MGT 528 – OPERATIONS: ECONOMICS & STRATEGY

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2. Supply-Chain Coordination

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École Polytechnique Fédérale de Lausanne
College of Management of Technology

AGENDA

Monopoly Pricing and Market Power

Supply-Chain Coordination and Coordination Failures

Double Marginalization and Coordination of a Two-Stage Supply Chain

Key Concepts to Remember

FIRMS USUALLY HAVE MARKET POWER

Definition: **Market power** is the ability of a firm to *increase its output prices above the competitive level*, and/or to *reduce its input prices below the competitive level*.

- **Monopoly**
  - Single seller of a product
- **Oligopoly**
  - Small number of sellers of a product

Sellers' Market

- **Monopsony**
  - Single buyer of a product
- **Oligopsony**
  - Small number of buyers of a product

Buyers' Market

ANALYSIS OF MARKET POWER
Initial Focus on Single Firm

- Consider first the case where one single firm has market power, in a monopoly or a monopsony. Other market participants' actions are aggregated to a market demand (for monopoly) or a market supply (for monopsony).
  - ❑ When more than one firm holds market power, it is necessary to model the interactions between those firms explicitly. For this, one needs the tools of *Game Theory*
- Since actions of all non-market-power-holding entities (the 'other' side of the market) are aggregated into a demand curve (or a supply curve), this is often referred to as partial equilibrium analysis. (1)

(1) In general equilibrium analysis, the optimizing behavior of all market participants is explicitly taken into account, and the consumers may own the firms (as is the case in a "private ownership economy").

STUDENT PROJECT (2013): LAITERIE BOURQUIN (in Renens)

Presentation of Laiterie Bourquin

Laiterie Bourquin:

A family company of 5 employees
A dairy products wholesaler and a retailer .

- **Its products:**

Milk, butter, cream, cheese, yogurt, desserts, and eggs.
Specialty : the plates of cheese and meat made and offered for special events
biggest margin

- **Its suppliers:**

Mainly the three big firms:
EMMI, LRG and Cremo

- **Its competitors:**

Its suppliers themselves.
No one from Laiterie Bourquin's size.
No real attraction of the market.

- **Its buyers:** Almost 250 from Aubonne to Martigny and Yverdon.
Restaurants, hospitals, health centers, companies, Kinden gardens, schools and small grocery shops. Deliveries thanks to small vans owned by the company.

KEY QUESTIONS

1) Laiterie Bourquin is selling miscellaneous products from yoghurts to creams, cheese and desserts.

What is the contribution of each product offered to the viability and the revenues of the company and what should be the sales strategy in the future?

2) Laiterie Bourquin fixed the price of its specialty (plates of cheese and meat) randomly.

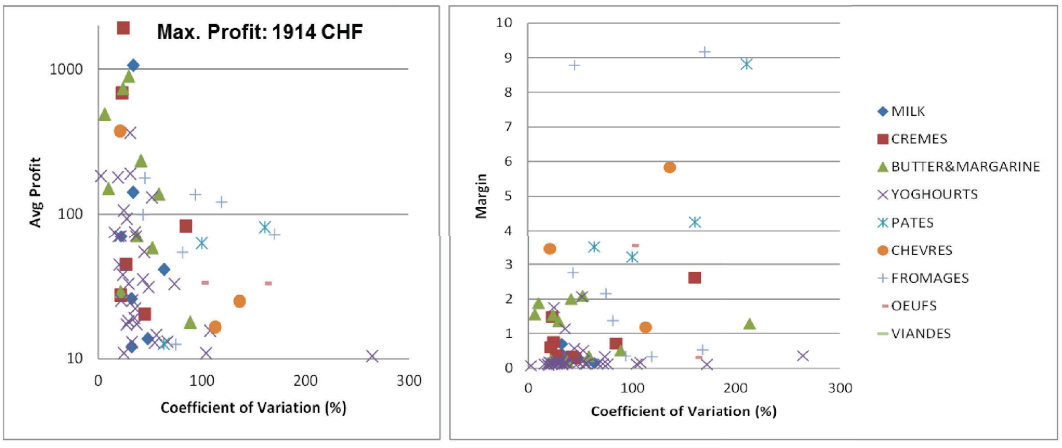
Is it possible to find an optimal price that would garantee the best profit?

Source: Belesiotis, A., Limniati, Y., Simon, A. (2013) "Product Analysis, Pricing and Inventory Control Applied to Laiterie Bourquin," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

STUDENT PROJECT (Cont'd): PRODUCT-PORTFOLIO ANALYSIS

•**METHODOLOGY:** a) Inspired by Growth-Share matrix and CAPM
b) Use Sales data of the last 5 months

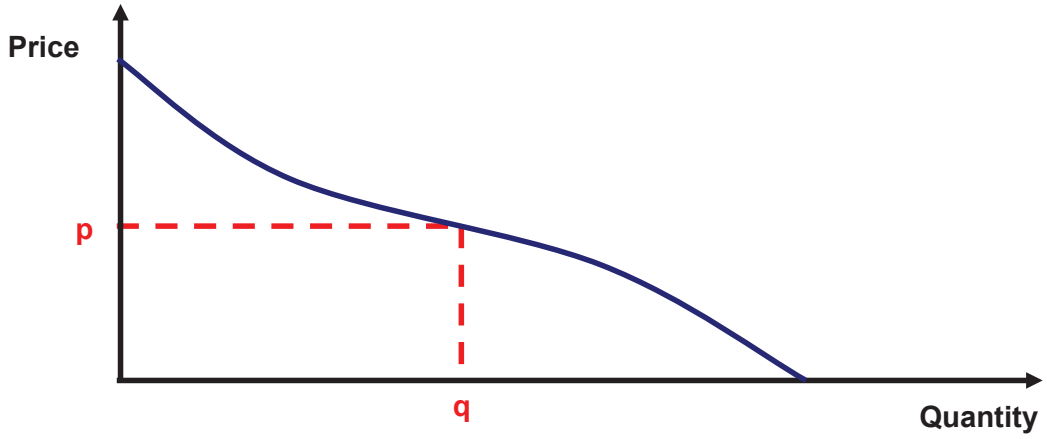
•**RESULTS:**



Source: Belesiotis, A., Limniati, Y., Simon, A. (2013) "Product Analysis, Pricing and Inventory Control Applied to Laiterie Bourquin," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

DEMAND

- The quantity of a product a firm can sell at price p, i.e., its demand D(p), is a decreasing function.
- Its inverse demand p(q), i.e., the price at which the firm can sell a quantity q of a product, is also a decreasing function.



OPTIMAL CHOICE OF MONOPOLY OUTPUT

Assume that a monopolist produces a quantity q of a single output and that the market price at that output is given by the *downward-sloping* inverse market demand p(q). The monopolist's cost function C(q) is *increasing and convex*.

Monopolist's profit: $\Pi(q) = \underbrace{R(q)}_{\text{Revenue}} - \underbrace{C(q)}_{\text{Cost}} = p(q)q - C(q)$

First-order necessary optimality condition:

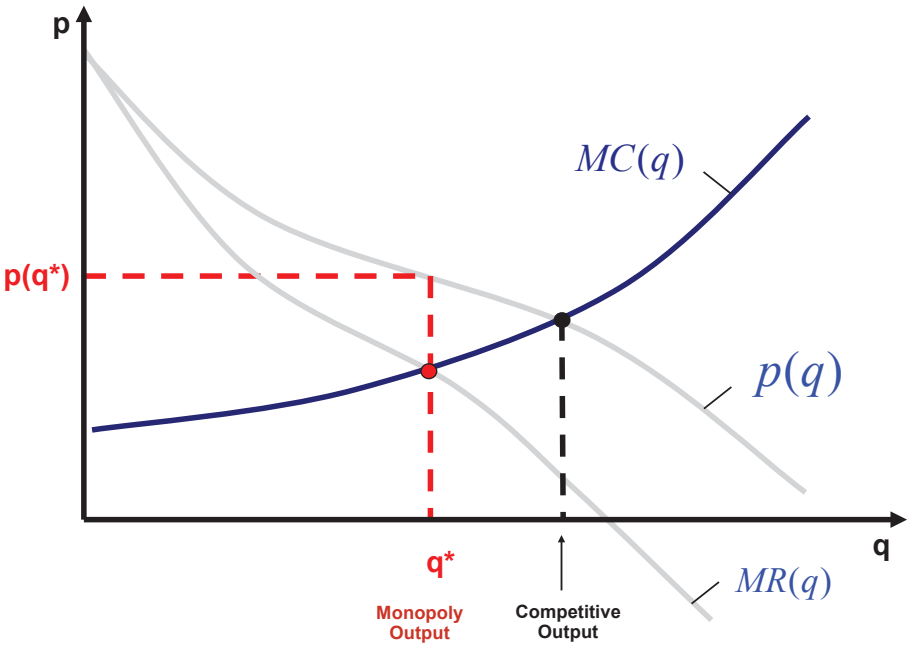
$$\frac{d\Pi(q)}{dq} = \frac{dR(q)}{dq} - \frac{dC(q)}{dq} = 0 \quad \Leftrightarrow \quad \frac{dR(q)}{dq} = \frac{dC(q)}{dq}$$

Hence,

$$p(q) > p(q) + q\underbrace{\frac{dp(q)}{dq}}_{<0} = \frac{dC(q)}{dq}$$

In other words, the market price in a monopoly exceeds marginal cost!

OPTIMAL MONOPOLY OUTPUT (Cont'd)



MONOPOLY PRICING
Inverse Elasticity Rule

Consider the monopolist's choice of a profit-maximizing price p, given its (downward-sloping) demand function D(p).

The (own-price) demand elasticity is $\varepsilon(p) = -\dfrac{p}{D(p)}\dfrac{dD(p)}{dp}$

Maximizing the monopolist's profit $\Pi(p) = pD(p) - C(D(p))$

yields the first-order necessary optimality condition

$$D(p) + p\frac{dD(p)}{dp} = \frac{dC(D(p))}{dq}\frac{dD(p)}{dp} \quad \textbf{or} \quad 1 = \left(-\frac{D'(p)}{D(p)}\right)\left(p - MC(D(p))\right) = \varepsilon(p)\frac{p - MC(D(p))}{p}$$

Hence, we obtain the "inverse elasticity rule" for monopoly pricing:

$$1 \geq \underbrace{\frac{p - MC(D(p))}{p}}_{\text{Relative Markup}} = \underbrace{\frac{1}{\varepsilon(p)}}_{\substack{\text{Inverse Demand Elasticity} \\ \text{(Lerner Index)}}}$$

STUDENT PROJECT (Cont'd): OPTIMAL PRICING

2) PRICING OF THE SPECIALTY

GOAL: find the optimal price.

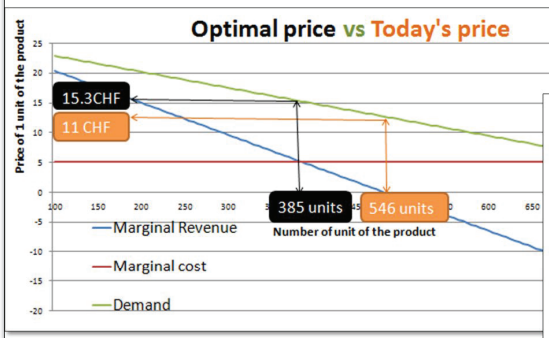
HYPOTHESIS: Laiterie Bourquin owns a monopoly on this product. → Monopoly model

Demand function: $Q = A.p + B$

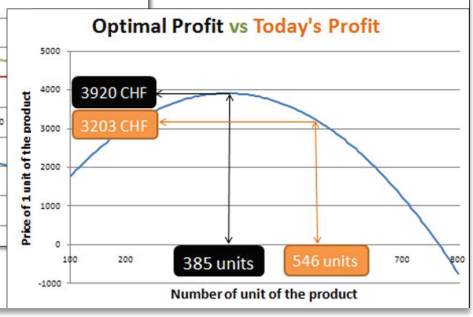
Total cost function: $TC = w.T.q + r.q$

METHODOLOGY:

For the demand curve, call 20 of the 100 clients of the specialty



RESULTS



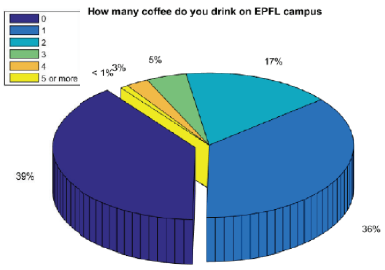
Source: Belesiotis, A., Limniati, Y., Simon, A. (2013) "Product Analysis, Pricing and Inventory Control Applied to Laiterie Bourquin," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

STUDENT PROJECT (2015): SELECTA (on the EPFL Campus)

COFFEE MARKET ON THE CAMPUS

Customers on the market

- 10'000 Students
- 61% Drinks coffee



Consumption of coffee

- 1.60 coffee per day per student
- Total market : 9760 coffees

METHODOLOGY

Market analysis

- Survey

Tools

- Monopoly pricing
- Price elasticity of demand
- Spatial competition

"Whereas a competitive firm must sell at the market price, a monopoly owns its market, so it can set its own prices. Since it has no competition, it produces at the quantity and price combination that maximizes its profits"

Peter Thiel

Source: Donzé, C., Pichler, N., Previdoli, B. (2015) "SELECTA on the EPFL Campus," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

STUDENT PROJECT (Cont'd): MONOPOLY PRICING

Definition

- **Profit :** $\Pi = TR - TC$
  - Total revenue TR: $TR = \tau \cdot q \cdot p(q) = \tau \cdot q \cdot (-0.2212q + 1.5737)$
  - Total cost TC : $TC = FC + VC = \frac{1}{N}\left[\frac{C_{machine}}{6 \cdot 365} + C_{employee}\right] + C_{beans} \cdot q$ (FC, VC)
- **Maximize profit (FOC):** $\frac{d\Pi}{dq} = MR - MC = 0$

Results

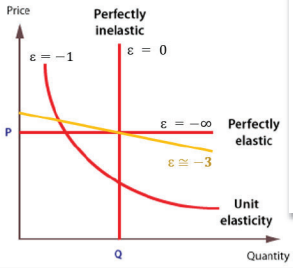
- **Optimal price:** $p^* = 0.89\ [\text{CHF/coffee}]$
- **Optimal quantity:** $q^* = 3.1\ [\text{coffe/day/person}]$

Definition

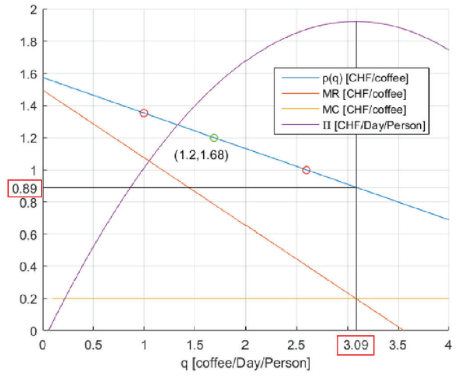
- **Formula** $\epsilon = \frac{\Delta q/q}{\Delta P/p} = \frac{\Delta q}{\Delta P} \cdot \frac{q}{P} = \frac{\partial q(p)}{\partial p} \cdot \frac{p}{q(p)}\Big|_{p=1.2} = -3.24$

Analysis

- **-1 < ε < 0** : inelastic demand
- **ε = -1** : unit elastic
- **ε < -1** : elastic demand



Graphically



Results

- **Profit**
  - Current: $\Pi_{current}(q = 1.7\ \&\ p = 1.20) = 1.51\ [\text{CHF / day / person}]$
  - New: $\Pi_{new}\ (q^* = 3.1\ \&\ p^* = 0.89) = 1.92\ [\text{CHF / day / person}]$

Source: Donzé, C., Pichler, N., Previdoli, B. (2015) "SELECTA on the EPFL Campus," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

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Monopoly Pricing and Market Power

Supply-Chain Coordination and Coordination Failures

Double Marginalization and Coordination of a Two-Stage Supply Chain

Key Concepts to Remember

SUPPLY-CHAIN COORDINATION

Definition: A supply chain is coordinated if the actions taken in the different stages maximize the sum of its payoffs as if all actions were controlled by a single payoff-maximizing agent.

The are numerous reasons why a decentralized(1) supply chain may not be coordinated, such as

1. **conflicting objectives of the agents operating the different stages**
2. **suboptimal response to demand uncertainty (e.g., bullwhip effect)**
3. **information asymmetries**
4. **lack in trust or ability to engage in binding contracts(2)**
5. **incomplete contracts (e.g., holdup problem)**

(1) In a *decentralized* supply chain, the different stages are controlled by different agents.
(2) Contractability = Observability + Verifiability

BULLWHIP EFFECT

The "bullwhip effect" is often given as explanation for

- **Excessive inventory & manufacturing**
- **Inefficient capacity utilization**
- **Boom and bust cycles in manufacturing**
- **Added transportation cost**
- **Poor product availability (long lead times and stockouts)**

UPSTREAM INCREASE IN ORDER VARIABILITY
Bullwhip Effect

Supplier → Manufacturer → Wholesaler (Distributor) → Retailer → Consumer

Source: Lee, H.L., Padmanabhan, V., Whang, S. (1997) "The Bullwhip Effect in Supply Chains," Sloan Management Review, Vol. 38, No. 3, pp. 93—102.

UPSTREAM INCREASE IN ORDER VARIABILITY
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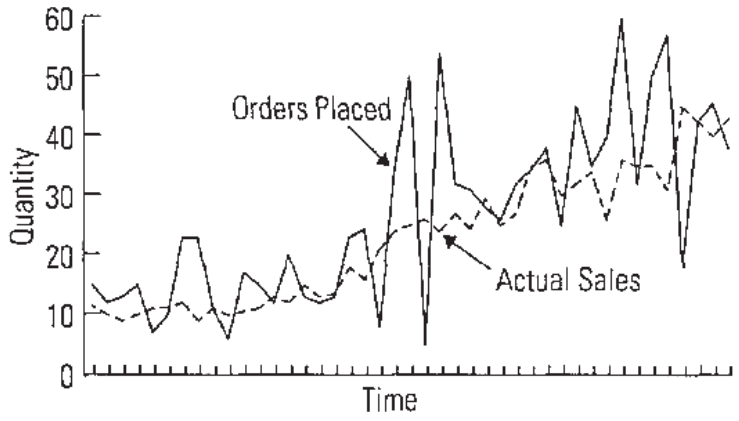
SIGNIFICANT AMPLIFICATION
Bullwhip Effect

Supplier → Manufacturer → Wholesaler (Distributor) → Retailer → Consumer

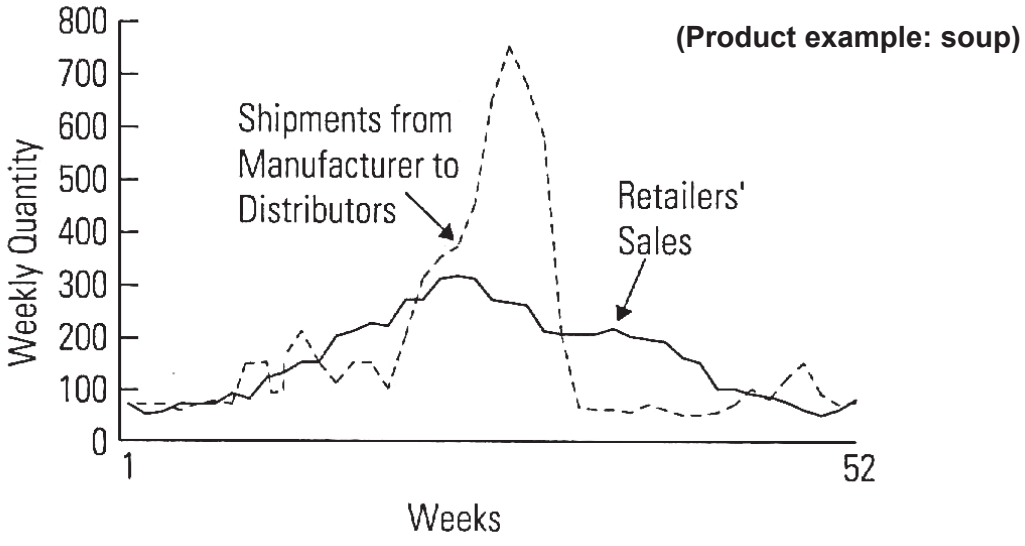


Source: Lee, H.L., Padmanabhan, V., Whang, S. (1997) "The Bullwhip Effect in Supply Chains," Sloan Management Review, Vol. 38, No. 3, pp. 93—102.

SEASONAL VARIATIONS CAN CAUSE LARGE SHIPMENT SWINGS
Bullwhip Effect

Supplier → Manufacturer → Wholesaler (Distributor) → Retailer → Consumer

(Product example: soup)



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SUPPLY-CHAIN COORDINATION INITIATIVES
Counteracting the Bullwhip Effect

Causes of Bullwhip	Information Sharing	Channel Alignment	Operational Efficiency
Demand Forecast Update	• Understanding system dynamics • Use point-of-sale (POS) data • Electronic data interchange (EDI) • Internet • Computer-assisted ordering (CAO)	• Vendor-managed inventory (VMI) • Discount for information sharing • Consumer direct	• Lead-time reduction • Echelon-based inventory control
Order Batching	• EDI • Internet ordering	• Discount for truck-load assortment • Delivery appointments • Consolidation • Logistics outsourcing	• Reduction in fixed cost of ordering by EDI or electronic commerce • CAO
Price Fluctuations		• Continuous replenishment program (CRP) • Everyday low cost (EDLC)	• Everyday low price (EDLP) • Activity-based costing (ABC)
Shortage Gaming	• Sharing sales, capacity, and inventory data	• Allocation based on past sales	

Source: Lee, H.L., Padmanabhan, V., Whang, S. (1997) "The Bullwhip Effect in Supply Chains," Sloan Management Review, Vol. 38, No. 3, pp. 93—102.

CAUSES FOR & EFFECTS OF LACK IN COORDINATION

1. **Conflicting objectives**
   - **Double marginalization**
   - **Suboptimal capacity investments**

2. **Suboptimal response to risk (bullwhip effect)**
   - **Excess capacity (= overinvestment)**
   - **Occurrence of excess inventory & stockout situations**
   - **Replenishment-lead-time variability**
   - **Variability in transportation cost**
   - **Variability of product availability**
   - **Strain in supply-chain relationships**
   - **Rationing games (when product is in short supply)**

CAUSES FOR & EFFECTS OF LACK IN COORDINATION (Cont'd)

3. **Information asymmetries**
   - Information distortion (e.g., retailer may exaggerate demand to encourage manufacturer to build higher capacity)
   - Adverse selection
   - Bounded rationality

4. **Lack in trust or contracting ability**
   - Moral hazard
   - Incentive misalignment
   - Difficult enforcement regime → relational contracts (= repeated game)

5. **Incomplete contracts**
   - Relationship-specific investments
   - SPOR: Shirking/Poaching/Opportunistic Renegotiation

THE BEER GAME: STERMAN (1989)
"Misperceptions of Feedback in a Dynamic Decision Making Experiment"

Classic experiment, which has become a key reference for the behavioral (and sometimes also normative) regularity of the "bullwhip effect"

The bullwhip effect is often cited when discussing the lack of coordination in a supply chain.

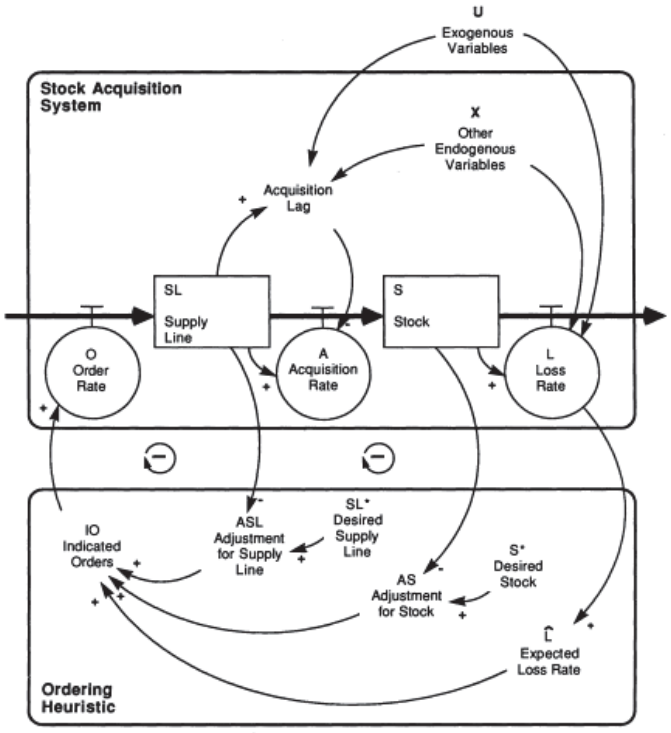
The causes of the bullwhip effect are (among others):

- Demand variability
- Lags in processing the demand signal
- Rationing game (when product is in short supply)
- Order batching
- Price fluctuations

Source: Sterman, J.D. (1989) "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment," *Management Science*, Vol. 35, No. 3, pp. 321—339.

GENERIC STOCK-MANAGEMENT SYSTEM
Sterman (1989)

'System Dynamics' Model:



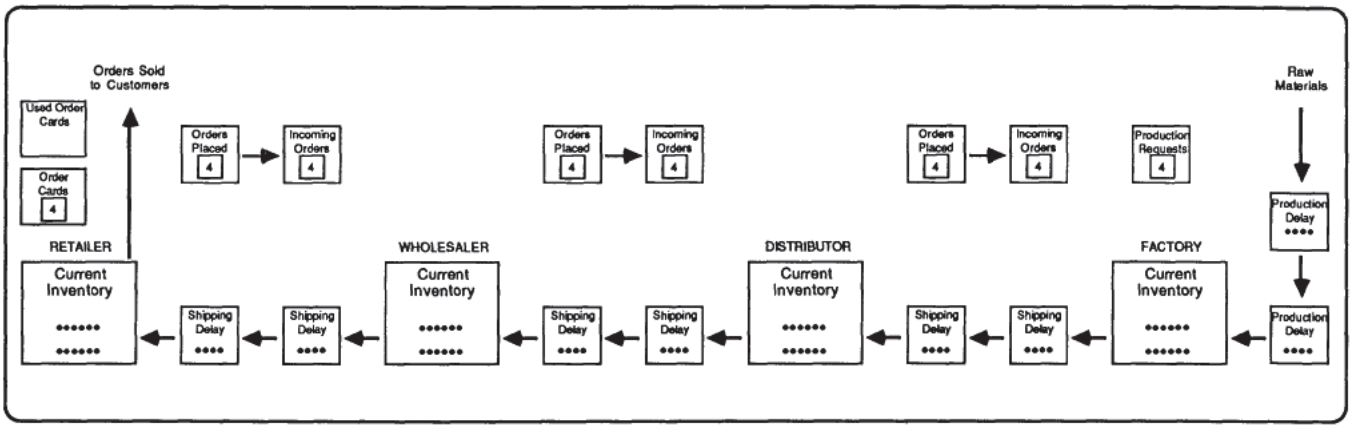
Source: Sterman, J.D. (1989) "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment," *Management Science*, Vol. 35, No. 3, pp. 321—339.

EXAMPLES OF STOCK-MANAGEMENT SYSTEMS
Sterman (1989)

System	Stock	Supply Line	Loss Rate	Acquisition Rate	Order Rate	Typical Behavior
Inventory Management	Inventory	Goods on Order	Shipments to Customers	Arrivals from supplier	Orders for goods	Business cycles
Capital investment	Capital Plant	Plant under construction	Depreciation	Construction completion	New contracts	Construction cycles
Equipment	Equipment	Equipment on order	Depreciation	Equipment delivery	New equipment orders	Business cycles
Human Resources	Employees	Vacanies & trainees	Layoffs and quits	Hiring rate	Vacancy creation	Business cycles
Cash Management	Cash balance	Pending loan applications	Expenditures	Borrowing rate	Loan application rate	?
Marketing	Customer Base	Prospective customers	Defections to competitors	Recruitment of new customers	New customer contacts	?
Hog farming	Hog stock	Immature and gestating hogs	Slaughter rate	Maturation rate	Breeding rate	Hog cycles
Agricultural commodities	Inventory	Crops in the field	Consumption	Harvest rate	Planting rate	Commodity cycles
Commercial construction	Building stock	Buildings under development	Depreciation	Completion rate	Development rate	15–25 year cycles
Cooking on electric range	Temperature of pot	Heat in coils of range	Diffusion to air	Diffusion from coils to pot	Setting of burner	Overcooked dinner
Driving	Distance to next car	Momentum of car	Friction	Velocity	Gas and Brake pedals	Stop-and-go traffic
Showering	Water Temperature	Water Temp. in pipes	Drain rate	Flow from showerhead	Faucet settings	Burn-then-freeze
Personal energy level	Glucose in bloodstream	Sugar and starch in GI tract	Metabolism	Digestion	Food consumption	Cycles of energy level
Social drinking	Alcohol in blood	Alcohol in stomach	Metabolism of alcohol	Diffusion from stomach to blood	Drinking rate	Drunkenness

Source: Sterman, J.D. (1989) "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment," *Management Science*, Vol. 35, No. 3, pp. 321—339.

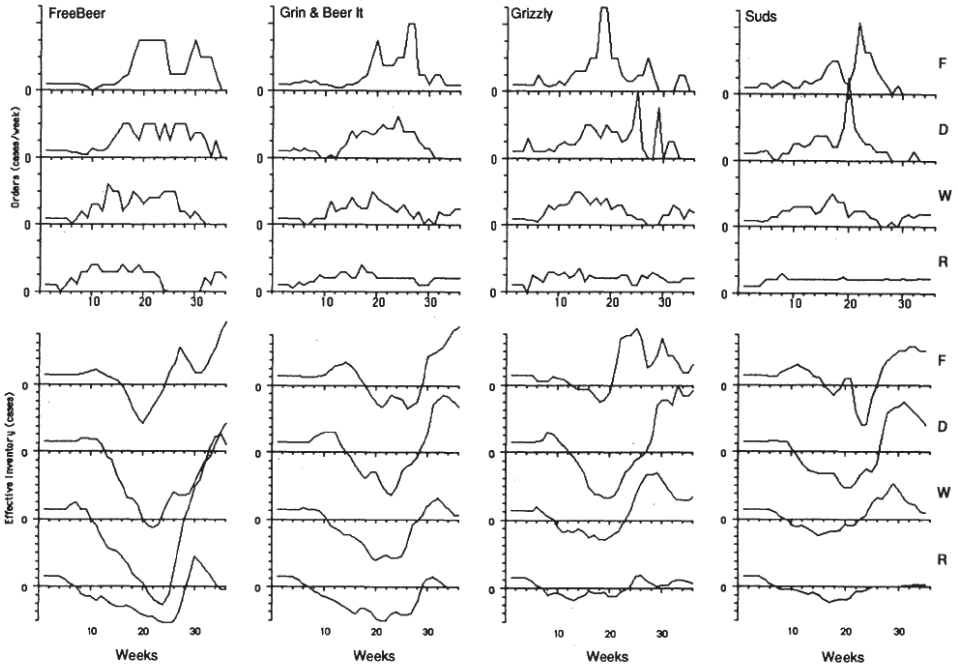
BEER GAME – SETUP
Sterman (1989)



- **Teams of 4 players each**
- **Game is played over different periods (weeks): 50 (truncated)**
- **Inventory holding cost: $0.50/case/week**
- **Stockout cost: $1.00/case/week**
- **Objective: Minimize total cost**

Source: Sterman, J.D. (1989) "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment," *Management Science*, Vol. 35, No. 3, pp. 321—339.

BEER GAME – EXPERIMENTAL RESULTS
Sterman (1989)



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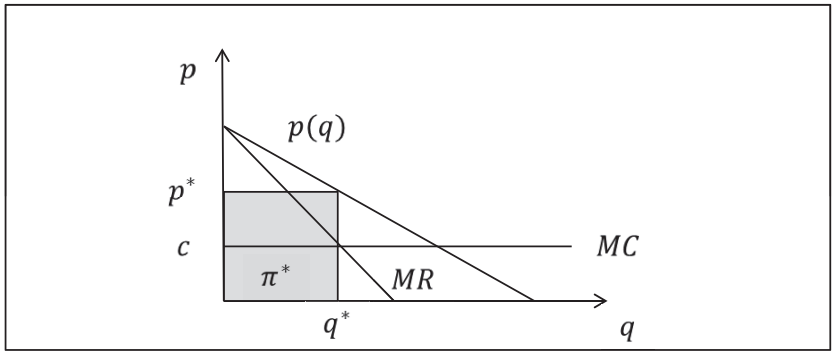
Key Concepts to Remember

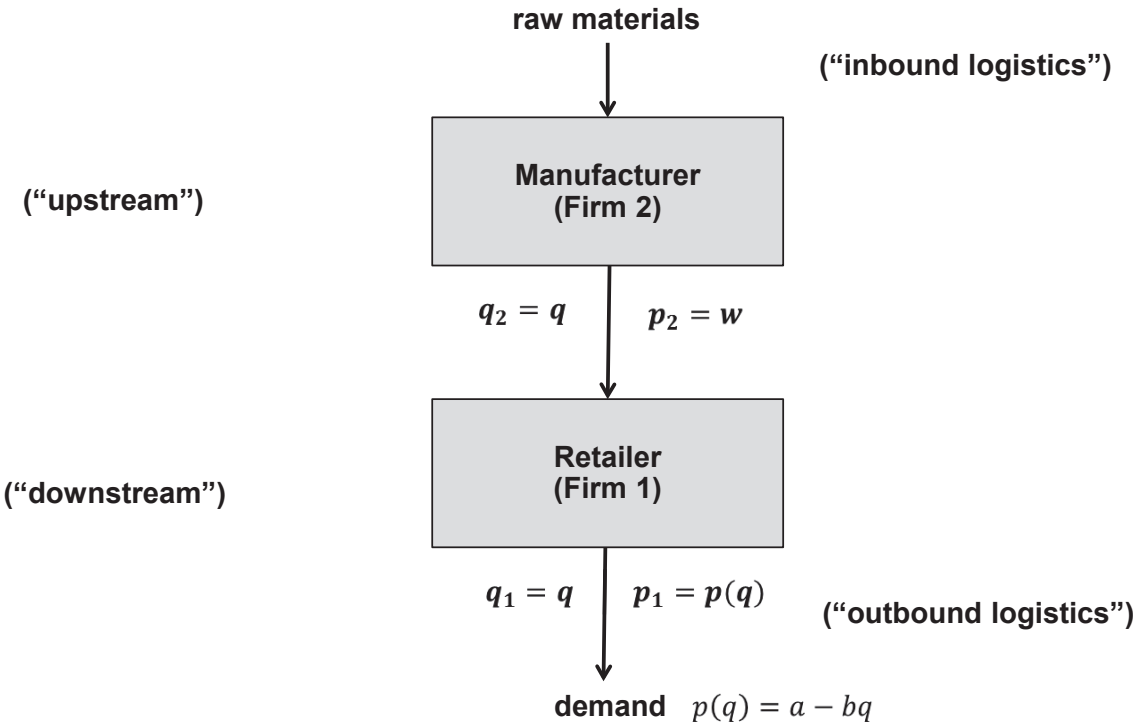
MONOPOLY PRICING RULE

Example: Linear (Inverse) Demand $p(q) = a - bq \qquad (a, b > 0)$

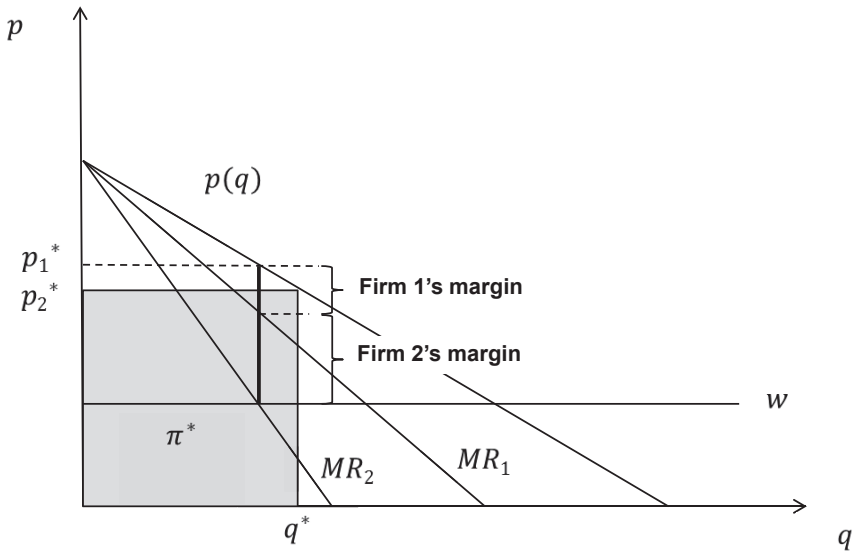
- **Assume constant marginal cost:** $C(q) = cq \qquad (0 < c < a)$
- **Profit:** $\pi(q) = p(q)q - cq = (a - bq)q - cq$
- **Marginal revenue (MR):** $MR(q) = p'(q)q + p(q) = a - 2bq$
- **Marginal cost (MC):** $MC(q) = C'(q) = c$
- **MR = MC:** $a - 2bq = c$
- **Optimal quantity:** $q^* = \frac{a-c}{2b}$
- **Optimal price:** $p^* = p(q^*) = \frac{a+c}{2}$



IN A SUPPLY CHAIN WE HAVE "VERTICAL RELATIONS"
Restrict Attention to 2 Stages



FIRMS' SELF-INTEREST LEADS TO INEFFICIENCY
Coordination Failure



(Assume zero marginal cost for simplicity)

COORDINATION CAN BE ACHIEVED USING REVENUE-SHARING
Cachon and Lariviere (2005)

The idea is very simple (even generally, when the firms have positive costs)

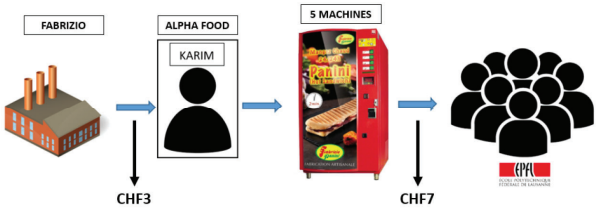
- **Let ϕ be the fraction of revenues that is obtained by firm 1 (retailer).**
- **The wholesale-price contract discussed earlier is the case when $\phi = 1$.**

Question. Show that a vertical revenue-sharing contract with ϕ, strictly between 0 and 1, and a wholesale transfer price $t = \phi (C_1 + C_2) - C_1$ coordinates the two-stage supply chain, where C_1 and C_2 are the firms' respective cost functions.

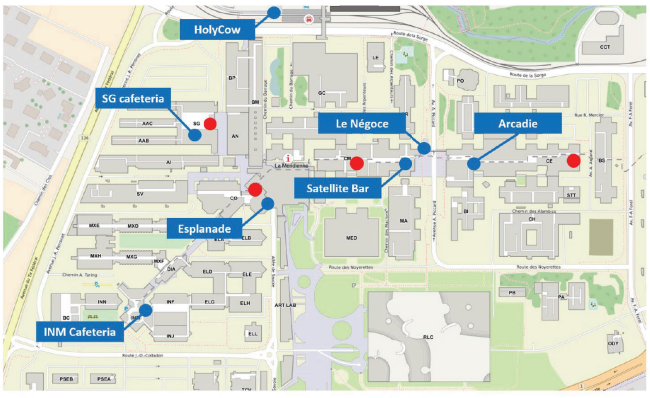
STUDENT PROJECT: PANINI @ EPFL

Introduction ⇒ Company / Supply chain

Company's name	Alpha Food
Owner	Karim
No. machines at EPFL	5
Waiting time to get a panini [min]	4

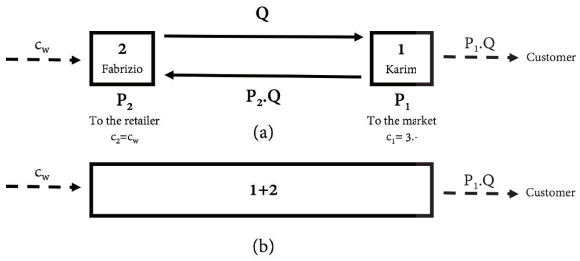


Introduction ⇒ Environment ⇒ Competitors

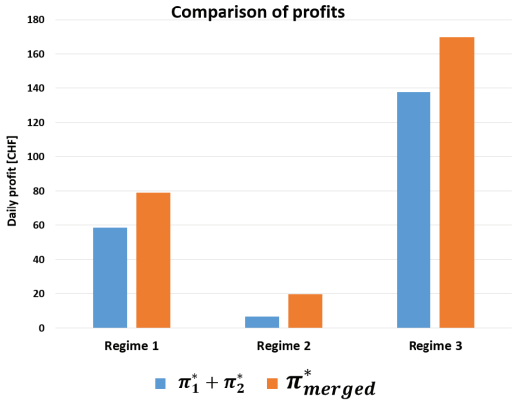


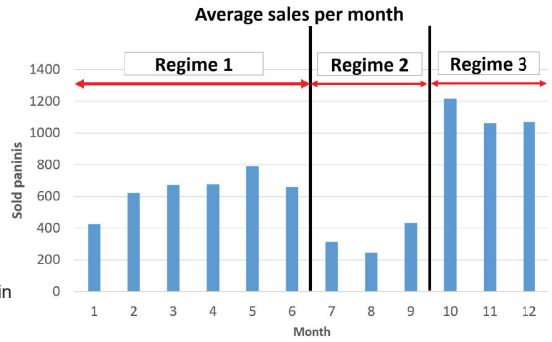
Source: Diab, A., Honsali, I., Rodriguez, J.R. (2017) "Panini on Campus: Future Improvements in a Competitive Environment," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

STUDENT PROJECT (Con'd): PANINI @ EPFL



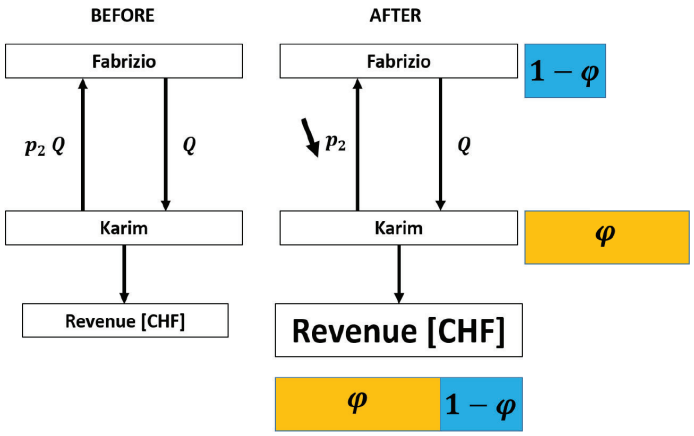
- c_w: marginal cost of producing one unit



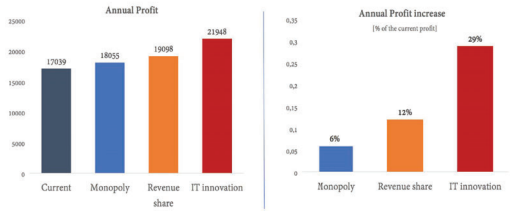


Source: Diab, A., Honsali, I., Rodriguez, J.R. (2017) "Panini on Campus: Future Improvements in a Competitive Environment," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

STUDENT PROJECT (Cont'd): PANINI @ EPFL



Conclusion ⇒ Improvements ⇒ Different strategies



Source: Diab, A., Honsali, I., Rodriguez, J.R. (2017) "Panini on Campus: Future Improvements in a Competitive Environment," MGT-528 Course Project, EPFL, Lausanne, Switzerland.

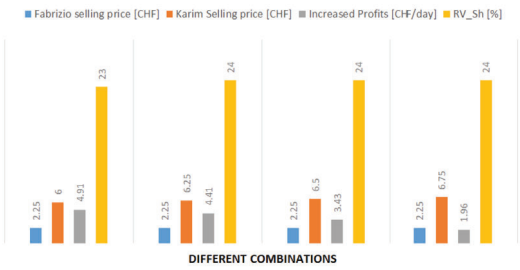


Figure 1: Profits for a fixed cost from Fabrizio of CHF 2.25

Figure 2: Profits for a fixed cost from Karim of CHF 6

AGENDA

Monopoly Pricing and Market Power

Supply-Chain Coordination and Coordination Failures

Double Marginalization and Coordination of a Two-Stage Supply Chain

Key Concepts to Remember

KEY CONCEPTS TO REMEMBER

- **Supply-chain coordination**
- **Causes for and effects of coordination failure**
- **Bullwhip effect**
- **Misperception of feedback**
- **Supply-chain coordination "initiatives"**
- **Market power**
- **Demand curve**
- **Inverse demand curve**
- **Price elasticity of demand**
- **Monopoly pricing rule**
- **Double marginalization**
- **Coordination via revenue-sharing**