COLUMBIA BUSINESS SCHOOL

Lecture 7

- Portfolio Optimization - III
- Introduction to Options
- GMS Stock Hedging
- Introduction to Retailer Simulation
- Summary and Preparation for next class

Note: Please bring your notebook computer to the next class (lecture 8).

Introduction to Options

- In the GMS investment case, we include the possibility of investing in options, specifically put options.
- Consider a put option on IBM stock. We briefly explain here its characteristics and payoff formula.
- A *one-month put option* on IBM is an option to sell one share of IBM stock at a fixed dollar price (the *strike* price) in one month.
- An option is defined by several factors:

Factor	Our option
☐ Underlying	IBM stock price ($)
☐ Expiration	1 month
☐ Strike (K)	$150
☐ Type	Put
☐ Cost	$25

- What is the payoff of this put option if IBM is at $130 in one month? $120? $170?

Introduction to Options (cont.)

- The put option gives you the option to sell a share of IBM for \$150 in one month.
- If the price of IBM is \$130 in one month, then we exercise the option and the payoff is:

  \$150 - \$130 = \$20.
- If the price of IBM is \$120 in one month, then we exercise the option and the payoff is:

  \$150 - \$120 = \$30.
- If the price of IBM is \$170 in one month, then we do not exercise the option. The payoff is \$0.

- If the strike price is *K* and if *X* is the price of IBM at expiration of the option, then the payoff of the put option is:

$$\text{Put Payoff} = \begin{cases} K - X, & \text{if } X \le K, \text{or} \\ 0, & \text{if } X > K. \end{cases}$$

Introduction to Options (cont.)

- In a spreadsheet, the payoff can be computed using the formula:

  =MAX(*K* - *X*, 0) or =IF(X<=*K*, *K* - *X*,0).
- What is the *return* of this put option?
- The return of any security is:

$$\text{Return} = \frac{\text{Final Price} - \text{Initial Price}}{\text{Initial Price}}$$

- For example, if the price of IBM is \$130 in one month, then the payoff of the put is \$20 and, since the option price is \$25, the return is:

$$\frac{\$20 - \$25}{\$25} = -20\%$$

- If the price of IBM is \$120 in one month, then the payoff of the put is \$30 and the return is:

$$\frac{\$30 - \$25}{\$25} = +20\%$$

- If the price of IBM is \$170 in one month, then the payoff is \$0 and the return is -100%.

Scenario Returns

- Consider one share of IBM stock, which today is priced at $145.
- Scenarios and probabilities for IBM stock in one month:

Scenario	1	2	3	4	5
Probability	0.1	0.3	0.3	0.1	0.2
IBM Stock Price	$190	$180	$160	$130	$110

- We consider the following one-month put option on IBM:

Option price	$25
Strike price	$150

- Suppose scenario 5 occurs. What is the return of IBM stock? What is the return of the put option?
  - For IBM stock in scenario 5, the stock price is $110. The return is:

$$\frac{\$110 - \$145}{\$145} = -24.14\%$$

  - For the put option, we exercise the option and the payoff is $150-$110=$40. The return is:

$$\frac{\$40 - \$25}{\$25} = 60\%$$

Returns for a Put Option

- The returns on the stock and the put option are as follows:

Scenario	1	2	3	4	5
Stock Price	$190	$180	$160	$130	$110
Stock Return	31.0%	24.1%	10.3%	-10.3%	-24.1%
Put Option Payoff	$0	$0	$0	$20	$40
Put Option Return	-100%	-100%	-100%	-20%	+60%

GMS Stock Hedging

- Gold mining stock (GMS) is identified as an attractive investment
  - New mining equipment
  - New land-mining rights
  - Gold is a safe haven if there is a global monetary crisis
  - Supply and demand favor gold-price increase

- Potential problem areas
  - GMS is a highly leveraged company
  - Investment in GMS alone is highly risky
  - Gold prices are not sure to rise
  - LionFund is a conservative risk-averse fund

How to participate in the upside potential of GMS stock without incurring the risk of this investment?

GMS Stock Hedging

Table 1. Scenarios and Probabilities for GMS Stock in One Month

Scenario	1	2	3	4	5	6	7
Probability	0.05	0.10	0.20	0.30	0.20	0.10	0.05
GMS Price	150	130	110	100	90	80	70

Table 2. Put Option Prices (Today)

Put option	A	B	C
Strike price	90	100	110
Option price	$2.20	$6.40	$12.50

- Today, GMS is $100 per share.
- *Problem:* What is the minimum risk (i.e., minimum standard deviation) portfolio that invests all $10 million in stock and options?

Scenario Returns (continued)

	E		F		G		H		I
6				GMS		Option A		Option B	Option C
7	Initial Price		$	100	$	2.20	$	6.40	$ 12.50
8	Option strike price				$	90	$	100	$ 110
9									
10	Final Prices			GMS		Option A		Option B	Option C
11	Scenario	1	$	150	$	-	$	-	$ -
12		2	$	130	$	-	$	-	$ -
13		3	$	110	$	-	$	-	$ -
14		4	$	100	$	-	$	-	$ 10
15		5	$	90	$	-	$	10	$ 20
16		6	$	80	$	10	$	20	$ 30
17		7	$	70	$	20	$	30	$ 40
18									
19	Returns (in %)			GMS		Option A		Option B	Option C
20	Scenario	1		50.0		-100.0		-100.0	-100.0
21		2		30.0		-100.0		-100.0	-100.0
22		3		10.0		-100.0		-100.0	-100.0
23		4		0.0		-100.0		-100.0	-20.0
24		5		-10.0		-100.0		56.3	60.0
25		6		-20.0		354.5		212.5	140.0
26		7		-30.0		809.1		368.8	220.0

=MAX(I$8-$F17,0)
(copied to G11:I17)

=100*(I17-I$7)/I$7
(copied to F20:I26)

Adjusting the model to handle scenarios with unequal-probabilities: calculating the average portfolio return

- So far our portfolio-optimization model has always assumed equal probability scenarios. In order to be able to model scenarios with unequal probabilities, we must change the way we calculate the average portfolio return and the portfolio's standard deviation. The calculations are as follows: (recall there are *m* scenarios)

	Equal Probabilities	Unequal Probabilities
Average Portfolio Return	$r_p = \sum_{i=1}^{m} \frac{1}{m} r_i$	$r_p = \sum_{i=1}^{m} p_i r_i$

- To illustrate let's take the portfolio that is made up of 100% GMS Stock.
- The returns by scenario are:
  - r_1=50%, r_2=30%, r_3=10%, r_4=0%, r_5= –10%, r_6= –20%, r_7= –30%.
- Since the probabilities by scenario are p_1=5%, p_2=10%,... p_7=5%, we have:

$$r_P = 0.05\ r_1 + 0.10\ r_2 + 0.20\ r_3 + 0.30\ r_4 + 0.20\ r_5 + 0.10\ r_6 + 0.05\ r_7$$

or

$$r_P = 0.05(50\%) + 0.10(30\%) + 0.20(10\%) + 0.30(0\%) + 0.20(–10\%) + 0.10(–20\%)\ r_6 + 0.05(–30\%)$$ **= 2.0%**.

- In Excel we'll use the =SUMPRODUCT() function.

Adjusting the model to handle scenarios with unequal-probabilities: calculating the portfolio standard deviation

- When the scenarios have unequal probabilities, the calculation of the portfolio standard deviation is more involved.
- The calculations are as follows:

	Equal Probabilities	Unequal Probabilities
Variance of Portfolio Return	$VAR_p = \sum_{i=1}^{m} \frac{1}{m}\left(r_i - r_p\right)^2$	$VAR_p = \sum_{i=1}^{m} p_i\left(r_i - r_p\right)^2$
Stnd. Dev. of Portfolio Return	$SD_p = \sqrt{VAR_p}$	$SD_p = \sqrt{VAR_p}$

Example: Calculating the Portfolio Standard Deviation

- Again, let's consider a simple portfolio made up of only GMS stock.
- When scenario returns are not equally likely, the portfolio standard deviation is calculated as follows. First we calculate the average return (as explained above) r_P=2%:

	(1) Portfolio return	(2) Deviation from r_P $(r_i - r_P)$	(3) Squared Deviation $(r_i - r_P)^2$	(4) Proba-bility
r_1 =	50.0	+ 48.0	2304.0	0.05
r_2 =	30.0	+ 28.0	784.0	0.10
r_3 =	10.0	+ 8.0	64.0	0.20
r_4 =	0.0	– 2.0	4.0	0.30
r_5 =	–10.0	– 12.0	144.0	0.20
r_6 =	–20.0	– 22.0	484.0	0.10
r_7 =	–30.0	– 32.0	1024.0	0.05

Using columns (3) and (4), we calculate first the variance:

$$VAR_p = \sum_{i=1}^{m} p_i (r_i - r_P)^2$$

$$= 0.05(2304) + 0.10(784) + \ldots + 0.05(1024) = 336$$

Standard Deviation of Return (cont.)

- The standard deviation (SD) is the square root of the variance, i.e.:

$$\text{Standard Deviation } (SD_p) = \sqrt{VAR_p}$$
$$= \sqrt{336}$$
$$= 18.33$$

- For the portfolio made up of only GMS stock, we get r_P = 2.0% and *SD* = 18.33%.

- We can now make these changes to our model and optimize.

GMS Hedging Spreadsheet Model

=SQRT(SUMPRODUCT(D20:D26,B20:B26))

Decision Variables

=10,000,000*I3/I7

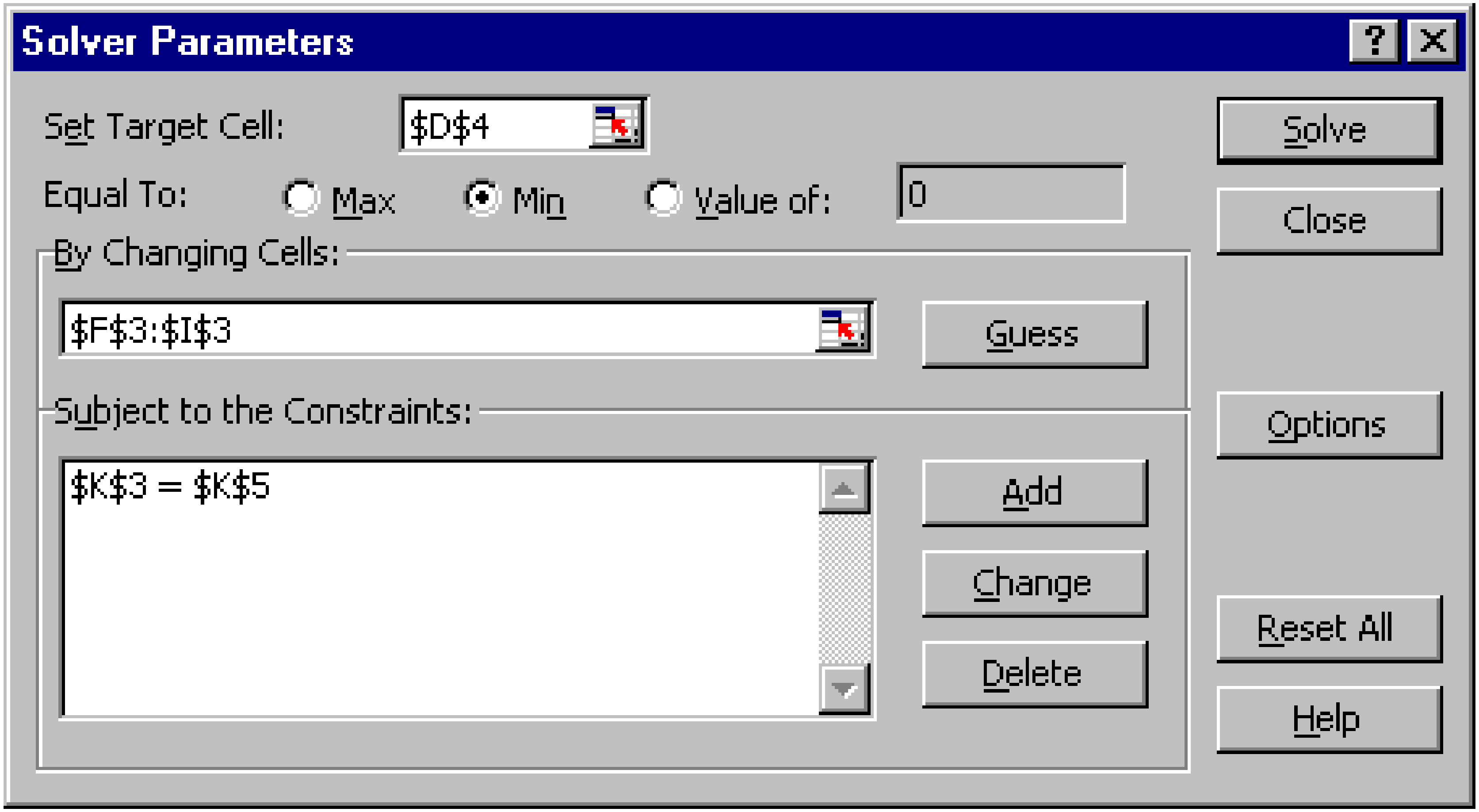
	A	B	C	D	E	F	G	H	I	J	K
1	GOLD.XLS			**Investment Non-Linear Program**							
2						GMS	Option A	Option B	Option C		Sum of Weights
3		Portfolio Return		Stnd. Dev.	Portfolio Weights	**84.9%**	**0.0%**	**0.0%**	**15.1%**		100%
4		1.095		7.95	Number of units	84,913	-	-	120,694		=
5											100%
6						GMS	Option A	Option B	Option C		
7					Initial Price	$ 100	$ 2.20	$ 6.40	$ 12.50		
8					Option strike price		$ 90	$ 100	$ 110		
9											
10					Final Prices	GMS	Option A	Option B	Option C		
11					Scenario 1	$ 150	$ -	$ -	$ -		
12					2	$ 130	$ -	$ -	$ -		
13					3	$ 110	$ -	$ -	$ -		
14					4	$ 100	$ -	$ -	$ 10		
15					5	$ 90	$ -	$ 10	$ 20		
16					6	$ 80	$ 10	$ 20	$ 30		
17					7	$ 70	$ 20	$ 30	$ 40		
18	Scen-	Proba-	Portfolio Ret. by	Squared	Security						
19	ario	bilities	Scenario	Deviation	Returns (in %)	GMS	Option A	Option B	Option C		
20	1	5%	27.37	690.38	Scenario 1	50.0	-100.0	-100.0	-100.0		
21	2	10%	10.39	86.35	2	30.0	-100.0	-100.0	-100.0		
22	3	20%	-6.60	59.14	3	10.0	-100.0	-100.0	-100.0		
23	4	30%	-3.02	16.91	4	0.0	-100.0	-100.0	-20.0		
24	5	20%	0.56	0.29	5	-10.0	-100.0	56.3	60.0		
25	6	10%	4.14	9.27	6	-20.0	354.5	212.5	140.0		
26	7	5%	7.72	43.85	7	-30.0	809.1	368.8	220.0		

=SUMPRODUCT(C20:C26,B20:B26)

=SUMPRODUCT($F$3:$I$3,F26:I26)

=(C26-$B$4)^2

GMS Hedging Solver Parameters



The solver parameters dialog box

GMS Hedging Solution

- The objective is to minimize standard deviation.
- The optimal solution is to have 84.9% of the portfolio in gold mining stock and 15.1% in Put Option C.
- With a $10 million budget, this means purchasing:
  - $10-million (84.913%) = $8,491,300 worth of GMS. This corresponds to $8,491,300 / $100 = 84,913 shares.
  - $10-million (15.087%) = $1,508,675 worth of Put Option C. This corresponds to $1,508,675 / $12.50 = 120,694 issues of Put Option C.
- For this portfolio, the average return is 1.095% and the standard deviation is 7.95%.

GMS Hedging without Non-negativity

	A	B	C	D	E	F	G	H	I	J	K
1	GOLD.XLS			**Investment Non-Linear Program**							
2						GMS	Option A	Option B	Option C		Sum of Weights
3		Portfolio Return		Stnd. Dev.	Portfolio Weights	**83.0%**	**-0.1%**	**-6.6%**	**23.8%**		100%
4		1.651		7.18	Number of units	82,972	(3,796)	(103,844)	190,057		=
5											100%
6						GMS	Option A	Option B	Option C		
7					Initial Price	$ 100	$ 2.20	$ 6.40	$ 12.50		
8					Option strike price		$ 90	$ 100	$ 110		
9											
10					Final Prices	GMS	Option A	Option B	Option C		
11					Scenario 1	$ 150	$ -	$ -	$ -		
12					2	$ 130	$ -	$ -	$ -		
13					3	$ 110	$ -	$ -	$ -		
14					4	$ 100	$ -	$ -	$ 10		
15					5	$ 90	$ -	$ 10	$ 20		
16					6	$ 80	$ 10	$ 20	$ 30		
17			Portfolio		7	$ 70	$ 20	$ 30	$ 40		
18	Scen-	Proba-	Ret. by	Squared	Security						
19	ario	bilities	Scenario	Deviation	Returns (in %)	GMS	Option A	Option B	Option C		
20	1	5%	24.46	520.17	Scenario 1	50.0	-100.0	-100.0	-100.0		
21	2	10%	7.86	38.60	2	30.0	-100.0	-100.0	-100.0		
22	3	20%	-8.73	107.78	3	10.0	-100.0	-100.0	-100.0		
23	4	30%	1.98	0.11	4	0.0	-100.0	-100.0	-20.0		
24	5	20%	2.30	0.42	5	-10.0	-100.0	56.3	60.0		
25	6	10%	2.25	0.35	6	-20.0	354.5	212.5	140.0		
26	7	5%	2.19	0.29	7	-30.0	809.1	368.8	220.0		

GMS Hedging without Non-negativity (cont.)

- The non-negativity constraint on portfolio weights is removed to allow short sales of puts.
- The optimal solution is to have 83.0% of the portfolio in gold stock, short 0.1% of put A, short 6.6% of put B, and have 23.8% in put C.
- With a $10M budget, this implies:
  - Purchasing $10,000,000(82.972%) = $8,297,200 worth of GMS, or equivalently $8,297,200/100 = 82,972 shares of GMS.
  - Shorting $10,000,000(0.0835%) = $8,350 worth of Put Option A, or equivalently $8,350/$2.20 = 3,796 issues of Put Option A.
  - Shorting $10,000,000(6.646%) = $664,600 worth of Put Option B, or equivalently $664,600/$6.40 = 103,844 issues of Put Option B.
  - Purchasing $10,000,000(23.757%) = $2,375,700 worth of Put Option C, or equivalently $2,375,700/$12.50 = 190,057 issues of Put Option C.
- The portfolio has an average return of 1.651% and a standard deviation of 7.18%.

Comparison of Alternative Solutions

Portfolio 1: *(all in stock)* 100% in gold stock

Portfolio 2: (*equal number of stock and option A)* 97.8% in stock, 2.2% in put option A (97,847 shares and 97,847 options)

Portfolio 3: *(optimal solution with no short sales)* 84.9% in stock, 15.1% in put option C

Portfolio 4: *(optimal solution with short sales)* 83.0% in stock, -0.1% in put A, -6.6% in put B, and 23.8% in put option C

Scenario Returns for Different Portfolios

Scenario	1	2	3	4	5	6	7
Prob.	5%	10%	20%	30%	20%	10%	5%
Port 1	50.0	30.0	10.0	0.0	-10.0	-20.0	-30.0
Port 2	46.8	27.2	7.6	-2.2	-11.9	-11.9	-11.9
Port 3	27.4	13.4	-6.6	-3.0	0.6	4.1	7.7
Port 4	24.5	7.9	-8.7	2.0	2.3	2.3	2.2

- Portfolio 1: avg ret = 2.00%, std = 18.3%
- Portfolio 2: avg ret = 1.76%, std = 15.6%
- Portfolio 3: avg ret = 1.10%, std = 8.0%
- Portfolio 4: avg ret = 1.65%, std = 7.2%

GMS Hedging Summary

- Portfolio 1: Investment in GMS stock alone
  - This investment is quite risky.
  - STD = 18.3%, maximum potential loss of 30%.
- Portfolio 2: Hedging each share of stock with one put-option A
  - Reduces risk only slightly.
- Portfolio 3: Minimum-variance solution with nonnegative portfolio weights
  - Reduces risk significantly.
- Portfolio 4: Minimum variance solution with negative portfolio weights allowed
  - Reduces risk and increases average return as compared to portfolio 3.
  - Has less than half the risk (as measured by *SD*) of Portfolio 2.

Portfolio-Optimization Software

- Many companies sell software packages for portfolio optimization. A few examples include:
  - BARRA
  - Sponsor-Software Systems, Inc.
    - The Asset Allocation Expert (AAE)
  - Wilson Associates
    - Capital Asset Management System (CAMS)
  - LaPorte
    - LaPorte Asset Allocation System
- Typical features of these systems include:
  - Historical databases
  - Graphical capabilities
  - Reporting capabilities
  - Technical support
- Typical prices are $2,000 - $10,000 for an initial license plus $1,000 - $4,000 per year for upgrades and database updates.

Other Applications

This portfolio-optimization model is one example of a *scenario LP* or *stochastic LP*. Similar models have been developed for:

- Bond-portfolio selection
  - scenarios are future yield-curve changes
  - SEC now regulates S&L's based on minimum capital requirements based on a range of future yield-curve scenarios (typically parallel yield-curve shifts)
- Corporate risk management
  - scenarios represent corporate risk factors

A model similar to the GMS case was developed by Cort Gwon (Columbia MBA '95):

- LibertyView Capital Management
- Invests in undervalued high yield (junk) bonds
- Spreadsheet optimization model is now used to hedge bond investments using stock and options
- Scenarios developed by the traders

Introduction to Retailer Simulation

- *Retailer* is a simulation exercise that places the user in the role of a manager of a large chain of retail clothing stores. In this setting, yield management boils down to deciding the *timing* and *magnitude* of price reductions.

Background Information:

Fashion Retail Merchandise

- Staple Items
  - Regularly purchased items, e.g., socks, underwear, T-shirts, etc.
- Fashion Items
  - Items with a strong fashion component; quick obsolescence
  - Specific selling seasons, e.g., winter, spring, cruise, holiday
  - Define the “style” of a store and position it relative to competitors
  - Demand is highly erratic: “hit” items can sell out in a few weeks, other items (“crawlers” or “dogs”) can sell very slowly.

Production and Distribution

- Garment design
  - Creative process, most important phase
  - Basic silhouettes, colors, and fabrics chosen
  - Typically begins *one year in advance* of the target selling season
- Production quantity decision, material procurement
  - Based on rough forecasts of likely sales
  - Vagaries of fashion and long lead times often result in highly inaccurate forecasts
  - Procurement lead time: 1-2 weeks for standard in-stock fabrics to several months for special-order fabrics
- Garment assembly
  - In-house or through subcontractors
  - Lead time: under 4 weeks (in-house) to several months (e.g., overseas subcontractor)
- Distribution
  - Takes 1-2 weeks (domestic supplier) to 4-6 weeks (e.g., overseas supplier using container ships for transportation)

Retailer Background

- Procurement and production lead time
  - Long for fashion items: ranging from many weeks to several months
  - Fashion items are usually produced in a *single production run*
  - No opportunity for restocking during a short 8-15 week selling season.

- Matching supply and demand to maximize revenue
  - Transfer merchandise between stores
  - Price changes: timing and magnitude decisions

- POS technology
  - Links cash registers to home-office computer
  - Links distribution centers to home-office computer
  - Managers have a “real-time” view of sales and inventory throughout the distribution chain

Financial Implications

The GAP - Operating Statement Information

($ Millions)	1991	1992
Net Sales	$ 2,518.0	$2,960.0
Cost of Goods Sold	1,568.0	1,955.6
S,G&A	575.7	661.3
Interest Expense	3.5	3.8
Pretax Income	370.8	339.8
Taxes	140.9	129.1
Net Income	229.9	210.7
EPS	$1.62	$1.47
Shares Out (mil)	142.0	143.7
Sales % Change	30.3%	17.7%
Comp-Stores	13.0	5.0
% OF SALES		
Cost of Goods Sold	62.3%	66.1%
S,G&A	22.9	22.3
Interest Expense	0.1	0.1
Pretax Income	14.7	11.5
Tax Rate	38.0	38.0

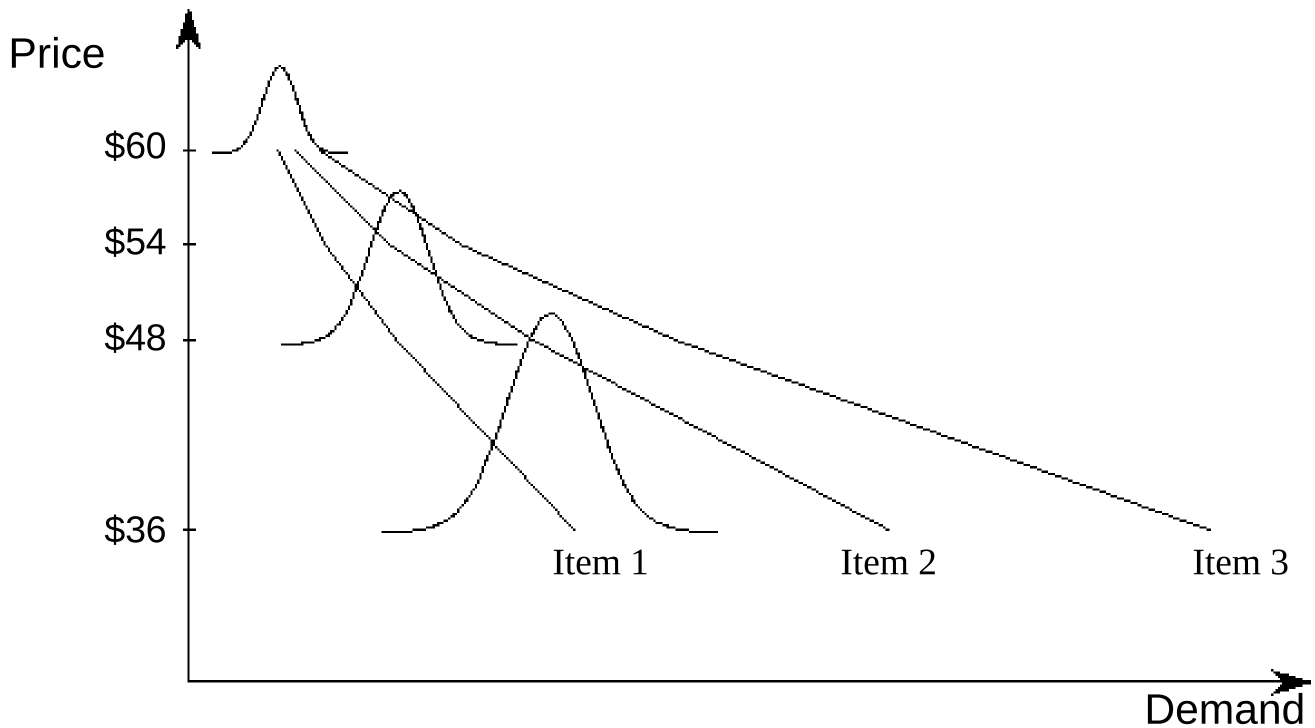
- Suppose a better markdown strategy produced a 2% revenue increase in 1992:
  - ⇒ $59 million increase in sales
  - ⇒ No change in cost of goods sold
  - ⇒ 17% increase in pretax income and net income
  - ⇒ 17% increase in earnings per share

  Relatively small changes in revenue can have a substantial impact on a company’s bottom line.

Retailer Parameters

- Stores are stocked with 2,000 units of a single fashion item
  - Management hopes for strong sales but demand is hard to predict
  - No chance for restocking the item or reallocating among stores
- Initial price is $60
- 15-week selling season
- Goal: *maximize the revenue* from the 2,000 units
  - Production and distribution costs have already been paid; they are sunk costs
- Four allowable price levels
  - $60 (full price), $54 (10% off), $48 (20% off), $36 (40% off)
- Management policy: price cannot be raised once it has been cut
- All items in stores that are not sold at the end of 15 weeks are sold to discounters (“jobbers”) for $25 per unit (salvage value)

Retailer Demand Curves



- There is a different demand curve for each item.
- For a given item, demand is random from week to week (even at the same price)
- The retailer does not know beforehand which kind of demand curve each product will have.

Preliminary Analysis

Problem: How to develop a sensible pricing policy?

Historical Sales Data

- Historical data on 15 previous fashion items are stored in the spreadsheet `RETAIL.XLS`.
- Each item is different — some turned out to be fast sellers while others did not sell so well.
- Although the items were different, their responsiveness to price cuts was quite similar.
- “Deseasonalized” data: the data has been normalized to remove the predictable effects of seasons and holidays on sales figures. (These effects are also removed from the *Retailer* simulation exercise.)
- Sales are quite variable: even at the same price, sales can vary considerably from week to week due to weather, competitors, and a host of other factors.

A	A	B	C	D	E	F
1	RETAIL.xls					
2						
3		Historical sales data for 15 different items				
4		for use with the RETAILER simulation game.				
5						
6			Qty on			
7	Item	Week	hand	Price	Sales	
8	1	1	2000	60	57	
9		2	1943	60	98	
10		3	1845	60	55	
11		4	1790	60	41	
12		5	1749	60	60	
13		6	1689	60	39	
14		7	1650	54	106	
15		8	1544	54	55	
16		9	1489	54	64	
17		10	1425	54	43	
18		11	1382	54	131	
19		12	1251	54	112	
20		13	1139	54	62	
21		14	1077	54	31	
22		15	1046	54	80	
23		16	966			
24						
25	2	1	2000	60	115	
26		2	1885	60	105	
27		3	1780	60	136	
28		4	1644	60	115	
29		5	1529	60	73	
30		6	1456	60	102	
31		7	1354	54	58	
32		8	1296	54	187	
33		9	1109	54	198	
34		10	911	54	196	
35		11	715	54	132	
36		12	583	54	60	
37		13	523	54	119	
38		14	404	54	131	
39		15	273	54	215	
40		16	58			
41						
42	3	1	2000	60	75	
43		2	1925	60	82	
44		3	1843	60	63	
45		4	1780	60	53	
46		5	1727	60	63	
47		6	1664	60	20	
48		7	1644	54	57	
49		8	1587	54	118	
50		9	1469	54	90	
51		10	1379	54	51	
52		11	1328	54	126	
53		12	1202	54	73	
54		13	1129	54	88	
55		14	1041	54	64	
56		15	977	54	74	
57		16	903			

Preliminary Analysis (continued)

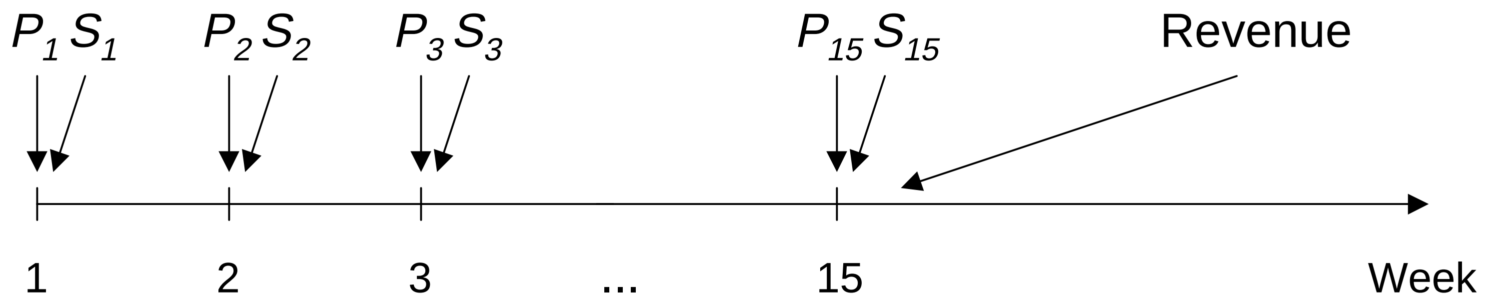
- In your group, analyze the historical data in `RETAIL.XLS` and try to develop a sensible markdown strategy. In your analysis, you might want to answer:
  - What is the average effect on sales of the different price cuts? For example, for a price cut from \$60 to \$54, what is the average increase in weekly sales?
  - How variable are sales from one item to the next?

- In developing a strategy, you might want to consider:
  - If demand was not variable, what would be the optimal price-cut strategy? For example, suppose the demand at a price of \$60 was a constant 80 items per week. Using your estimated demand sensitivities, to what level and at what point in the selling season would you cut the price?
  - How might your strategy be altered to account for uncertainty in demand?

- You should work out any desired formulas in advance, so that necessary calculations can be done simply and quickly in class.

Retailer

Retailer is a multi-period simulation.



P_i is the price set for week i (decision variable)
S_i is the sales in week i (random).
The *Retailer* simulation will do some calculations automatically.

Retailer Simulation Screen

Week	Qty on hand	Price	Sales	Rev	Cum Rev	Avg Sales	Std Err	Proj Sales
1	2000	60	99	5940	5940	99	-	1485
2	1901							

Columns labeled Week, Qty on hand, Price, and Sales are self-explanatory.

- Rev: The revenue for the current week, i.e.,

  Rev = Price $\times$ Sales .

- Cum Rev: Total (or cumulative) revenue since the beginning of the selling season.
- Avg Sales: The average of weekly sales at the current price.
- Std Err: Standard error of the average sales, i.e., $s/\sqrt{n}$ where *s* is the std dev of sales and *n* is the number of weeks of sales (at the current price).
- Proj Sales: Projected total sales after 15 weeks. The projection is made using cumulative sales thus far plus sales continuing at the current average. For example, 1485 = 99 $\times$15.

Retailer Simulation Screen (continued)

Week	Qty on hand	Price	Sales	Rev	Cum Rev	Avg Sales	Std Err	Proj Sales
1	2000	60	99	5940	5940	99	-	1485
2	1901	60	53	3180	9120	76	23	1140
3	1848							

- The user had the choice of four price levels: \$60, \$54, \$48, and \$36. The user chose to maintain the price at \$60.

  Cum Rev: \$9120 = 5940 + 3180.

  Avg Sales: 76 = (99 + 53)/2.

  Std Err: 23 = $s/\sqrt{2}$, where s = 32.5.

  Proj Sales: Current total sales + future sales at average rate:
  1140 = (99 + 53) + 13 $\times$ 76 .

- At this point, the user can again choose from 4 price levels: \$60, \$54, \$48, and \$36. The user chose to cut the price to \$54.

Retailer Simulation Screen (continued)

Week	Qty on hand	Price	Sales	Cum Rev	Avg Rev	Std Sales	Proj Err	Sales
1	2000	60	99	5940	5940	99	-	1485
2	1901	60	53	3180	9120	76	23	1140
3	1848	54	85	4590	13710	85	-	1257
4	1763							

- Cum Rev: \$13710 = 5940 + 3180 + 4590.

  Avg Sales: 85 (average at the current price of \$54).

  Std Err: Undefined, since there is only one week of sales at the current price of \$54.

  Proj Sales: Current total sales + future sales at average rate:
  $1257 = (99 + 53 + 85) + 12 \times 85$.

- At this point, the user can choose from only 3 price levels: \$54, \$48, and \$36.

  At the end of 15 weeks, *revenue from sales will be added to revenue from salvage to determine total revenue*.

Summary

- Application to stock hedging using options
- Introduction to Retailer

For next class

- <u>Remember to bring your notebook computer to the next class.</u>
- Read the case "Retailer: A Retail Pricing Simulation Exercise" on pp.529-534 in the W&A text. Download the Retailer files from the course webpage. (Put all of the Retailer-related files into the same directory on your computer.)
- Optional readings: "His Goal: No Room at the Inns," "Computers as Price Setters Complicate Travelers' Lives," "Making Supply Meet Demand in an Uncertain World," and "Yield Management at American Airlines" in the readings book.