ISOM 2700: Operations Management Session 7.3. Revenue Management: price based control

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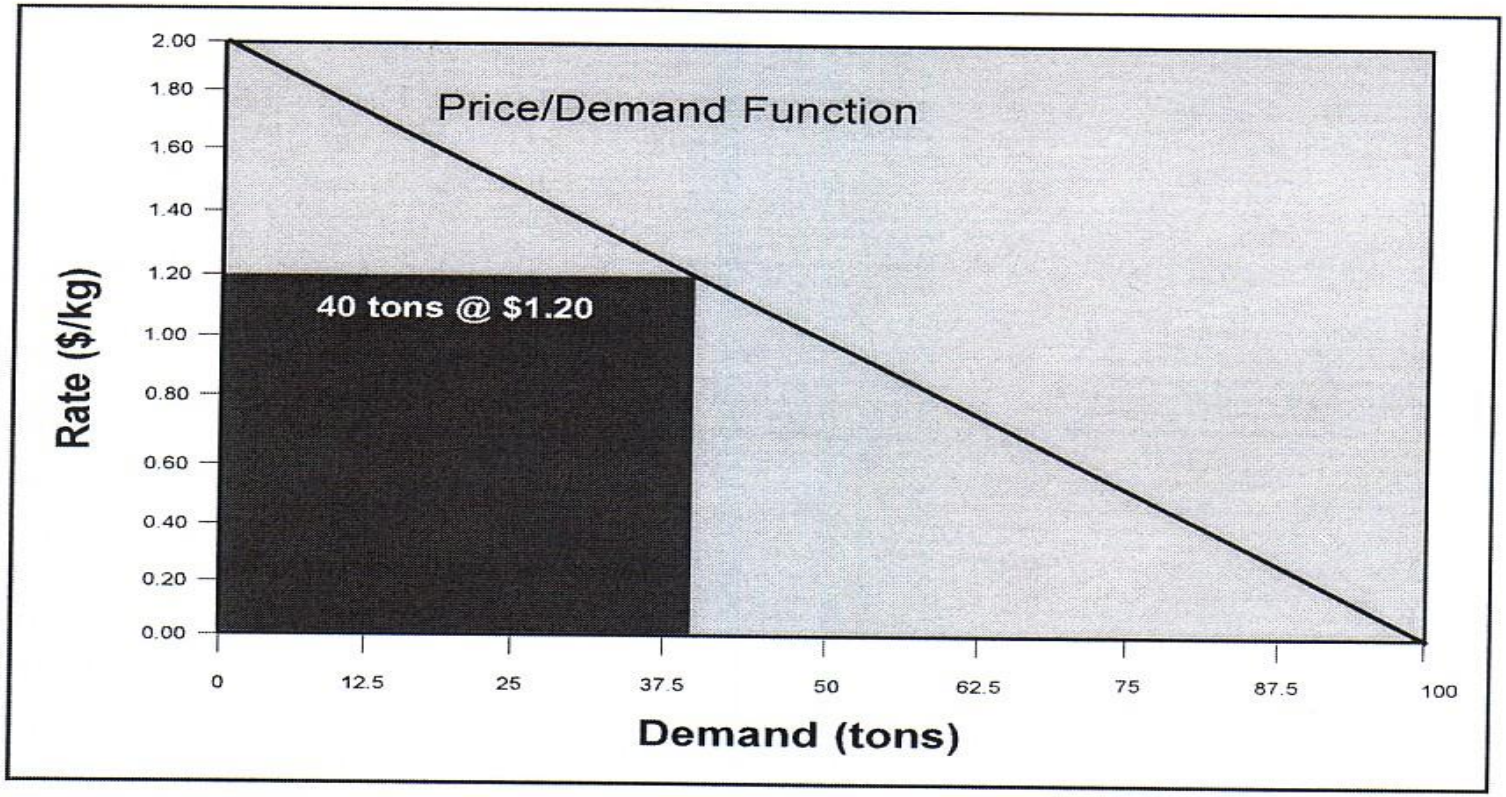
Recall from the beginning…

Suppose we have a capacity of 100 tons of oil, how should we sell it to maximize our profit?

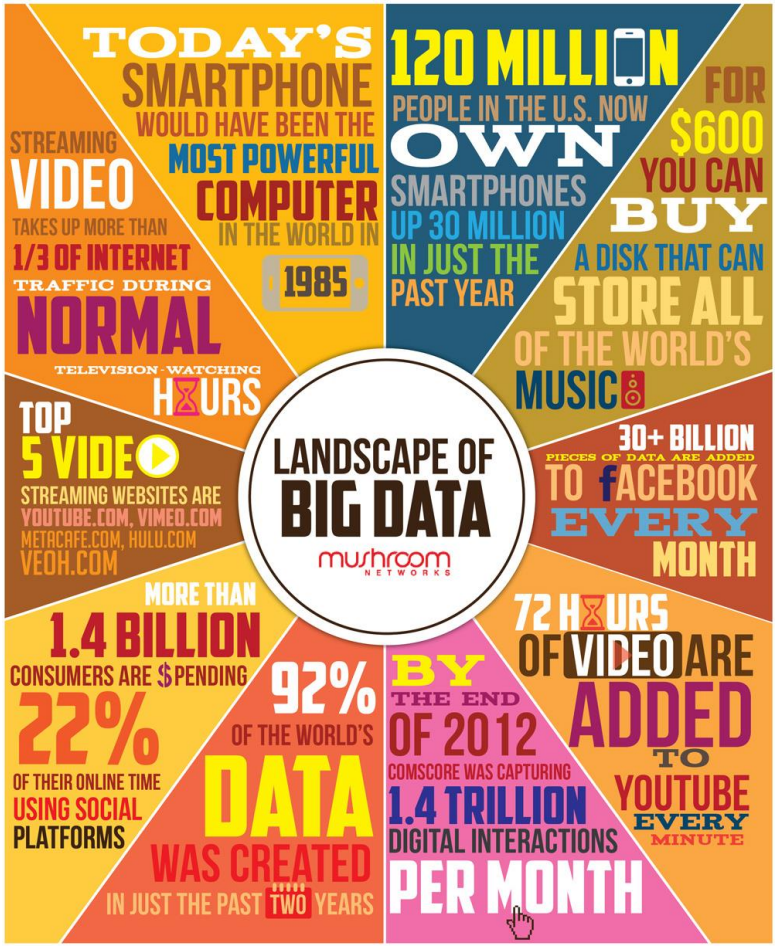
Figure 1 Revenue without price differentiation



Recall from the beginning: Coca-Cola's Failure in 1999

- A vending machine with temperature-scanning capability was introduced, charging variable price depending on the weather
- "Charge higher price for more thirsty customers"
- Result: Failure
  - Angry Coke drinkers denounced the idea
  - Pepsi gleefully accused its rival of exploiting customers
- Would this idea work in 2020?

Available Data is Exploding



- ….And Computing cost is plummeting
- Complete works of Shakespear: 5 megabytes
- One DVD: 17 gigabytes
- A terabyte hard drive now costs about HKD 400

Price Optimization is Everywhere

- Price optimization has become a common tactic in RM

airbnb

DELTA

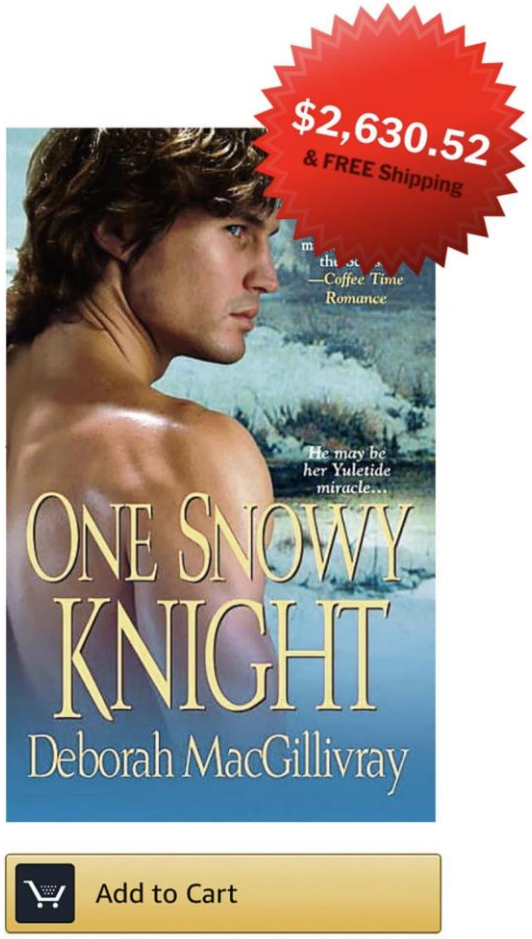
Uber

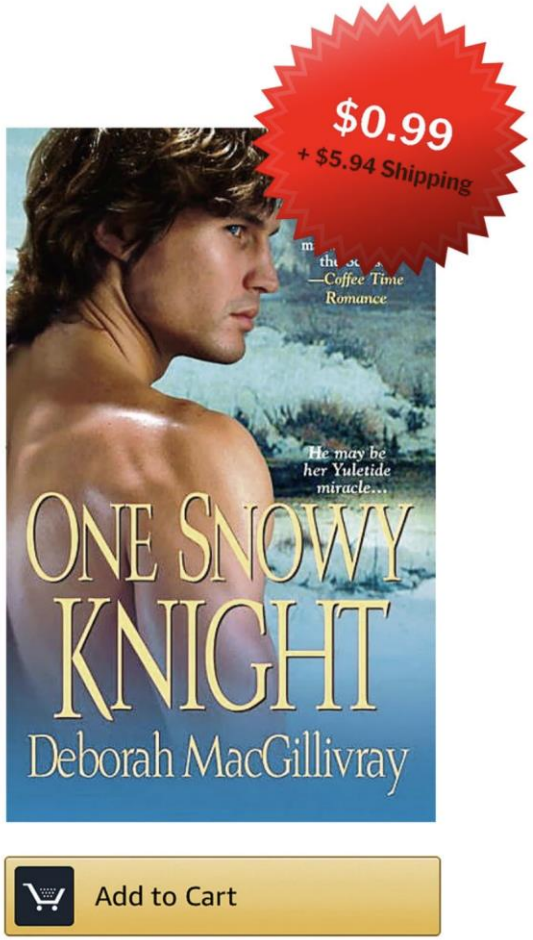
amazon

GAP

Google

A Horror Story on Amazon: $2,630.52 for Used Paperback





Linear Demand Model

- Suppose the demand (# of textbooks) is a linear function of price p

$$D(p) = a - bp$$

- The revenue at price p is given by

$$R(p) = p \times D(p) = p(a - bp)$$

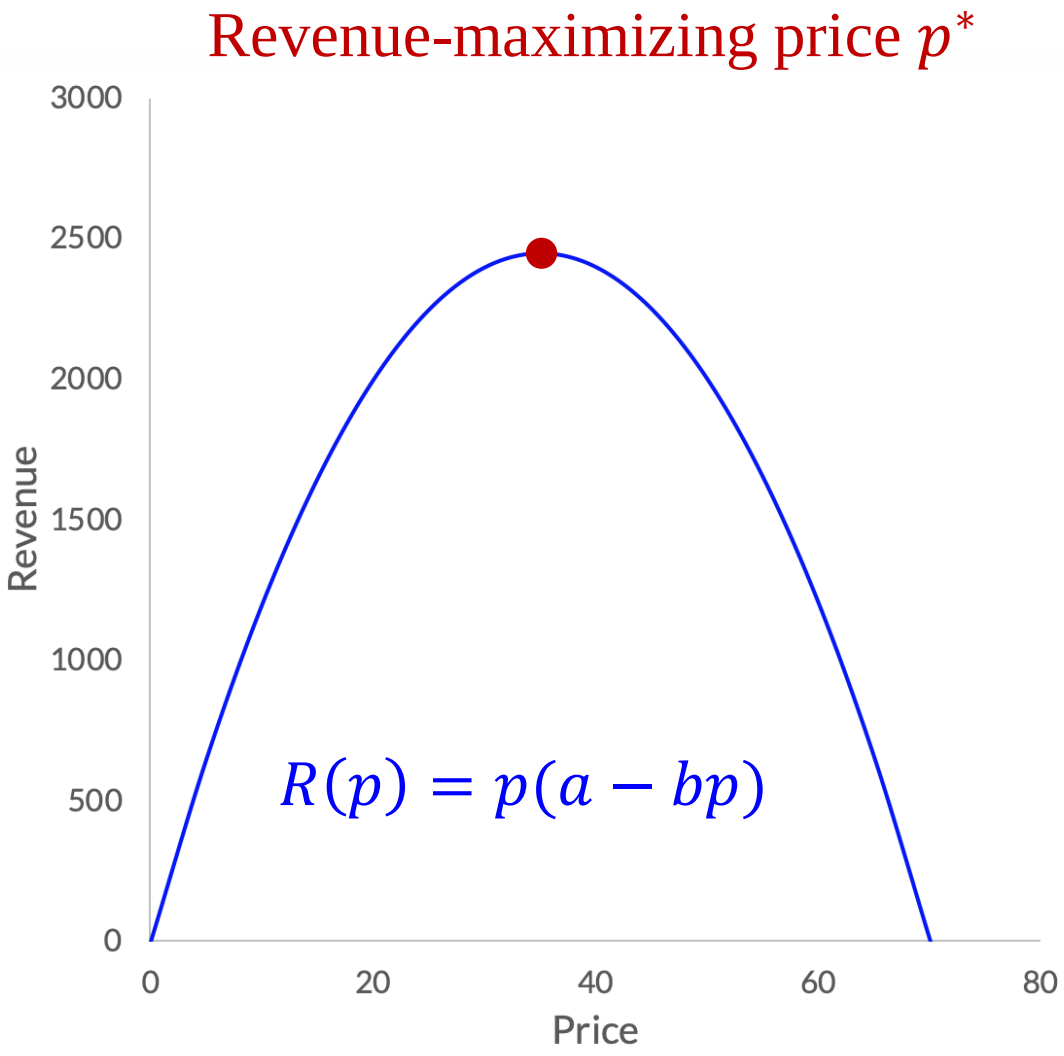
- The revenue-maximizing price p^* satisfies

$$\frac{dR(p^*)}{dp} = 0$$

or equivalently,

$$p^* = \frac{a}{2b}$$

Linear Demand Model

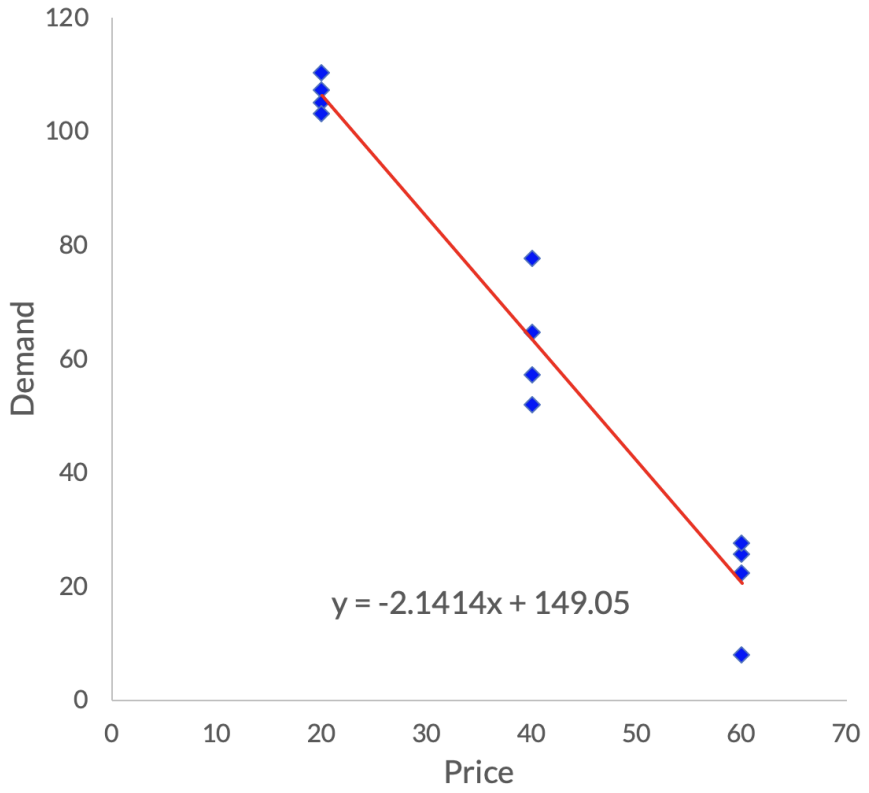


- Linear demand model leads to quadratic revenue curve
- Unique maximum
- Too good to be true?

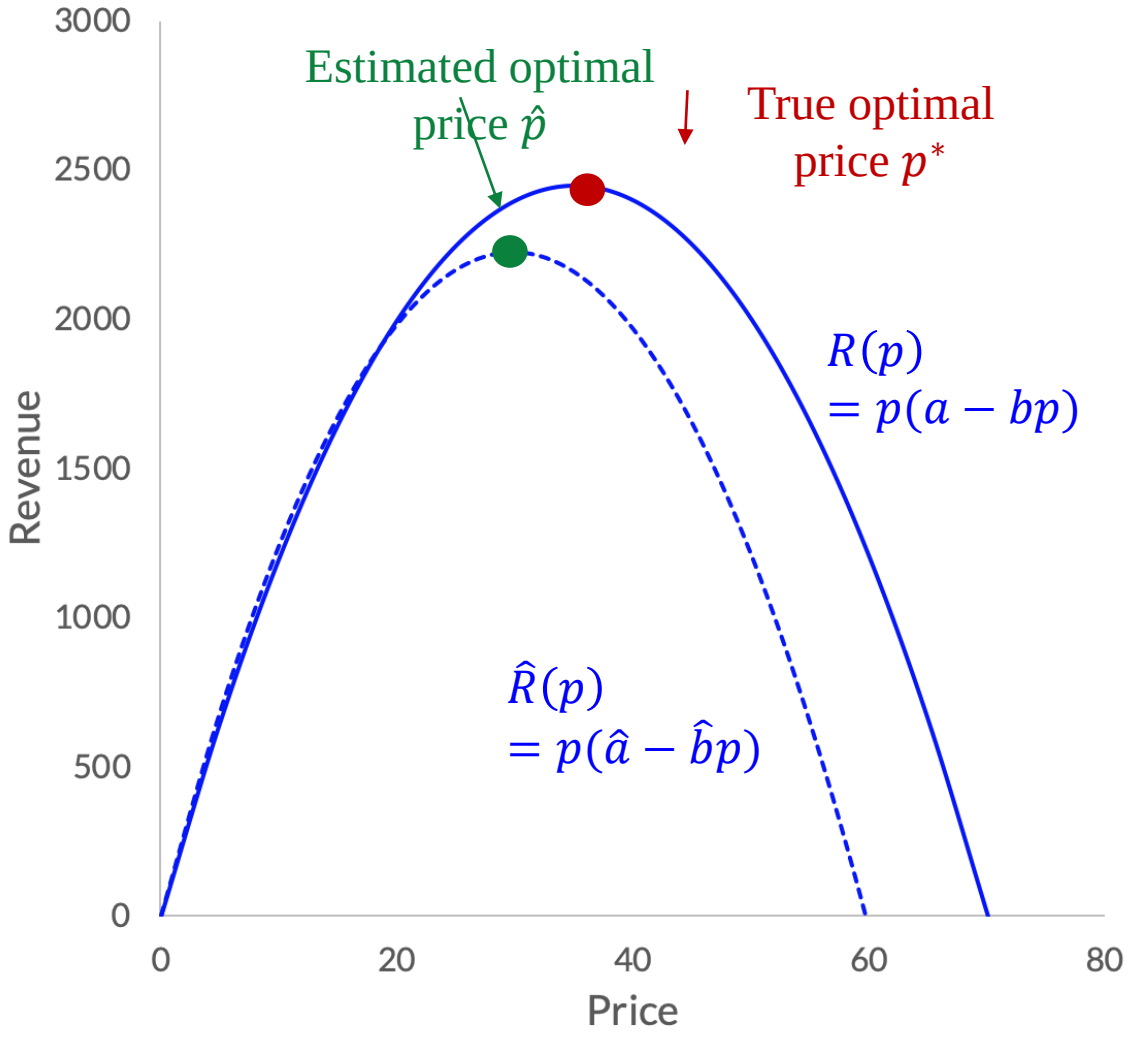
What If the Linear Model is Not Known?

- The coefficients a and b in the linear demand model are unknown

- Price experiments
  - Days 1-4: Charge $20
  - Days 5-8: Charge $40
  - Days 9-12: Charge $60
- Estimated parameters
  - $\hat{a} = 149.05$
  - $\hat{b} = 2.1414$
- True parameters
  - $a = 140$
  - $b = 2$

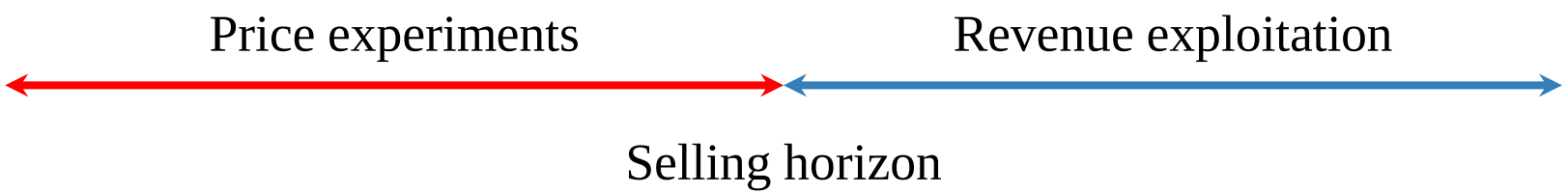


What if the Linear Model is Not Known



- In general, the more data, the better approximation to the true revenue function
- That is, estimated optimal price $\hat{p}$ approaches to the true optimal price p^* with more experimental data
- However…

What if the Linear Model is Not Known

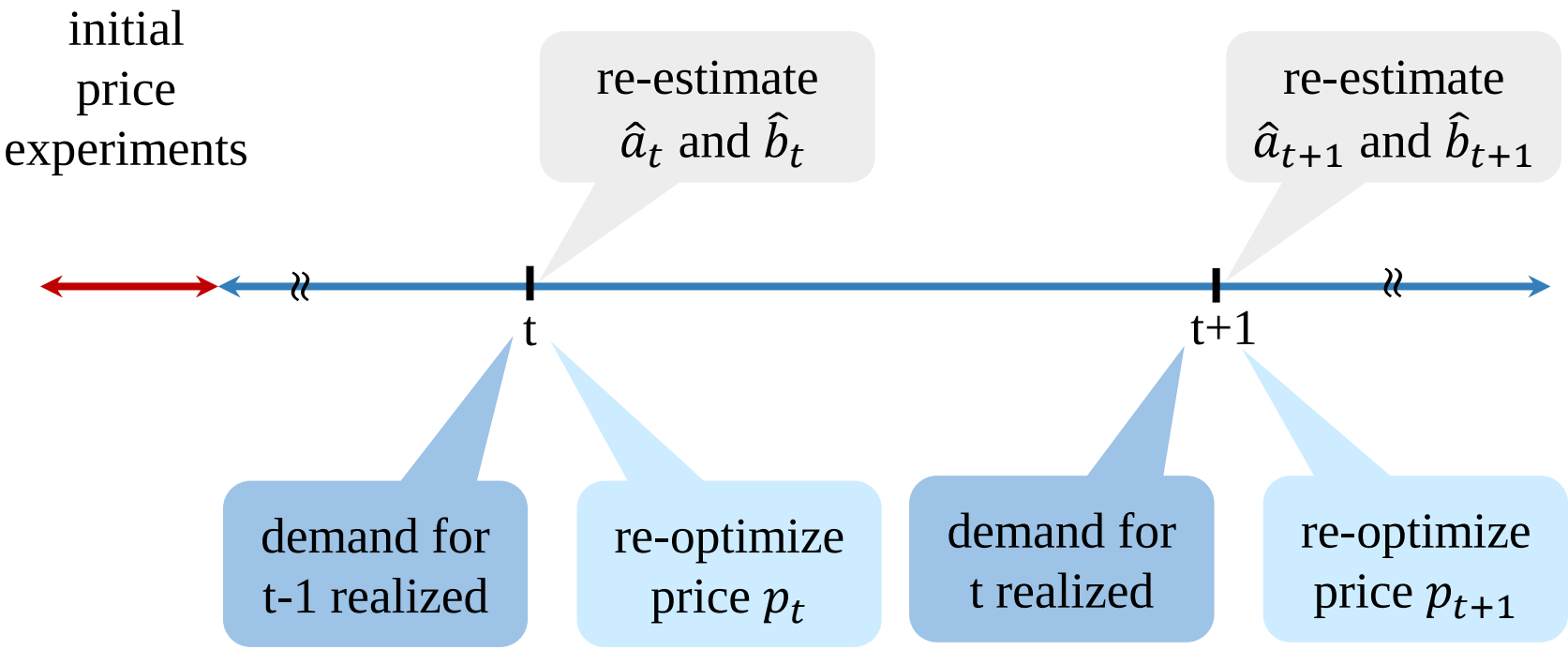


Tradeoff

- Too many price experiments may hurt revenue
- Too little price experiments may lead to an inaccurate estimation, eventually hurting revenue

- Current: Fix a price after price experiments
- Remedy: Adjust price dynamically by re-estimating the coefficients whenever new data arrives

Myopic Pricing Policy



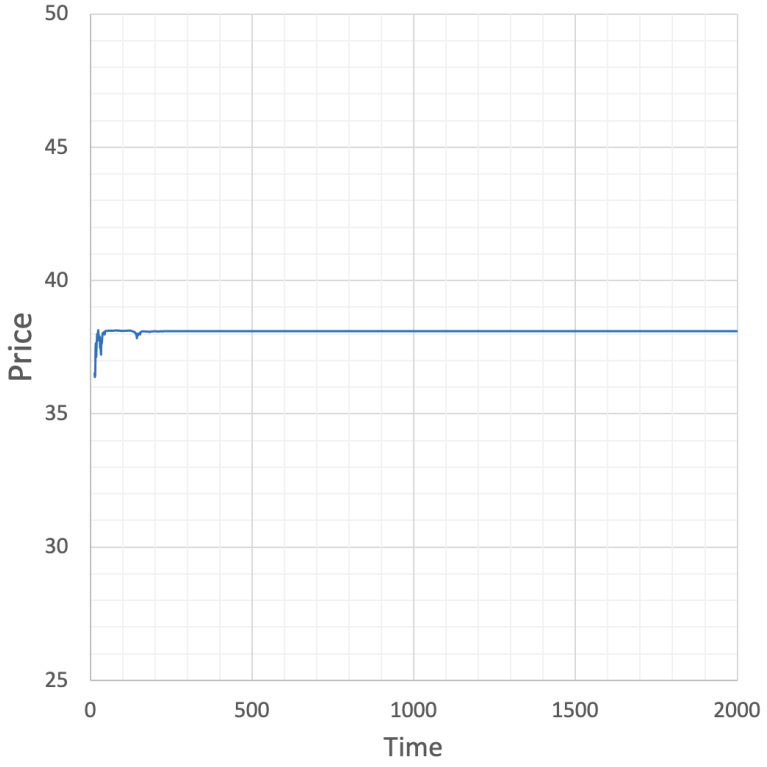
Performance of Myopic Pricing Policy

myopic_pricing.xlsx

- What is the optimal price if the true demand model is known?
- Does the price converge to the optimal price?
- If not, why so and how to fix it?

Performance of Myopic Pricing Policy

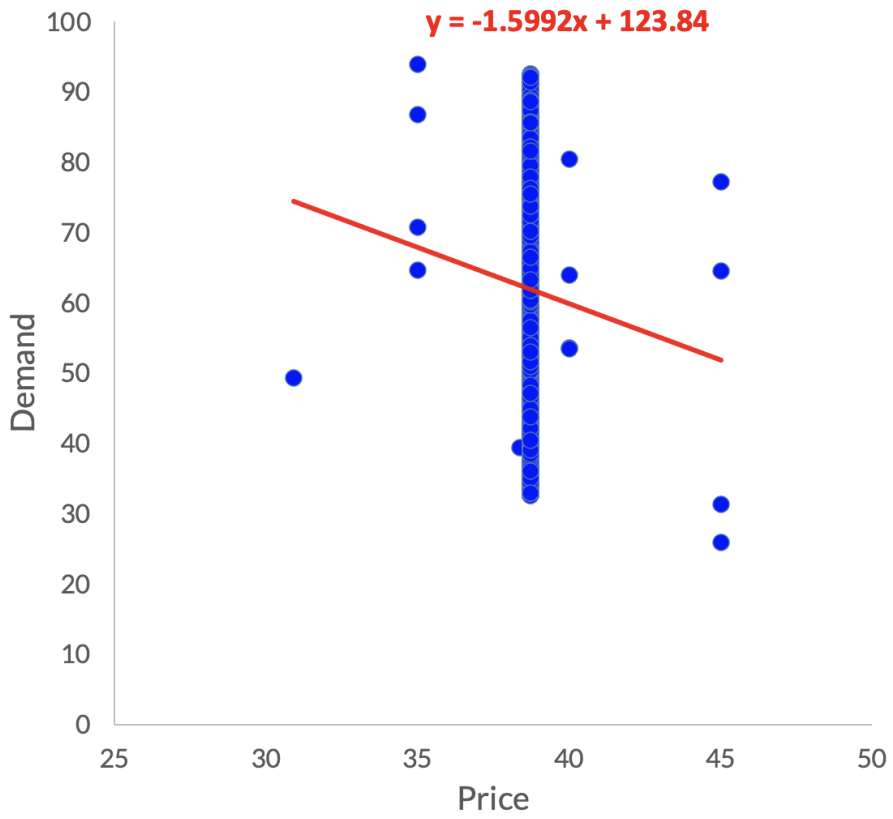
Optimal price = $35



- Price does not converge to $35, even if you continue learning over 2000 periods
- Learning stopped prematurely (incomplete learning)
- Remedy?

Semi-Myopic Pricing Policy

- The main culprit of incomplete learning



Not enough variation in price!

Semi-Myopic Pricing Policy

- If the estimated optimal price is too close to the average price, add a perturbation

$$\tilde{p}_t = \frac{\hat{a}_t}{2\hat{b}_t} \pm e_t$$

- Otherwise, just offer the estimated optimal price

$$p_t = \frac{\hat{a}_t}{2\hat{b}_t}$$

- In sum

$$p_t^* = \begin{cases} \dfrac{\hat{a}_t}{2\hat{b}_t} \pm e_t & if \left| \dfrac{\hat{a}_t}{2\hat{b}_t} - \bar{p}_t \right| < e_t \\ \dfrac{\hat{a}_t}{2\hat{b}_t} & otherwise \end{cases}$$

Semi-Myopic Pricing Policy

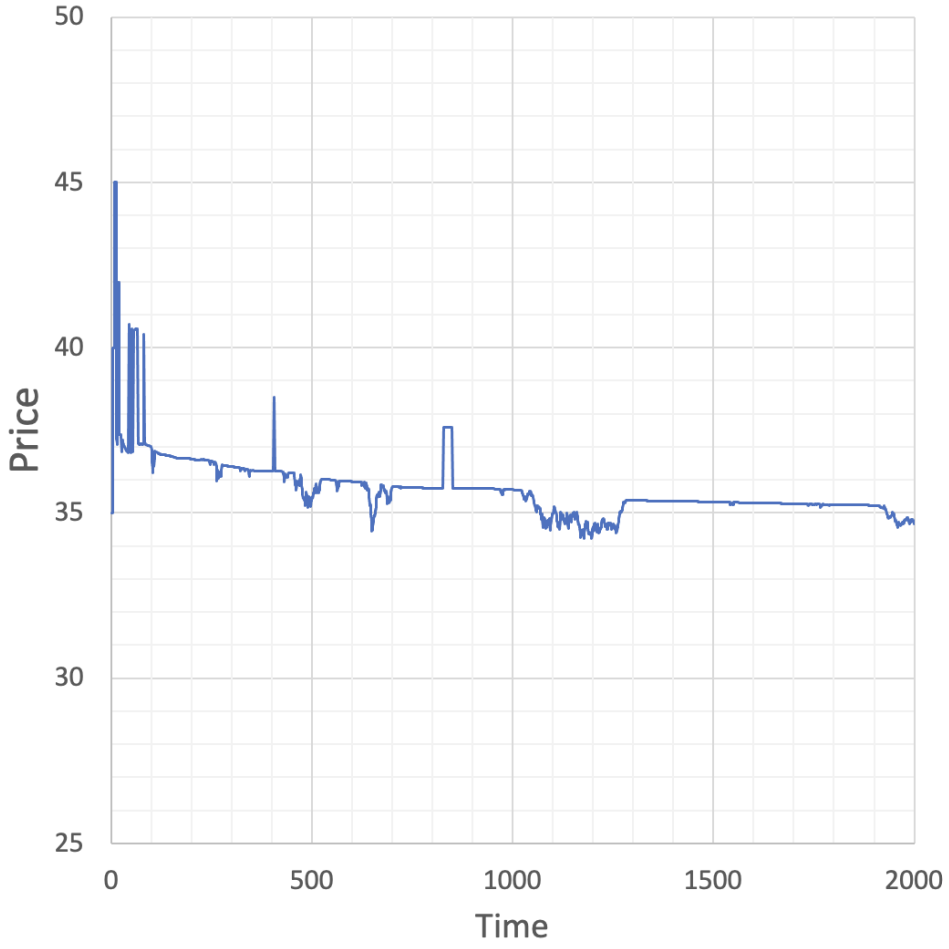
- The amount of perturbation, e_t, must be
  - Sufficiently large to ensure enough variation in price
  - Sufficiently small as time t increases to infinity…

- Example: $e_t = \frac{c}{t^{1/4}}$ for some constant $c > 0$

semi_myopic_pricing.xlsx

Performance of Semi-Myopic Pricing

Optimal price = $35



- Forced variation ensures that the estimated optimal price does not stuck at a wrong value!

Other related topics

- Other related topics
  - Markdown Pricing
  - Penetration Pricing
  - Bundle Pricing
  - Psychological Pricing

Markdown Pricing

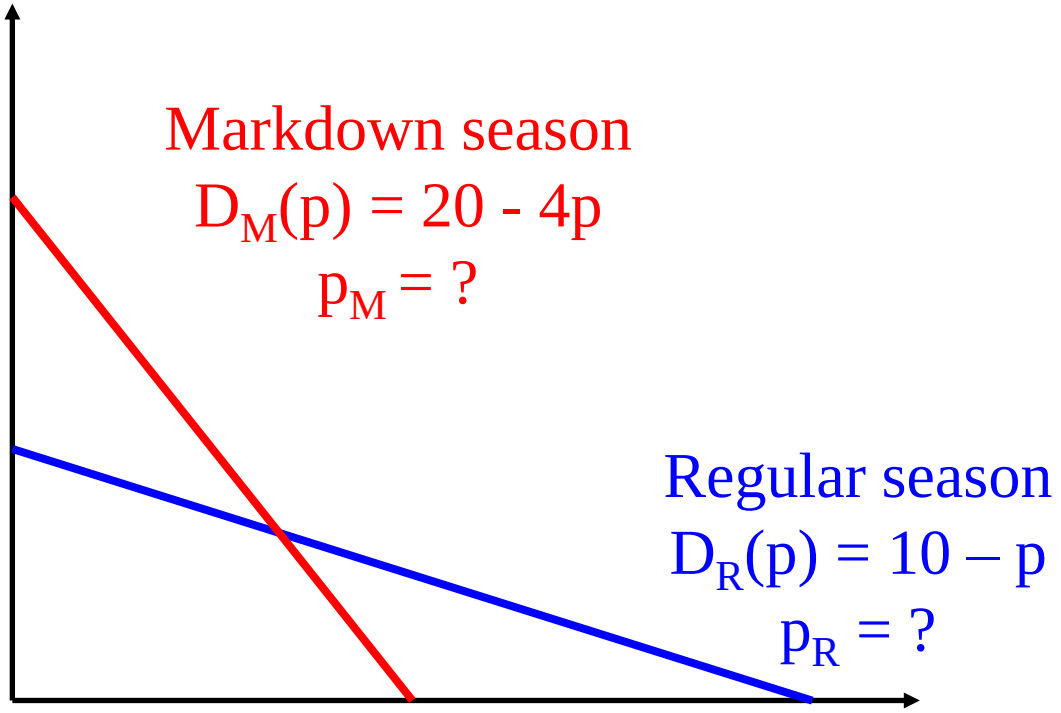
- Markdown is a permanent reduction in price whereas promotions are temporary

Reasons for Markdowns

- Fixed inventory (capacity) must be sold by a certain date
  - E.g., Halloween costumes, tickets for musicals
- Obsolescence
  - E.g., markdown before the arrival of the next generation of iPad
- Time of use
  - E.g., markdown for winter coats in February
- Deterioration
  - E.g., 1-day old bread/bakery sold at half price

Markdown Pricing

- Regular season vs. markdown season



- Cannibalization: What if customers wait for a cheaper product?

Penetration Pricing

- Penetration pricing is a pricing strategy where the price of a product is initially set low to rapidly reach a wide fraction of the market and initiate *Word of Mouth (WoM)*
  - Example on Amazon
  - Go to camelcamelcamel.com to see price history

- Advantages of penetration pricing
  - Fast diffusion and adoption
  - Create goodwill of early adopters
  - Discourages the entry of competitors
  - High inventory turnover

Bundle Pricing

- Two cable buyers, “sports lover” and “history lover”
- Willingness-to-pay for the two buyers

	ESPN	History channel
Sports lover	$10	$3
History lover	$3	$10

- A single channel costs $9
- Sports lovers would buy ESPN and history lovers would buy History channel; hence, total revenue = $9+$9=$18
- A bundle of the two channels costs $11.7; hence, total revenue = $11.7+$11.7=$23.4

Both buyers and sellers benefit from bundling

Psychological Pricing: Decoy Effect

- Customers have a preference between two options
- When a third option appears, customers tend to have a specific change in preference between two options
- *The Economist* magazine subscription
  - Option 1: Economist.com subscription at 490 HKD
  - Option 2: Print subscription at 990 HKD
  - Option 3: Both print and online subscriptions at 990 HKD

Video: Popcorn example

Psychological Pricing: The Magic Number 9

- Charm prices ($49, $79, $1.49 and so on) are reported to boost sales by an average of 24% relative to nearby prices

Home Basic	Home Premium	Business	Ultimate
Buy Now	Buy Now	Buy Now	Buy Now
Upgrade Now	Upgrade Now	Upgrade Now	Upgrade Now
$199.95	$259.95	$299.95	$319.95

Takeaways

- Willingness-to-pay determines whether a customer will purchase at a given price

- Understand pros and cons of pricing based on (linear) demand models