

Chapter 15: Pricing and the Revenue Management

Outline

- ◆ The Role of RM (Revenue Management) in the SCs
- ◆ RM for Multiple Customer Segments
- ◆ RM for Perishable Assets
- ◆ RM for Seasonable Demand
- ◆ RM for Bulk and Spot Customers
- ◆ Using RM in Practice
- ◆ Summary of Learning Objectives

The Role of RM in SCs

- ◆ Revenue management is the use of pricing to increase the profit generated from a limited supply of supply chain assets
 - SCs are about matching demand and capacity
 - Prices affect demands
- ◆ Yield management similar to RM but deals more with quantities rather than prices
- ◆ Supply assets exist in two forms
 - Capacity: expiring
 - Inventory: often preserved
- ◆ Revenue management may also be defined as offering different prices based on customer segment, time of use and product or capacity availability to increase supply chain profits
- ◆ Most common example is probably in airline ticket pricing
 - Pricing according to customer segmentation at any time
 - Pricing according to *reading days* for any customer segment
 - » *Reading days*: Number of days until departure

Conditions for RM to Work

- ◆ The value of the product varies in different market segments
 - Airline seats: Leisure vs. Business travel
 - Films: Movie theater goers, DVD buyers, Cheap movie theater goers, TV watchers.
- ◆ The product is highly perishable or product waste occurs
 - Fashion and seasonal apparel
 - High tech products
- ◆ Demand has seasonal and other peaks
 - Products ordered at Amazon.com, peaking in December
 - Supply Chain textbook orders peaking in August and January.
- ◆ The product is sold both in bulk and on the spot market
 - Owner of warehouse who can decide whether to lease the entire warehouse through long-term contracts or save a portion of the warehouse for use in the spot market
 - Truck capacities for a transportation company

RM for Multiple Customer Segments

- ◆ If a supplier serves multiple customer segments with a fixed asset, the supplier can improve revenues by setting different prices for each segment
 - Must figure out customer segments
- ◆ Prices must be set with *barriers* such that the segment willing to pay more is not able to pay the lower price
 - *Barriers*: Time, location, prestige, inconvenience, extra service
- ◆ In the case of time barrier,
 - The amount of the asset reserved for the higher price segment is such that quantities below are equal
 - » the expected marginal revenue from the higher priced segment
 - » the price of the lower price segment

Barrier: Extra service

What is the targeted demand?
What is the Revenue?
Could we do better?

Money left on the table = 160,000

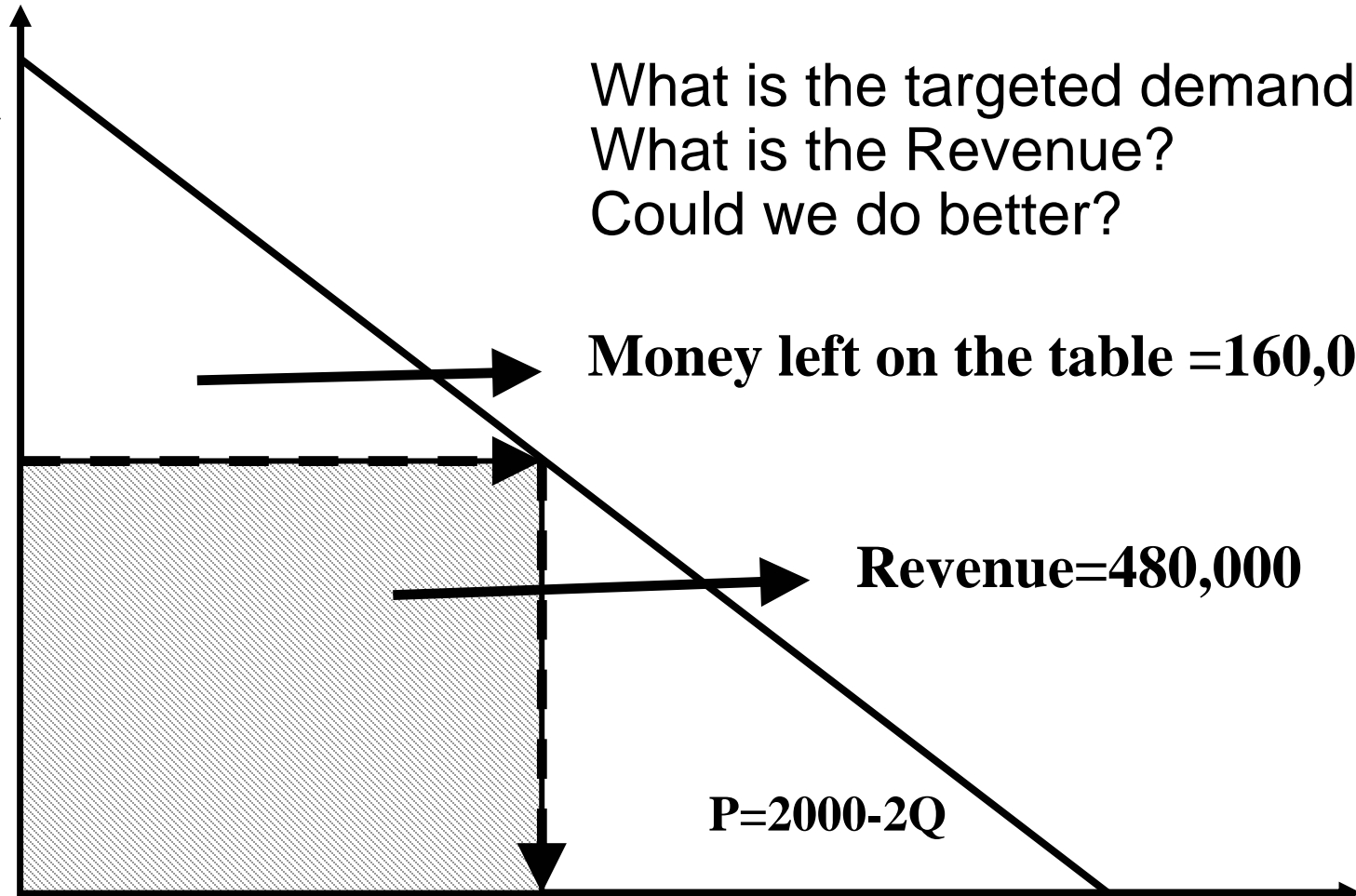
$P_0 = 1200$

Revenue = 480,000

$$P = 2000 - 2Q$$

$C = 400$

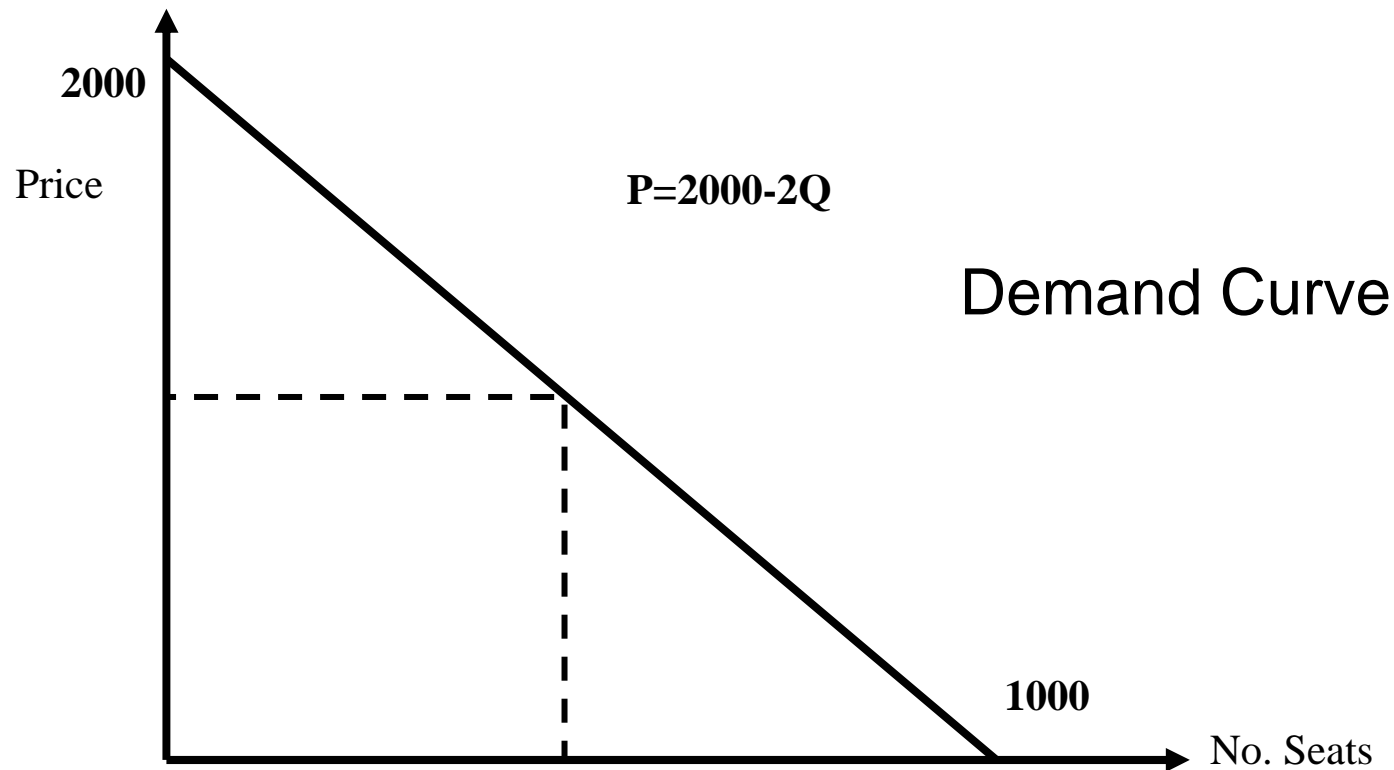
No. seats



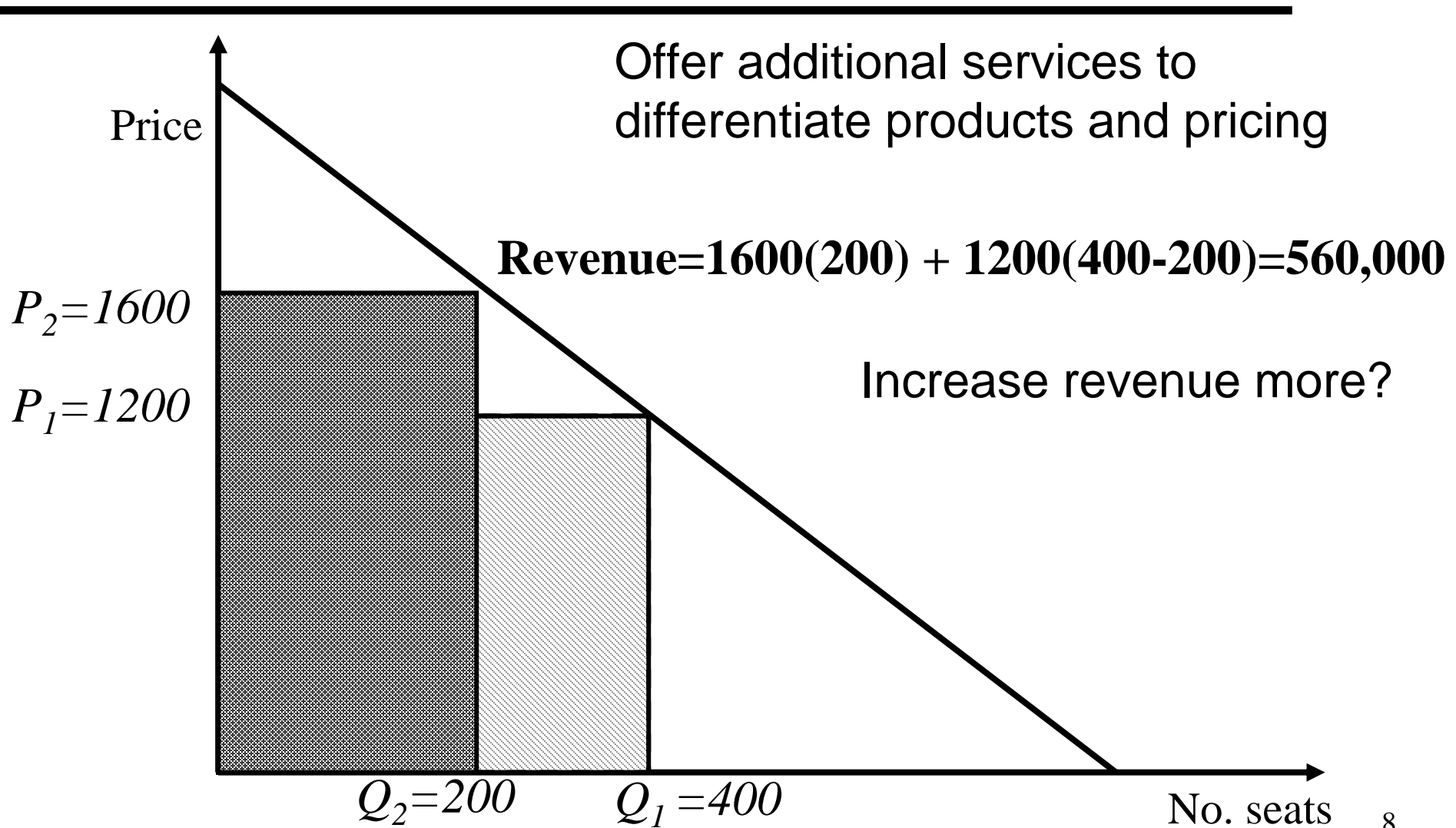
Customer Segmentation by extra service

Example: Cruise ship

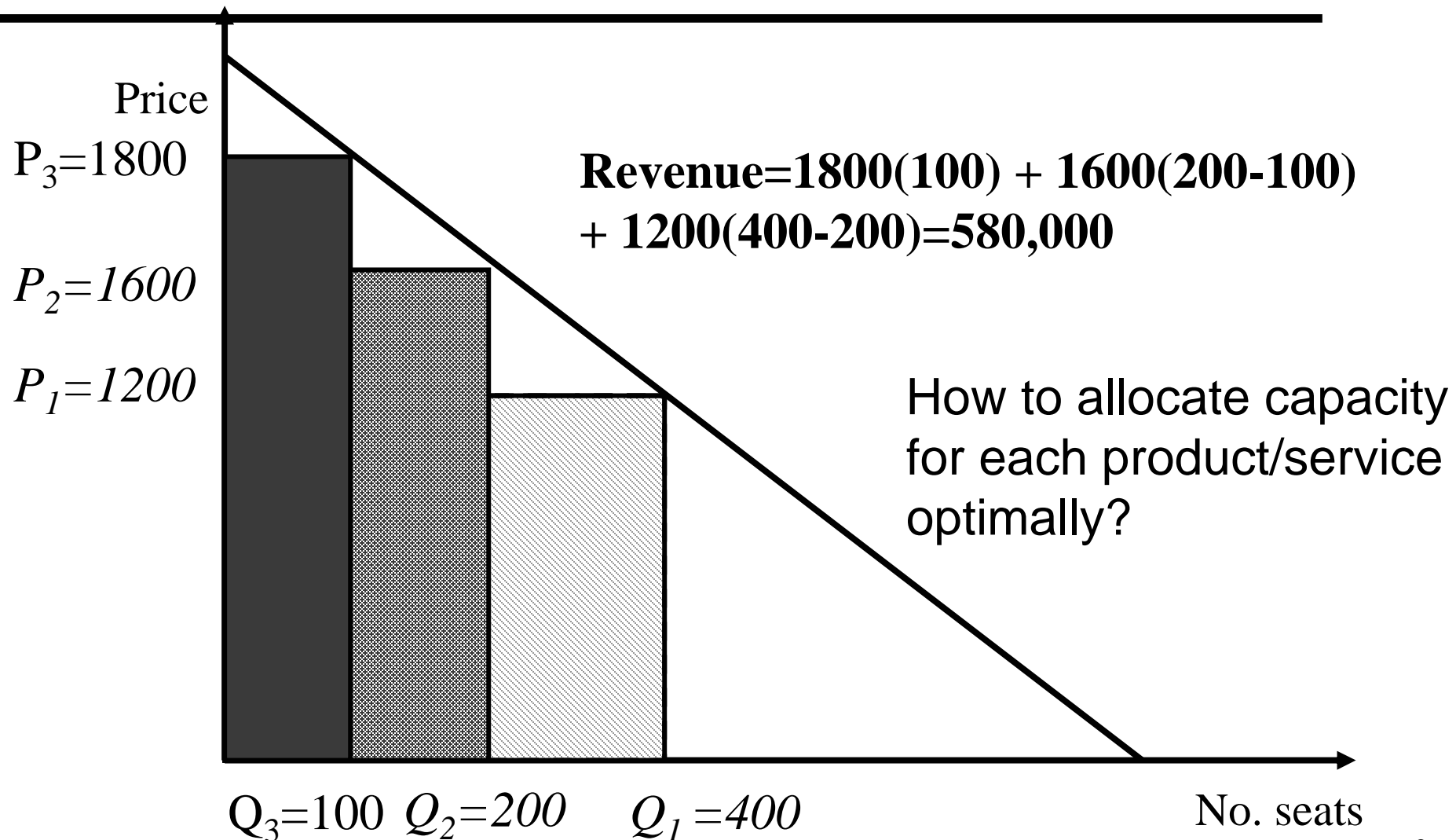
- ◆ A cruise ship with $C=400$ identical cabins
- ◆ What is the price to maximize revenue?



Example: Cruise ship



Example



Barrier: Time which implies Customer Segment RM for Multiple Customer Segments

p_L = the price charged to the lower price segment

p_H = the price charged to the higher price segment

D_H = mean demand for the higher price segment

σ_H = standard deviation of demand for the higher price segment

C_H = capacity reserved for the higher price segment

$R_H(C_H)$ = expected marginal revenue from reserving more capacity
= $\text{Prob}(\text{Demand from higher price segment} > C_H) \times p_H$

Optimality by equivalence of marginal revenues: $R_H(C_H) = p_L$

which leads to

$$\text{Prob}(\text{Demand from higher price segment} > C_H) = p_L / p_H$$

$$C_H = F^{-1}(1 - p_L/p_H, D_H, \sigma_H) = \text{Norminv}(1 - p_L/p_H, D_H, \sigma_H)$$

Example 15.1: ToFrom Trucking

Revenue from segment A = p_A = \$3.50 per cubic ft

Revenue from segment B = p_B = \$2.00 per cubic ft

Mean demand for segment A = D_A = 3,000 cubic ft

Std dev of segment A demand = σ_A = 1,000 cubic ft

$$\begin{aligned}C_A &= \text{Norminv}(1 - p_B/p_A, D_A, \sigma_A) \\ &= \text{Norminv}(1 - (2.00/3.50), 3000, 1000) \\ &= 2,820 \text{ cubic ft}\end{aligned}$$

If p_A increases to \$5.00 per cubic foot, then

$$\begin{aligned}C_A &= \text{Norminv}(1 - p_B/p_A, D_A, \sigma_A) \\ &= \text{Norminv}(1 - (2.00/5.00), 3000, 1000) \\ &= 3,253 \text{ cubic ft}\end{aligned}$$

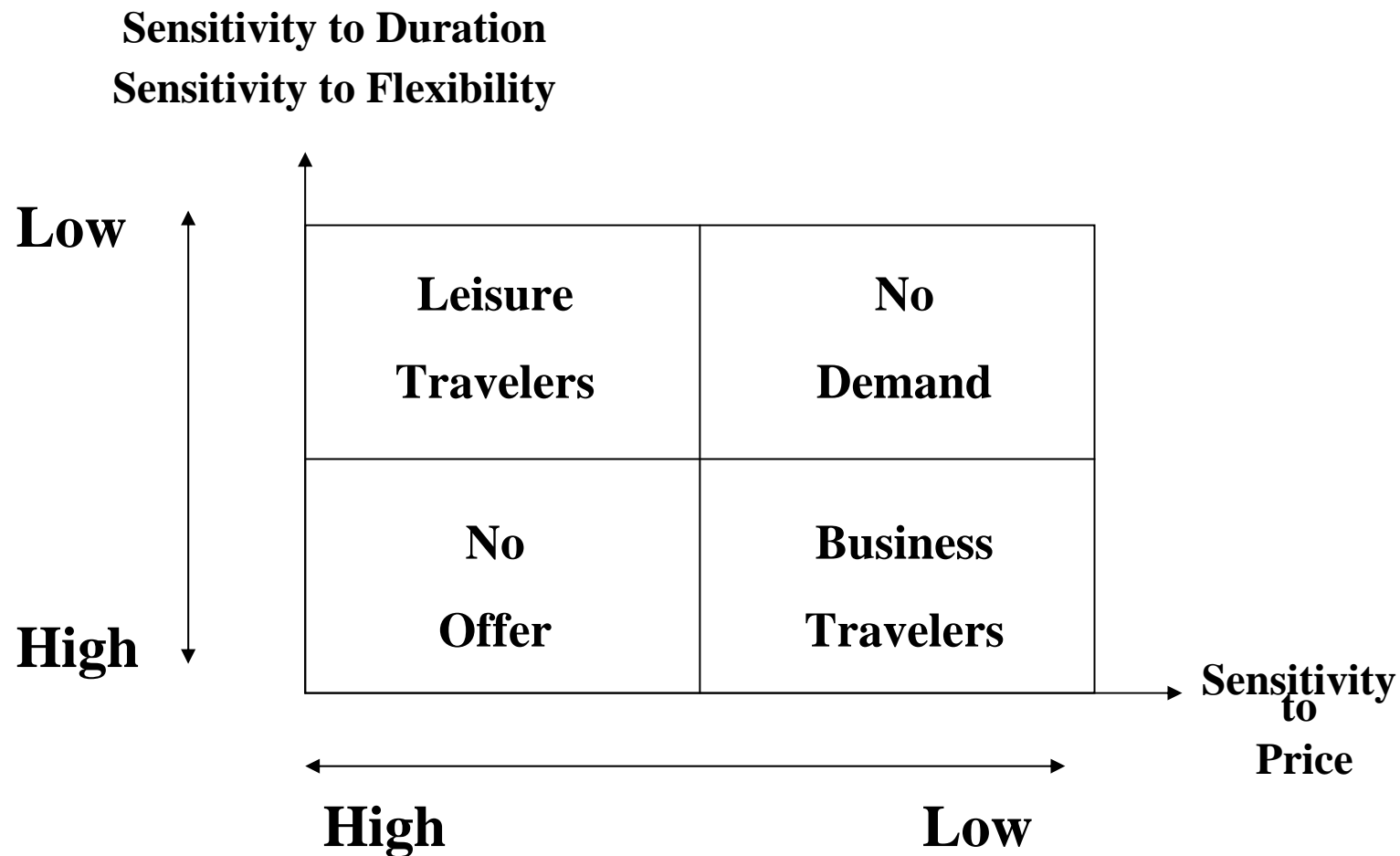
Two questions:

- ◆ What happens to the capacity reserved for the high paying segment, when the high paying segment starts paying about the low paying segment?
 - How much does the high paying segment value quick service?
- ◆ We never consider the distribution of the demand for low paying segment when computing the reserved capacity for the high paying segment. Can this be correct, why?

RM in the Service Industries

- ◆ Airline Industry uses RM the most.
- ◆ Evidence of airline revenue increases of 4 to 6 percent:
 - With effectively no increase in flight operating costs
- ◆ RM allows for tactical matching of demand vs. supply:
 - Booking limits can direct low-fare demand to empty flights
 - Protect seats for highest fare passengers on forecast full flights
- ◆ Hotel, Restaurant, Car rental, Overseas shipping, Cruise travel, Transportation capacity providers, Computation capacity providers (computer farms) and sometimes Health care industries show similarities to airline industry in using RM.

What are the barriers among customer segments in the airline industry?



A RM Model

- ◆ Expected Revenue = Expected Revenue from Business Class + Expected Revenue from Leisure Class
- ◆ Assume demand distribution for the business class is known and the demand for leisure class is $\geq C$

r_B = revenue/business passenger, r_L = revenue/leisure passenger, C = Airplane capacity

$$R(Q) = r_B \left[\int_0^Q xf(x)dx + Q \int_Q^\infty f(x)dx \right] + (C - Q)r_L$$

$$\frac{dR(Q)}{dQ} = r_B[1 - F(Q)] - r_L = 0$$

Marginal revenue of business class = Marginal revenue of leisure class

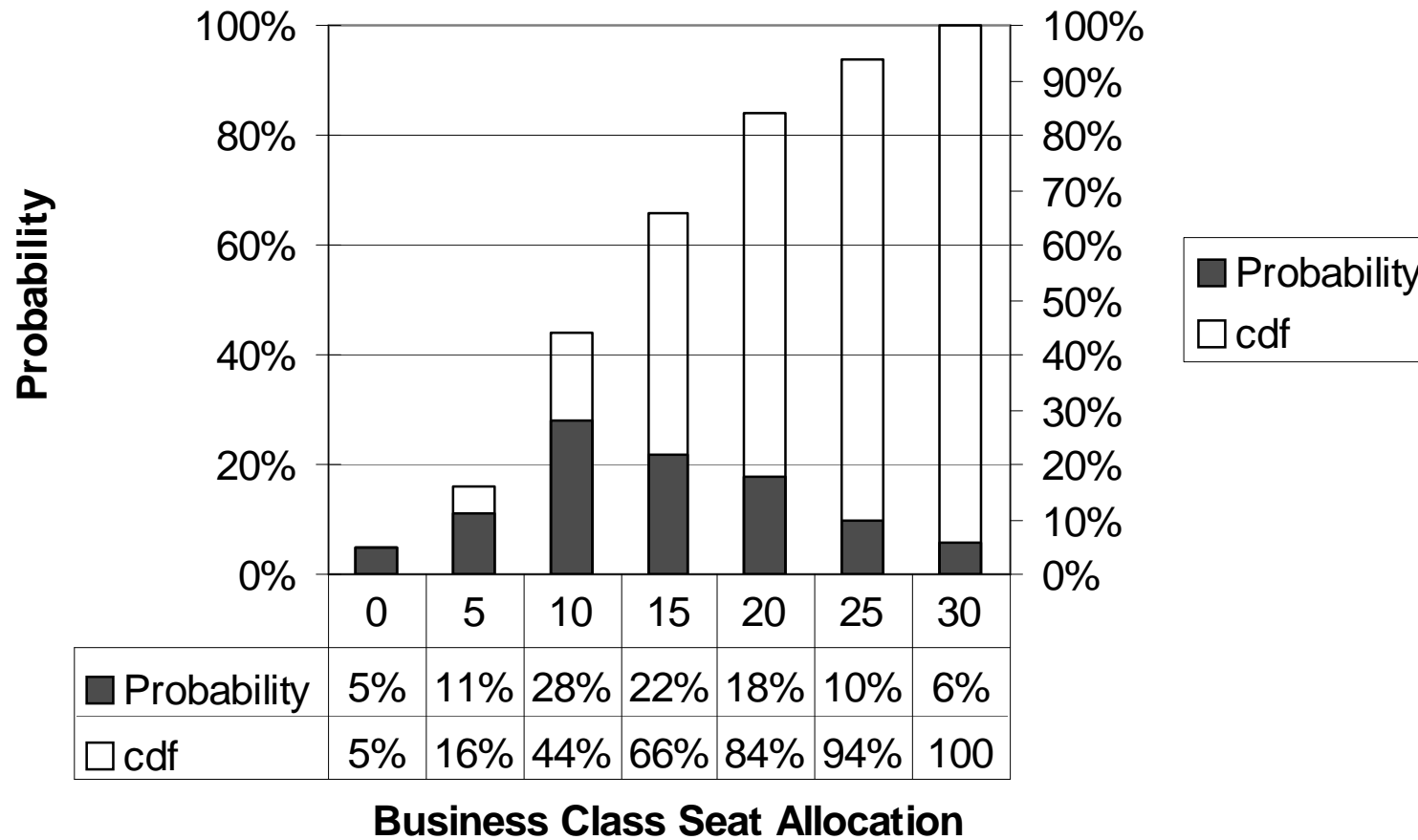
$$F(Q^*) = \frac{r_B - r_L}{r_B} \quad \longrightarrow \quad \text{SL: Service Level}$$

Example: Airline seat classes

- ◆ There are only two price classes
 - Leisure: (f2) \$100 per ticket
 - Business: (f1) \$250 per ticket
- ◆ Total available capacity= 80 seats
- ◆ Distribution of demand for business class is known
- ◆ Assume enough demand for the leisure class

- ◆ **How many seats to allocate to the business class to maximize expected revenue?**

Business Class Demand Distribution



Identifying Optimal Allocation

SL= 0.60

Note:

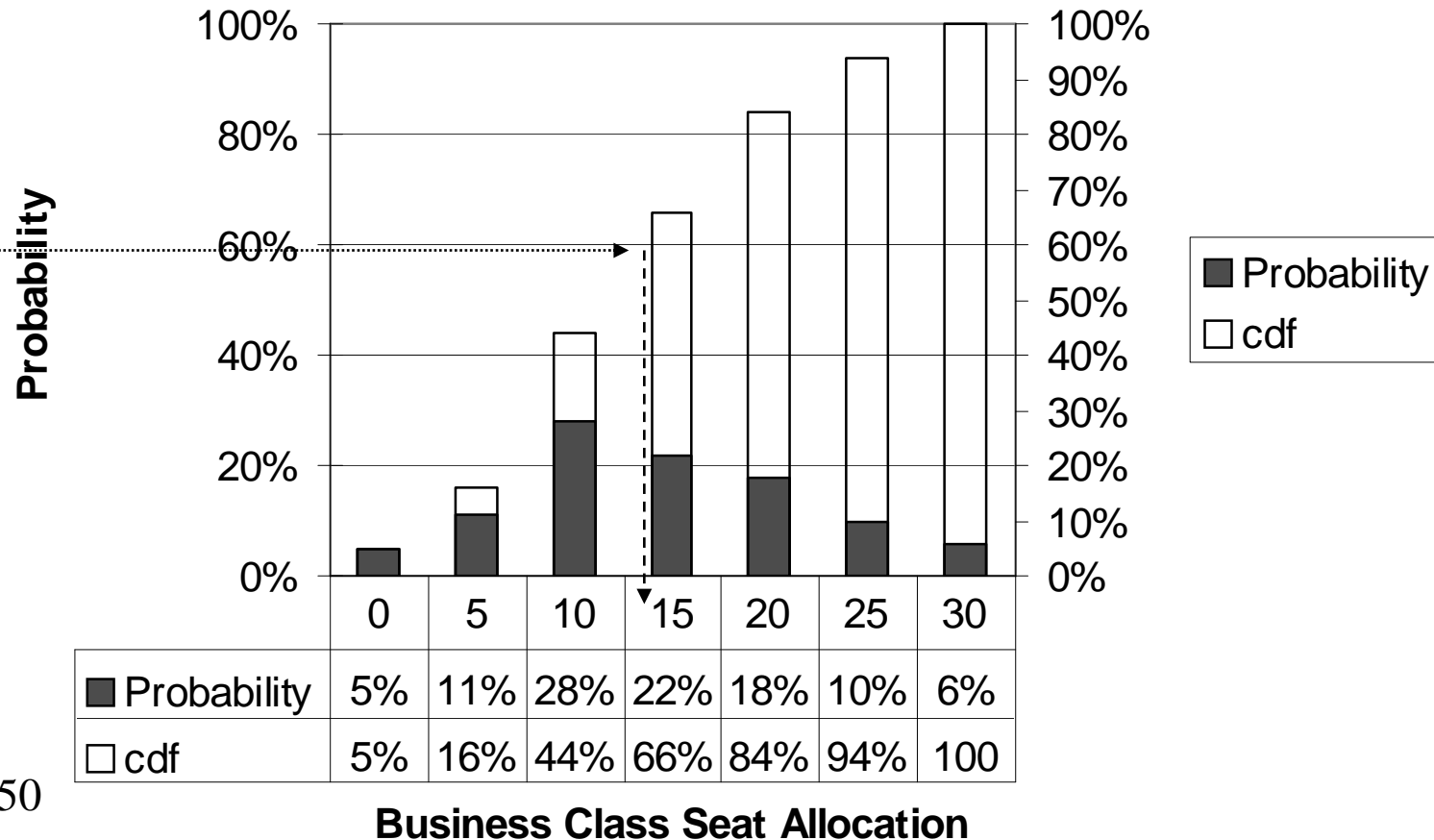
r_B : 250,

r_L : 100

$$SL = (r_B - r_L) / r_B$$

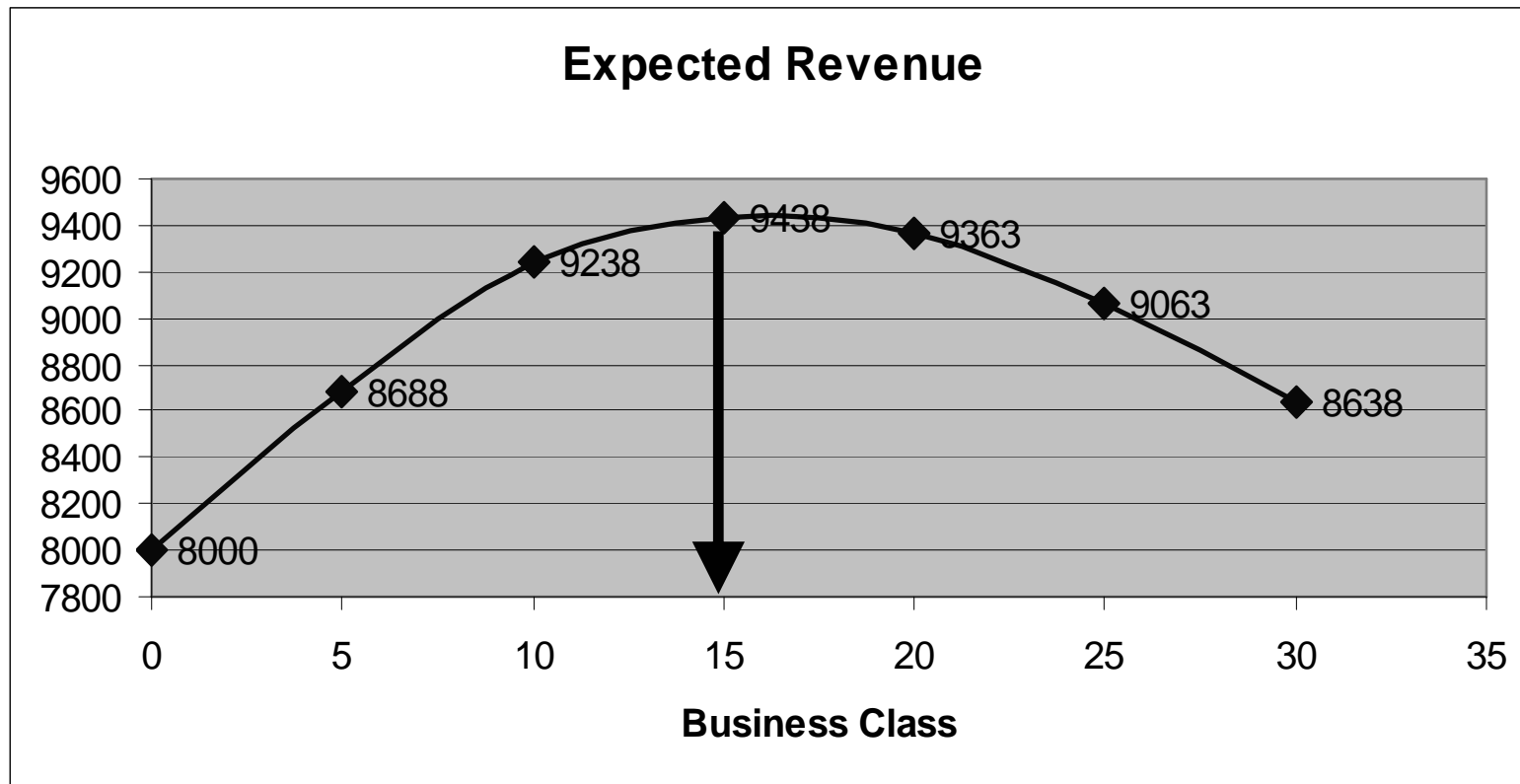
$$= (250 - 100) / 250$$

$$= 60\%$$



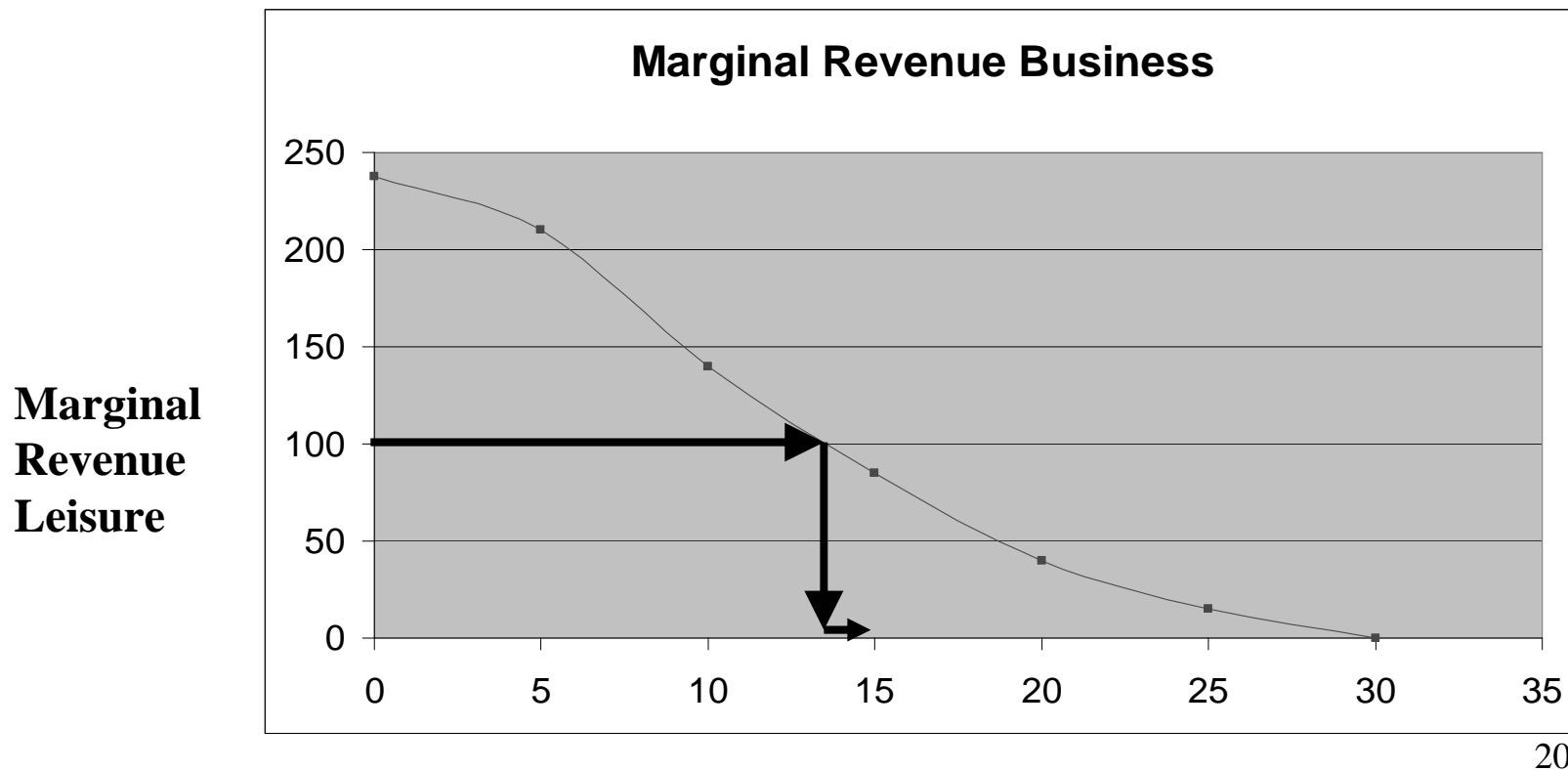
Optimal Allocation Quantity = 15

Expected Revenue



Optimality Condition

- ◆ **Optimality Condition:** Choose the number of seats for the business class such that marginal revenue from business class is the same as the marginal revenue from the leisure class.



RM for Perishable Assets

- ◆ Any asset that loses value over time is perishable
- ◆ Examples: high-tech products such as computers and cell phones, high fashion apparel, underutilized capacity, fruits and vegetables
- ◆ Two basic approaches:
 - Dynamic Pricing: Vary price over time to maximize expected revenue
 - Overbooking: Overbook sales of the asset to account for cancellations
 - » Airlines use the overbooking most
 - » Passengers are “offloaded” to other routes
 - » Offloaded passengers are given flight coupons
 - » This practice is legal
 - Dynamic pricing belongs to RM while overbooking can be said to more within the domain of Yield management.
 - » But concepts are more important than the names!

RM for Perishable Assets

- ◆ Overbooking or overselling of a supply chain asset is valuable if order cancellations occur and the asset is perishable
- ◆ The level of overbooking is based on the trade-off between the cost of wasting the asset if too many cancellations lead to unused assets (*spoilage*) and the cost of arranging a backup (*offload*) if too few cancellations lead to committed orders being larger than the available capacity
- ◆ Spoilage and offload are actually terms used in the airline industry

RM for Perishable Assets

p = price at which each unit of the asset is sold

c = cost of using or producing each unit of the asset

b = cost per unit at which a backup can be used in the case of shortage

$C_w = p - c$ = marginal cost of wasted capacity = Overage cost

$C_s = b - c$ = marginal cost of a capacity shortage = Underage cost

O^* = optimal overbooking level

$$\mathbf{P(\text{Demand} < \text{Capacity})} = C_u / (C_u + C_o)$$

$$\mathbf{P(\text{Demand} \geq \text{Capacity})} = C_o / (C_u + C_o)$$

$$\mathbf{P(\text{Order cancellations} \leq O^*)} = C_o / (C_u + C_o)$$

$$\mathbf{s^* := \text{Probability}(\text{order cancellations} \leq O^*)} = C_w / (C_w + C_s)$$

Beware: This is the newsvendor formula in disguise.

RM for Perishable Assets

If the distribution of cancellations is known to be normal with mean μ_c and standard deviation σ_c then

$$O^* = F^{-1}(s^*, \mu_c, \sigma_c) = \text{Norminv}(s^*, \mu_c, \sigma_c)$$

If the distribution of cancellations is known only as a function of the booking level (capacity L + overbooking O) to have a mean of $\mu(L+O)$ and std deviation of $\sigma(L+O)$, the optimal overbooking level is the solution to the following equation:

$$\begin{aligned} O^* &= F^{-1}(s^*, \mu(L+O), \sigma(L+O)) \\ &= \text{Norminv}(s^*, \mu(L+O), \sigma(L+O)) \end{aligned}$$

Example 15.2

Cost of wasted capacity = $C_w = \$10$ per dress

Cost of capacity shortage = $C_s = \$5$ per dress

$$s^* = C_w / (C_w + C_s) = 10 / (10 + 5) = 0.667$$

$$\mu_c = 800; \sigma_c = 400$$

$$\begin{aligned} O^* &= \text{Norminv}(s^*, \mu_c, \sigma_c) \\ &= \text{Norminv}(0.667, 800, 400) = 973 \end{aligned}$$

If the mean is 15% of the booking level and the coefficient of variation is 0.5, then the optimal overbooking level is the solution of the following equation:

$$O^* = \text{Norminv}(0.667, 0.15(5000 + O^*), 0.075(5000 + O^*))$$

Using Excel Solver, $O^* = 1,115$

RM for Seasonal Demand

- ◆ Seasonal peaks of demand are common in many SCs\
 - Most retailers achieve a large portion of total annual demand in December
 - » Amazon.com
- ◆ Off-peak discounting can shift demand from peak to non-peak periods
- ◆ Charge higher price during peak periods and a lower price during off-peak periods
- ◆ Read Section 9.3: Managing Demand [with discounts] of the textbook.

RM for Bulk and Spot Customers

- ◆ Most consumers of production, warehousing, and transportation assets in a supply chain face the problem of constructing a portfolio of long-term bulk contracts and short-term spot market contracts
 - Long-term contracts for low cost
 - Short-term contracts for flexibility
- ◆ The basic decision is the size of the bulk contract
- ◆ The fundamental trade-off is between wasting a portion of the low-cost bulk contract and paying more for the asset on the spot market

RM for Bulk and Spot Customers

For the simple case where the spot market price is known but demand is uncertain, a formula can be used

c_B = bulk rate

c_S = spot market price

Q^* = optimal amount of the asset to be purchased in bulk

p^* = probability that the demand for the asset does not exceed Q^*

Marginal cost of purchasing another unit in bulk is c_B .

The expected marginal cost of not purchasing another unit in bulk and then purchasing it in the spot market is $(1-p^*)c_S$.

Revenue Management for Bulk and Spot Customers

If the optimal amount of the asset is purchased in bulk, the marginal cost of the bulk purchase should equal the expected marginal cost of the spot market purchase, or $c_B = (1-p^*)c_S$

Solving for p^* yields $p^* = (c_S - c_B) / c_S$

If demand is normal with mean μ and std deviation σ , the optimal amount Q^* to be purchased in bulk is

$$Q^* = F^{-1}(p^*, \mu, \sigma) = \text{Norminv}(p^*, \mu, \sigma)$$

Example 15.3: Buying transportation capacity to bring goods from China

Bulk contract cost = c_B = \$10,000 per million units

Spot market cost = c_S = \$12,500 per million units

Demand for transportation: μ = 10 million units

σ = 4 million units

$$p^* = (c_S - c_B) / c_S = (12,500 - 10,000) / 12,500 = 0.2$$

$$Q^* = \text{Norminv}(p^*, \mu, \sigma) = \text{Norminv}(0.2, 10, 4) = 6.63$$

The manufacturer should sign a long-term bulk contract for 6.63 million units per month and purchase any transportation capacity beyond that on the spot market

If the demand is exactly 10 million units without any variability, how much long-term bulk contract with the transporter?

Using RM in Practice

- ◆ Evaluate your market carefully
 - Understand customer requirements for services and products
 - Price, flexibility (time, specs), value-added services, etc.
 - Based on requirements identify customer segments (groups)
 - Differentiate products/services and their pricing according to customer segments
 - » Dell:
 - » Same product is sold at a different price to different consumers (private/small or large business/government/academia/health care)
 - » Price of the same product for the same industry varies

Using RM in Practice

- ◆ Quantify the benefits of revenue management
- ◆ Implement a forecasting process
- ◆ Apply optimization to obtain the revenue management decision
- ◆ Involve both sales and operations
- ◆ Understand and inform the customer
- ◆ Integrate supply planning with revenue management

Summary of Learning Objectives

- ◆ What is the role of revenue management in a supply chain?
- ◆ Under what conditions are revenue management tactics effective?
- ◆ What are the trade-offs that must be considered when making revenue management decisions?

Smart Pricing Through Rebates

Rebate Examples

- ◆ Nikon Coolpix digital camera is sold either on-line or in stores for \$600. the manufacturer provides a rebate of \$100 independently of where the camera is purchased.
- ◆ Sharp VL-WD255U digital camcorder is sold for about \$500 at retail or virtual stores. Sharp provides a rebate to the customer of \$100 independently of where the product is purchased.

Nikon

Coolpix® Digital Camera Rebate

\$100⁰⁰ • Coolpix 995

How To Receive Your Nikon Rebate

1. Purchase and take delivery of a new Nikon Coolpix 995 Digital Camera from October 1, 2001 through December 31, 2001.
2. Complete the application below, attach all required proofs-of-purchase for each eligible product and mail to Nikon.
3. Subject to you fulfilling all terms of this offer, Nikon Inc. will mail you a rebate check within 4-6 weeks.

Please read complete Terms of Offer on reverse side.

Product	Product #	Rebate
Coolpix 995	25047	\$ 100.00

Complete this section, enclose proofs-of-purchase & mail to:
Nikon Coolpix Rebate • P.O. Box 6602 • Melville, New York 11775-6602

Dealer Purchased From:

Name _____

Address _____

City _____ State _____ Zip _____

List Eligible Products Purchased:

Qty.	Serial #	Rebate
		\$
		\$
		\$
		\$
TOTAL REBATE CLAIMED		\$

Your Information:

Name _____

Address _____

City _____ State _____ Zip _____

E-mail _____

Signature _____ Date of Purchase _____

Please indicate any Nikon camera(s) you own:
 F5 _____ F100 _____ N90(s) _____ Coolpix _____ N65 _____ N70 _____ N80 _____ Other _____

YOU MUST ENCLOSE FOR EACH ELIGIBLE PRODUCT:
 1. Copy of your bill-of-sale 2. UPC code label from side panel of box 3. Serial number label with bar code from side panel of box

No Time Like
the Present!

Save
\$100

when you purchase a Sharp VL-WD650U,
VL-WD450U or VL-WD255U Digital Viewcam
October 1, 2001–January 5, 2002. Mail-in Rebate.

Request must be postmarked by February 2, 2002.



VL-WD255U



VL-WD450U



VL-WD650U

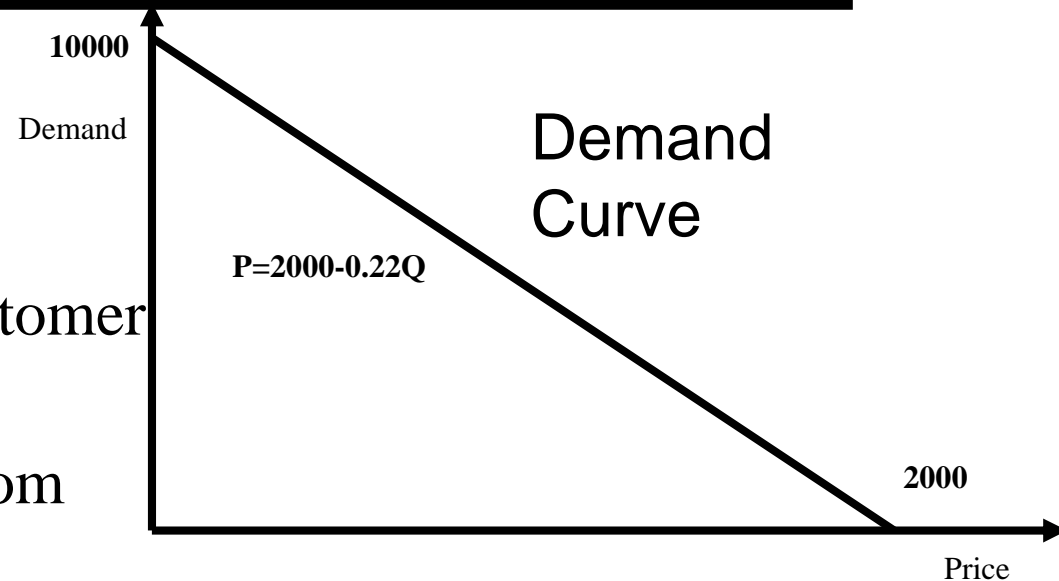
SHARP.

Mail-in-Rebate

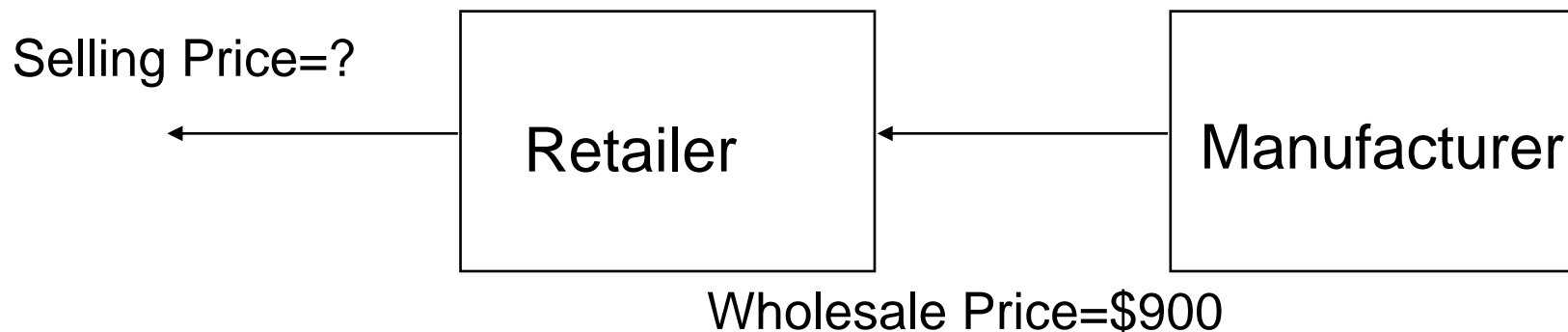
- ◆ What is the manufacturer trying to achieve with the rebate?
 - Why the manufacturer and not the retailer?
- ◆ Should the manufacturer reduce the wholesale price instead of the rebate?
- ◆ Are there other strategies that can be used to achieve the same effect?

Example

- ◆ A Retailer and a manufacturer.
 - Retailer faces customer demand.
 - Retailer orders from manufacturer.



Variable Production Cost=\$200



Example

◆ Retailer profit = $(P_R - P_M)(1/0.22)(2,000 - P_R)$

◆ Manufacturer profit = $(P_M - CM)(1/0.22)(2,000 - P_R)$

◆ Retailer takes $P_M = \$900$

– Sets $P_R = \$1450$ to maximize $(P_R - 900)(1/0.22)(2,000 - P_R)$

– $Q = (1/0.22)(2,000 - 1,450) = 2,500$ units

– Retailer Profit = $(1,450 - 900) \cdot 2,500 = \$1,375,000$

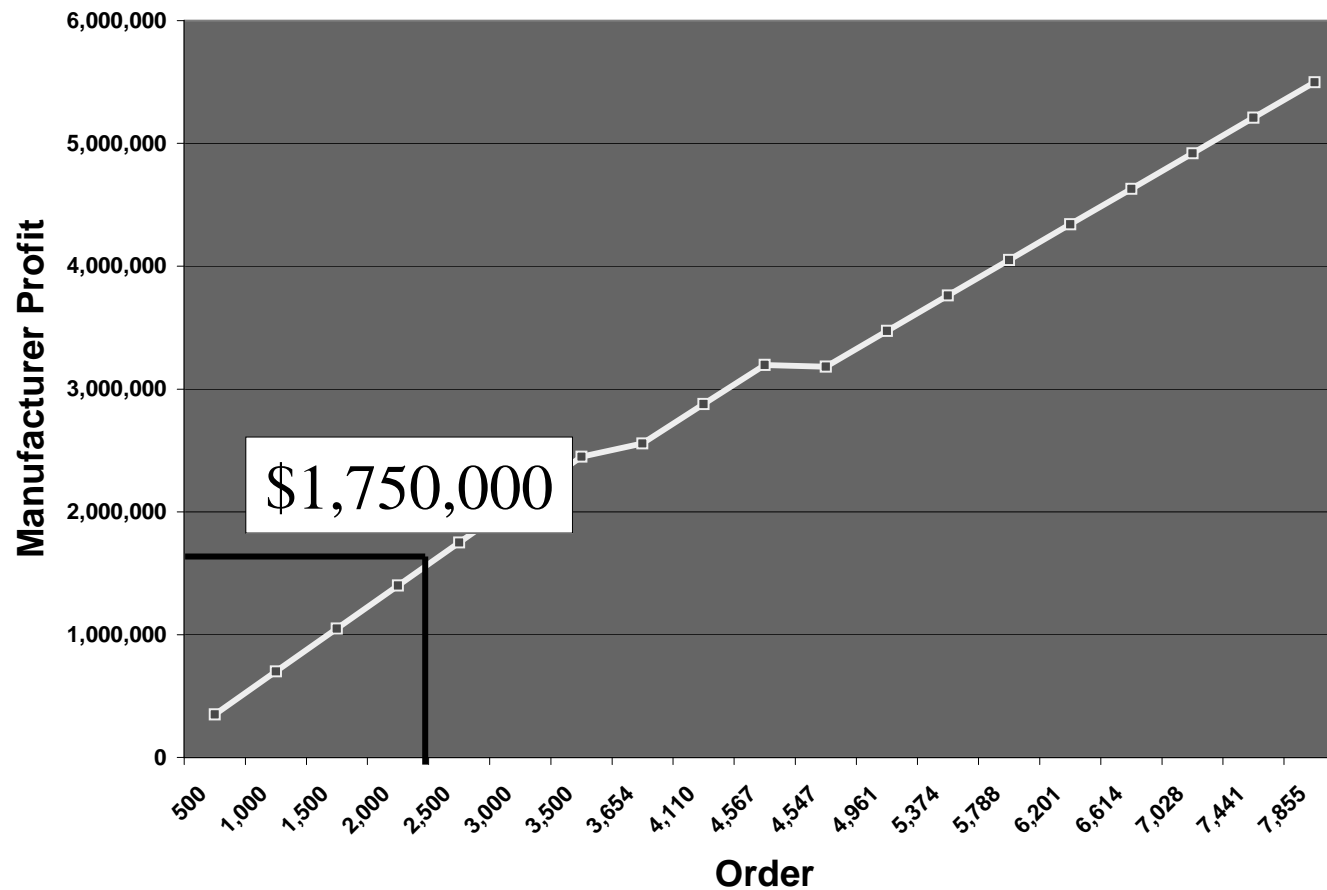
◆ Manufacturer takes $CM = \text{variable cost}$

– Manufacturer profit = $(900 - 200) \cdot 2,500 = \$1,750,000$

Retailer Expected Profit (No Rebate)



Manufacturer Profit (No Rebate)



Example: Customer Mail-in Rebate

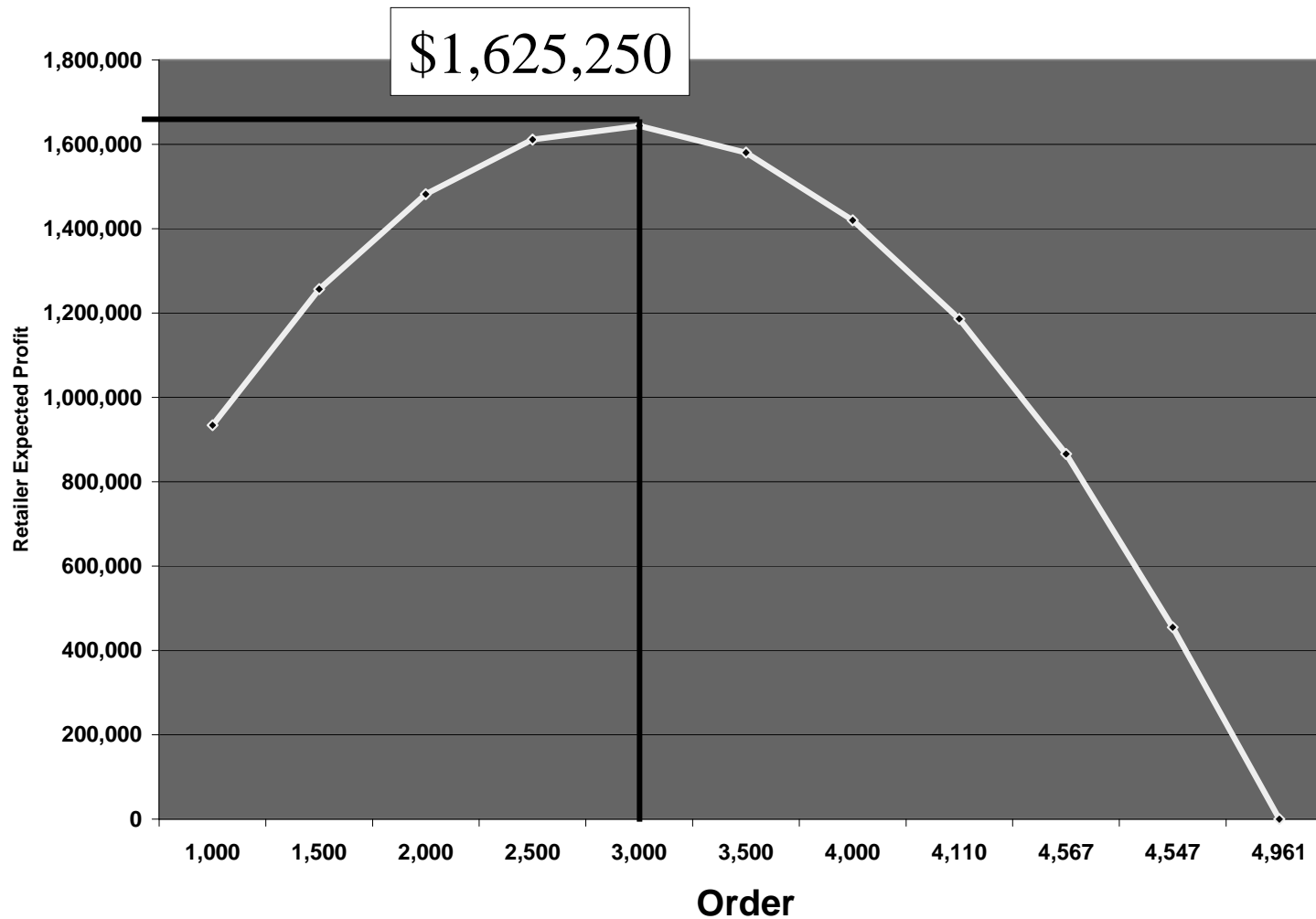
◆ What happens with \$100 customer mail-in rebate?

- Note that it is a discount for the customer so the demand should go up!!!

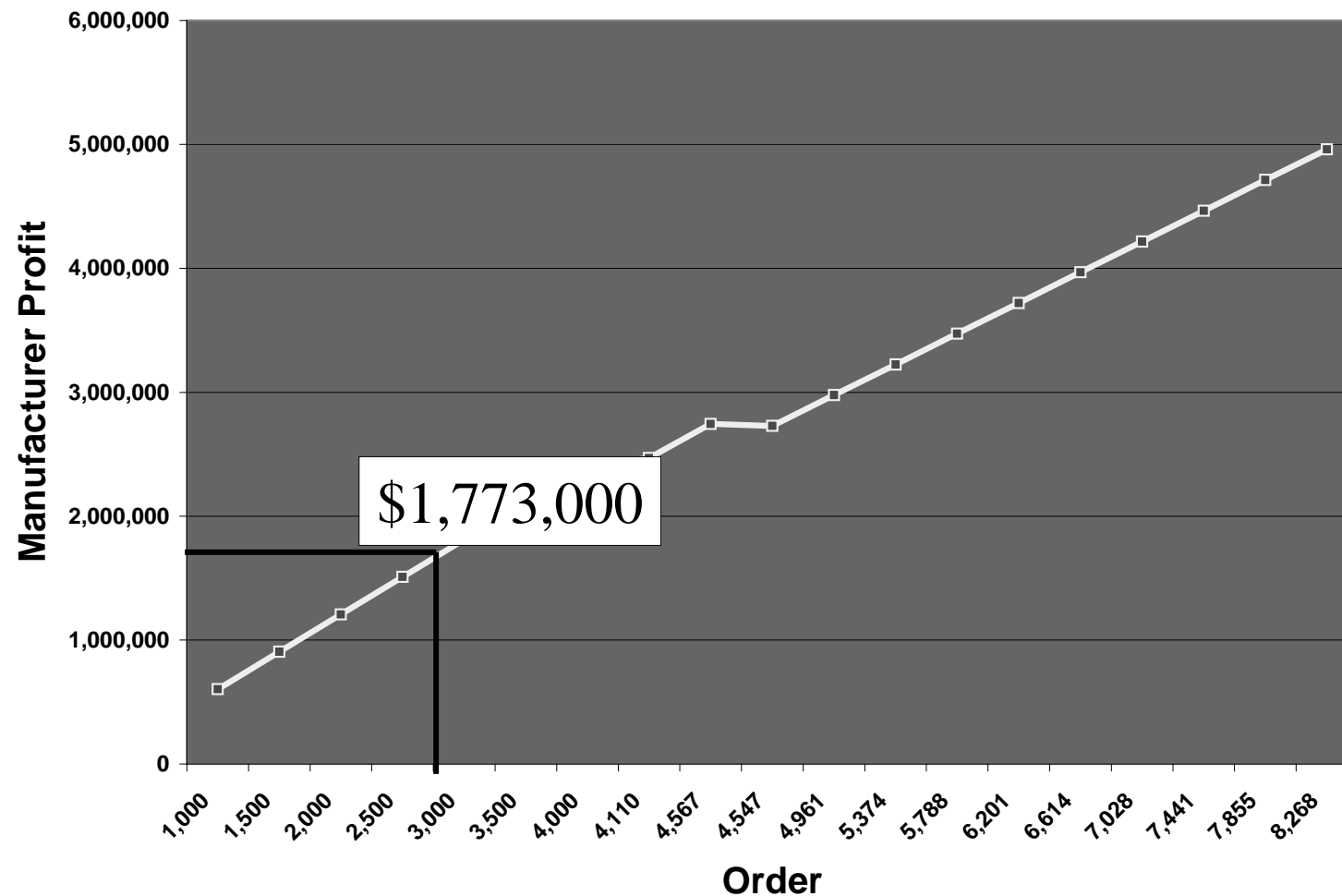
$$\gg Q = (1/0.22) [2,000 - (P_R - \text{Rebate})] = (1/0.22) [2,000 - (1450 - 100)] = 2954$$

- Retailer Profit = $(1,450 - 900) \cdot 2,955 = \$1,625,250$
- Manufacturer profit = $(900 - 200 - 100) \cdot 2,955 = \$1,773,000$

Retailer Expected Profit (\$100 Rebate)



Manufacturer Profit (\$100 Rebate)



Example: Wholesale discount

- ◆ What happens with \$100 wholesale discount to retailer?
- ◆ Retailer takes $P_M = \$800$
 - Sets $P_R = \$1400$ to maximize $(P_R - 800) (1/0.22)(2,000 - P_R)$
 - $Q = (1/0.22)(2,000 - 1,400) = 2,727$ units
 - Retailer Profit = $(1,400 - 800) \cdot 2,727 = \$1,499,850$
- ◆ Manufacturer takes $P_R = \$800$ and $CM = \text{variable cost}$
 - Manufacturer profit = $(800 - 200) \cdot 2,727 = \$1,499,850$

Example: Global Optimization

- ◆ What happens if manufacturer sells directly or optimizes for the whole system globally?
 - Manufacturer sets $P_R = \$1,100$ to maximize $(P_M - 200)(1/0.22)(2,000 - P_M)$
 - $Q = (1/0.22)(2,000 - 1,100) = 4,091$ units
 - Manufacturer profit $= (1,100 - 200) \cdot 4,091 = \$3,681,900$

Strategy Comparison

Strategy	Retailer	Manufacturer	Total
No Rebate	1,370,096	1,750,000	3,120,096
With Rebate (\$100)	1,625,250	1,773,000	3,398,250
Reduce Wholesale P (\$100)	1,499,850	1,499,850	2,999,700
Global Optimization			3,681,900

Managerial Insights

- ◆ Mail in Rebate allows supply chain partners to move away from sequential strategies toward **global optimization**
 - Provides retailers with **upside incentive**
- ◆ Mail in Rebate **outperforms** wholesale price discount for manufacturer
- ◆ Other advantages of rebates:
 - Not all customers will remember to mail them in
 - Gives manufacturer better control of pricing

Smart Pricing

◆ Customized Pricing

- Revenue Management Techniques
 - » Distinguish between customers according to their price sensitivity
- Influence retailer pricing strategies
- Move supply chain partners toward global optimization

◆ Dynamic Pricing

- Changing prices over time without necessarily distinguishing between different customers
- Find the optimal trade-off between high price and low demand versus low price and high demand

When does Dynamic Pricing Provide Significant Profit Benefit?

- ◆ Limited Capacity
- ◆ Demand Variability
- ◆ Seasonality in Demand Pattern
- ◆ Short Planning Horizon

The Internet makes Smart Pricing Possible

- ◆ Low Menu Cost
- ◆ Low Buyer Search Cost
- ◆ Visibility
 - To the back-end of the supply chain allows to coordinate pricing, production and distribution
- ◆ Customer Segmentation
 - Difficult in conventional stores and easier on the Internet
- ◆ Testing Capability

A Word of Caution

- ◆ Amazon.com experimented with dynamic pricing
 - customers responded negatively
- ◆ Coca-Cola distributors rebelled against a seasonal pricing scheme
- ◆ Opaque fares (priceline.com, hotwire.com)
 - Determining the correct mix of opaque and regular fares is difficult.