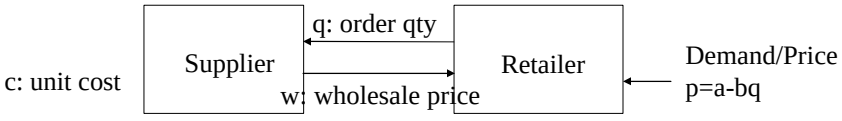
Supply chains are…	**which leads to …**	**Potential solutions to eliminate inefficiencies**
Decentralized, but interconnected Complex tradeoffs, conflicting objectives	Inefficiencies	• Vertical integration • Coordinate with contracts • Collaborate

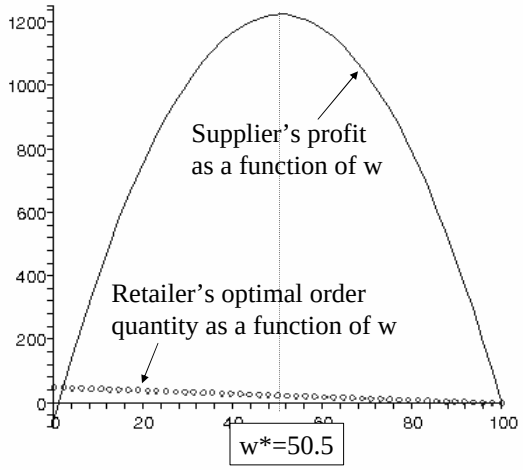
Example: Simple supply chain under wholesale price contract



- Supplier's unit cost of production is c
- Supplier quotes unit wholesale price w
- Retailer chooses order quantity q
- Both the supplier and the retailer try to maximize their own profits (decentralized system)
  - Retailer's profit $(\Pi_R) = (p-w)q = (a-bq-w)q$
  - Supplier's profit $(\Pi_S) = (w-c)q$
    - q depends on w. In choosing w, the supplier "anticipates" the retailer's response q

Decentralized solution

- a=101, b=1, c=1,p=100-q

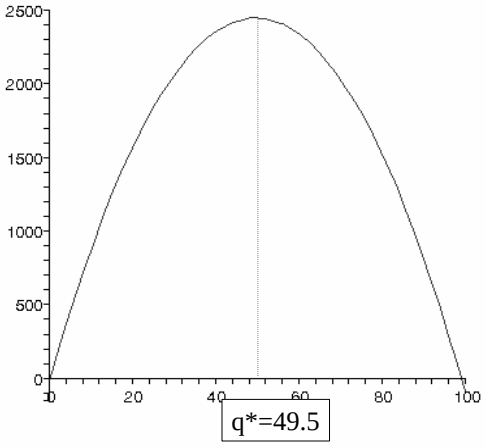


Decentralized SC solution

w = 50.5
q = 24.75
p = 75.25
Π_S = 1225
Π_R = 612
Π = Π_S + Π_R = 1837

Centralized (Integrated) solution

- Supply chain profits: (p-c)q



Decentralized SC solution

w = 50.5
q = 24.75
p = 75.25
Π_S = 1225
Π_R = 612
Π = Π_S + Π_R = 1837

Centralized SC solution

q = 49.5
p = 50.5
Π = 2450
w = ?

Wholesale price contract

- Sequence of events
  - Supplier offers wholesale price w
  - Retailer chooses order quantity q
  - Demand is realized, sales are made
  - The profits (payoffs) are realized
- Assume all of this information is common knowledge
- Game setting
  - Number of players?
  - Static or dynamic game?
  - Complete or incomplete information?
  - Perfect information?

Equilibrium solution for the decentralized supply chain (DSC)

Supplier's wholesale price (w)	$w=(a+c)/2$
Retailer's quantity (q)	$q=(a-c)/4b$
Market price (P)	$P=(3a+c)/4$
Supplier's profit (Π_S)	$\Pi_S=(a-c)^2/8b$
Retailer's profit (Π_R)	$\Pi_R=(a-c)^2/16b$
Total SC profits (Π)	$\Pi=3(a-c)^2/16b$

Comparison of the decentralized (DSC) and centralized supply chains (CSC)

	Decentralized Supply Chain (DSC)	Centralized Supply Chain (CSC)
Supplier's wholesale price (w)	$w=(a+c)/2$	?
Retailer's quantity (q)	$q=(a-c)/4b$	$q^*=(a-c)/2b$
Market price (P)	$P=(3a+c)/4$	$P^*=(a+c)/2$
Supplier's profit (Π_S)	$\Pi_S=(a-c)^2/8b$	?
Retailer's profit (Π_R)	$\Pi_R=(a-c)^2/16b$	?
Total SC profits (Π)	$\Pi=3(a-c)^2/16b$	$\Pi^*=(a-c)^2/4b$

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Total SC profits (Π)	$\Pi=3(a-c)^2/16b$	$\Pi^*=(a-c)^2/4b$

Measuring performance

$$\text{Efficiency} = \frac{\Pi}{\Pi^*} = \frac{\text{Total profits}}{\text{Optimal total profits}}$$

Supplier's profit as a fraction of optimal total profits:

$$\frac{\Pi_S}{\Pi^*} = \underbrace{\frac{\Pi_S}{\Pi}}_{\text{Supplier's share of profits}} \times \underbrace{\frac{\Pi}{\Pi^*}}_{\text{Efficiency}}$$

Retailer's profit as a fraction of optimal total profits:

$$\frac{\Pi_R}{\Pi^*} = \frac{\Pi_R}{\Pi}\frac{\Pi}{\Pi^*}$$

Centralized vs. decentralized supply chain

- In the decentralized supply chain
  - Sales quantity is lower
  - Market price is higher
  - Total profit is lower

Double Marginalization

compared to the centralized supply chain.

Why not do “vertical integration” of supply chains?

Vertical integration example – Ford in the early 20th century

- Focus: mass customization – make Model T better, faster, and cheaper
  - Owned rubber plantation, glass factory, steel mills, iron ores, railroads and ships, etc.
  - **Cost / price**: The price of Model T fell from $825 in 1908 to $290 in 1924
  - **Market share**
    - By 1914, Ford had a 48% share of the American market
    - By 1920 Ford was producing half the cars made worldwide.

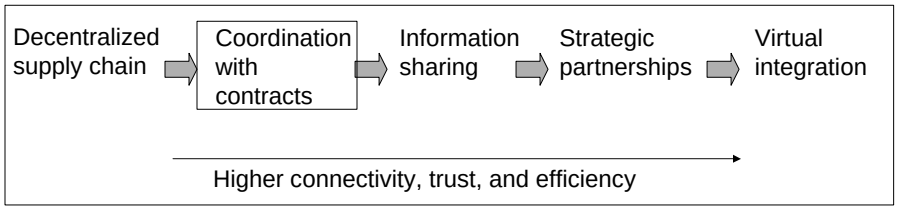
What are the benefits/problems with this approach?

GM's alternative strategy

- Decentralization instead of vertical integration
  - Chevrolet, Oldsmobile, Buick, Cadillac (and a few year later Pontiac)
  - Use outside suppliers
- New models every year
- By 1960s, GM's profits were three times Ford's
- Cadillac sales slumped from 350,000 cars in 1978 to 172,000 in 2001, by which time the average Cadillac buyer was 66 years old
- In 2004 GM announced it would stop making Oldsmobiles, a brand that went back to 1897 and was older than GM itself

What are the benefits/problems with this approach?

Coordination / Collaboration



Coordination with Contracts

- Simple wholesale price contract
  - Inefficiencies due to decentralization
- Alternative “simple” contracts
  - Take-it-or-leave-it
  - Marginal pricing
  - Two-part tariff
- Quantity discounts
- Revenue sharing
  - Reduced “double marginalization”
- Buy-back (return) contract
  - Risk sharing and improved efficiencies

Alternative "simple" contracts for increasing supply chain profits

- Take-it-or-leave-it contract
  - Supplier offers to sell q* at w=P*, and no other quantity
- Marginal pricing
  - Supplier sells at wholesale price w=c

Desirable properties for coordinating contracts

- Achieve high supply chain profits
- Allow for flexible division of profits
  - Retailer gets α fraction of SC profits, supplier gets (1-α)
- Easy and cost effective to administer

Two-part tariff

- Supplier charges
  - a fixed fee F
  - a wholesale price w per unit

Example:
For travelers who value flexibility and the increased security of knowing everyone on the flight, there is a compelling incentive for opting for fractional ownership. [...] Under NetJets' scheme, a one-sixteenth share of a small Cessna Encore, which seats seven passengers, costs $487,500 plus a monthly management fee of $6,350 and an occupied hourly fee of $1,390 for each of the allotted 50 hours." (Financial Times, December 12, 2001)

Quantity Discounts

- "We offer a quantity discount for orders of 10 pieces and more of the same products." (www.decor24.com)
- "Server quantity discounts start at 10 units, with further breaks at 25, 50, 100, 250 and above." (www.greyware.com)
- "Quantity discounts on miscellaneous accessories:" (www.frye.com)
  - 0 - 4 = 0%
  - 5 - 9 = 5%
  - 10 - 24 = 10%
  - 25 - 49 = 15%
  - 50 - up = 20%

Revenue sharing in video cassette sales

- Traditional contract (before 1998)
  - Cost of each copy of a tape to retailer: $65
  - Revenue: ~$3-4 per rental
  - Need to rent about 22 times to break even
  - Peak demand usually lasts <10 weeks
  - Low inventory, stock-outs: 20% of customers were unable to rent the movie they wanted
- Revenue sharing contract
  - Initial price per tape: $8
  - Blockbuster pays 30-45% of its revenue to the supplier
  - Break even: ~ 6 rentals
  - Increase in revenues: ~75%
  - Increase in market share: From 25 to 31%

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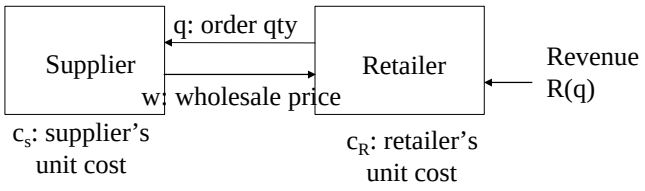
- Recap
  - Basic model: one supplier one retailer
  - Wholesale price contract
    - Inefficiencies due to decentralization
  - Coordinating contracts
    - Take-it-or-leave-it
    - Marginal pricing
    - Two-part tariff
    - Quantity discounts
- Today
  - Revenue sharing
  - Return (buy-back) contracts

Decentralized supply chain under revenue sharing contract



- Retailer keeps α fraction of his revenues, supplier gets 1-α fraction, $0<\alpha<1$
- Both the supplier and the retailer try to maximize their own profits (decentralized system)

Decentralized supply chain under revenue sharing contract

- Centralized chain ($c= c_s+c_R$)
  - $\Pi = R(q) - cq \rightarrow \Pi' = R'(q)-c = 0 \rightarrow \boxed{R'(q^*)=c}$
  - Marginal revenue = Marginal cost
- Retailer's problem (given w):
  - Retailer's profit $\Pi_R = \alpha R(q) - (w+c_R)q$
  - $\Pi'_R= \alpha R'(q) - (w+ c_R) = 0 \rightarrow \boxed{R'(q) = (w+ c_R)/\alpha}$
  - To have $q= q^*$, we need $c= (w+ c_R)/\alpha \rightarrow w= \alpha c- c_R$
  - $w= \alpha c- c_R= \alpha(c_s+c_R) - c_R= \alpha c_s - (1- \alpha)c_R< c_s$
  - To coordinate, supplier must sell below cost!

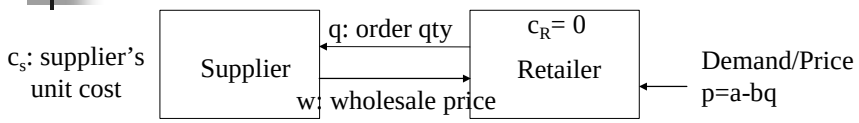
Decentralized supply chain under revenue sharing contract

- $w = \alpha c - c_R \rightarrow q = q^*$
- Retailer's profit
  - $\Pi_R = \alpha R(q) - (\alpha c - c_R + c_R)q = \alpha R(q) - \alpha cq = \alpha(R(q^*) - cq^*)$
  - Retailer gets α fraction of the optimal (centralized) SC profits
  - Retailer's profit function becomes an affine transformation of the centralized supply chain's profit function
- Supplier's profit
  - $\Pi_S = (1-\alpha)R(q) + (\alpha c - c_R)q - c_s q =$
  - $\Pi_S = (1-\alpha)R(q) + (\alpha c_s + \alpha c_R - c_R)q - c_s q =$
  - $\Pi_S = (1-\alpha)R(q) + (\alpha c_s - (1-\alpha)c_R)q - c_s q =$
  - $\Pi_S = (1-\alpha)R(q) - (1-\alpha)c_s q - (1-\alpha)c_R q =$
  - $\Pi_S = (1-\alpha)R(q) - (1-\alpha)\, cq$
  - Inserting $q = q^*$, $\Pi_S = (1-\alpha)\,\Pi^*$
  - Supplier gets $(1-\alpha)$ fraction of the optimal (centralized) SC profits

How to choose in a revenue sharing contract

- Depends on the bargaining power of the supplier and the retailer
- For the wholesale price to be positive, we need $w = \alpha c - cR \geq 0 \rightarrow \alpha \geq cR / c$
- What happens to the retailer's profit function as $\alpha \rightarrow 0$?
- Can we choose α so that both parties benefit compared to the wholesale price contract?

Example: Revenue sharing contract with linear demand function

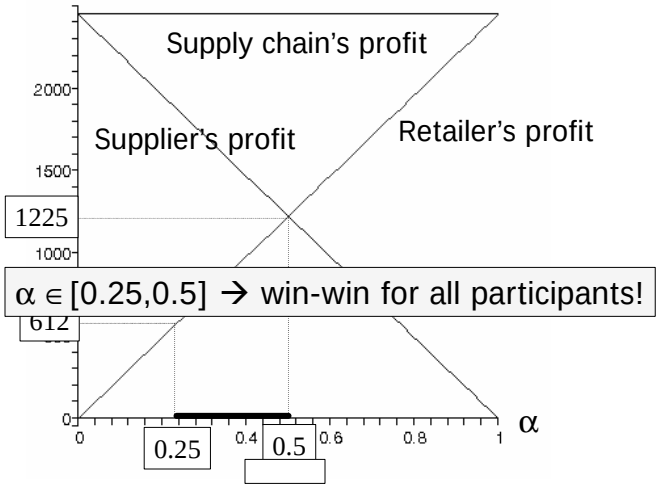


- Retailer shares 1-α fraction of his revenues with the supplier, $0<\alpha<1$
- Both the supplier and the retailer try to maximize their own profits (decentralized system)
  - Retailer's profit (Π_R) = $\alpha pq - wq$
  - Supplier's profit (Π_S) = $(w-c)q + (1-\alpha)pq$
  - Supply chain profit (Π) = $(p-c)q$

If the supplier sets $w= \alpha c$ we get $\Pi_R = \alpha\Pi$!
The retailer orders q*, and the supplier makes $\Pi_S = (1-\alpha)\Pi$.

Decentralized supply chain under revenue sharing contract

- a=101, b=1, c=1, p=100-q, w= αc

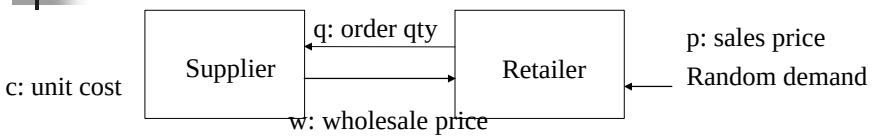


Revenue sharing with competing retailers

Issues about revenue sharing contract

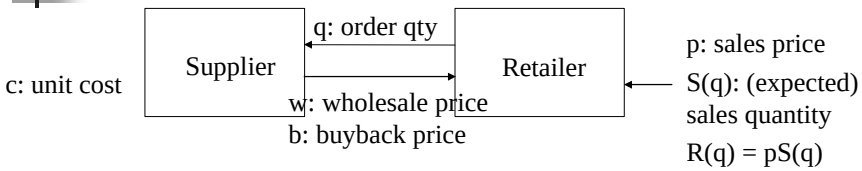
- Administrative costs and trust
- Multiple retailers
  - Supplier may have to price-discriminate
  - Capacity restrictions
- Retailer sells competing goods and sets prices
- Impact on sales effort/advertising

Example: Simple supply chain with demand uncertainty



- Demand > q → lost sales
- Demand < q → excess inventory

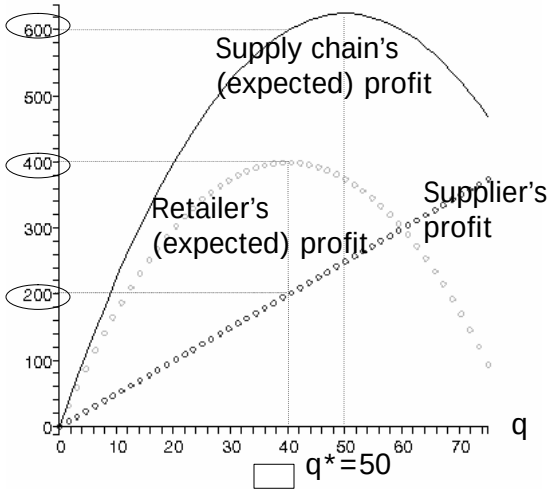
Buy-back (return) contract



- The retailer can return any unsold units at the end of the selling season to the supplier and receive b<w
- Buyback contract allocates the risk of excess inventory between the supplier and the retailer

Wholesale price contract

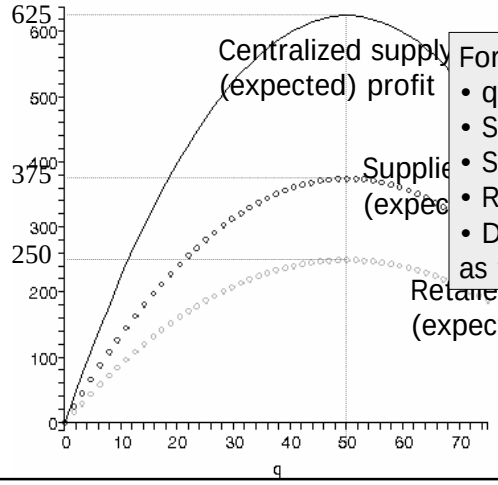
- c=25, p=50, Demand~Uniform[0,100], w=30



For any w>c, retailer's order quantity in the decentralized supply chain is less than q*

Buy-back (return) contract

- c=25, p=50, Demand~Uniform[0,100], w=37.5, b=25



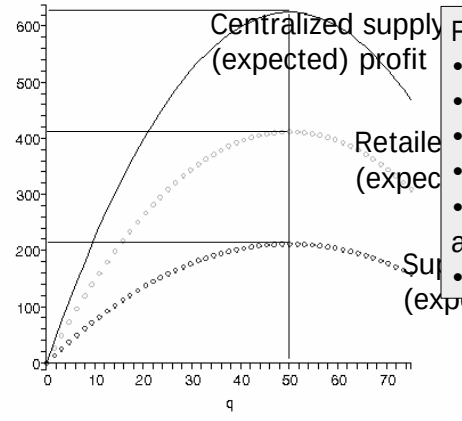
For this combination of w and b:
- q ↑ (40→50)
- SC profit ↑ (600→625)
- Supplier's profit ↑ (200→375)
- Retailer's profit ↓ (400→250)
- Decentralized SC behaves same as the centralized SC !

Buy-back (return) contract

- To "coordinate" the supply chain and receive (1- α) fraction of total supply chain profits, supplier must set
  - $w = p(1-\alpha)+\alpha c-c_R$
  - $b = p(1-\alpha)-c$
- Buyback contract allows for "flexible" division of profits between the supplier and the retailer → Can choose contract parameters for win-win!!

Buy-back (return) contract

- c=25, p=50, Demand~Uniform[0,100], w=33.5, b=17



For this combination of w and b:
- q ↑ (40→50)
- SC profit ↑ (600→625)
- Supplier's profit ↑ (200→212.5)
- Retailer's profit ↑ (400→412.5)
- Decentralized SC behaves same as the centralized SC
- Win-win for the players!

Coordination / Collaboration