COLUMBIA BUSINESS SCHOOL

Decision Models

Lecture 11

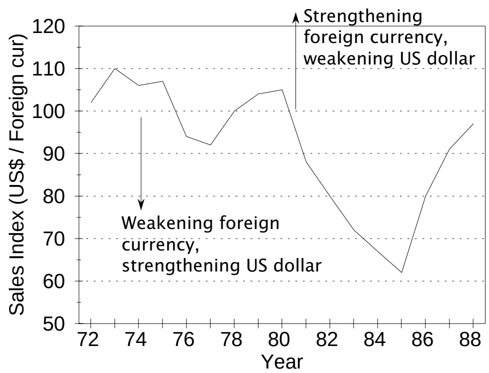
- Using Simulation for Risk Management
  - → Risk management at Merck
  - → Should corporations hedge?
  - → Simulating foreign exchange rates
  - → Evaluating hedging effectiveness using simulation
- Summary and Preparation for next class

Foreign Exchange Risk Management at Merck: Background

- Merck & Company is a producer and distributor of pharmaceutical products worldwide.
- Based in New Jersey, Merck is a multinational company which does business in over 100 countries. Its worldwide market share is about 5%, with competition from European and Japanese companies.
- Merck is one of the ten largest U.S. firms by market capitalization, worth about $80 billion. It is one of the world's largest sellers of pharmaceuticals.
- About 1/3 of its revenue is from foreign sources, but relatively little of its costs are foreign expenses.
- If foreign currency prices decline, the U.S. dollar value of Merck's revenue declines.
- Should Merck hedge its foreign exchange (FX) risk, i.e., buy or sell financial securities to reduce its FX exposure?

Merck Sales Index

- Merck has exposures to about 40 currencies.
- To measure its FX exposure, Merck uses a “sales index.” This is an average of FX rates (expressed in US$ per FX) weighted by sales in each currency. The index is normalized to 100 in 1978.



- Index levels above 100 indicate foreign currencies are strong versus the dollar, which has a positive impact on Merck’s dollar revenues.
- Index levels below 100 indicate a strong dollar or weak foreign currencies. This has a negative impact on Merck’s dollar revenues.

Impact of Changes in FX Rates

- In 1995 Merck had worldwide sales of $16.7 billion, about $5.3 billion in sales were foreign. R&D expenses were $1.3 billion. Net earnings were $3.3 billion.
- Suppose that the dollar strengthens by 20%. What is the impact on net earnings?
- Is management to blame for the shortfall?
- How would management deal with the shortfall?
  - → Cut dividends?
  - → Cut R&D?
  - → Issue new debt?
  - → Issue new equity?

From Merck’s 1995 annual report, p.37:

“The ability to finance ongoing operations primarily from internally generated funds is desirable because of the high risks inherent in research and development required to develop and market innovative new products and the highly competitive nature of the pharmaceutical industry.”

To Hedge or Not to Hedge?

Issues in Merck's FX Hedging Decision

- Does hedging increase shareholder value?
- Relationship between stock price and exchange rates?
- Do investors want exposure to FX rates?
- Reduce earnings volatility
- Maintain constant or growing dividend
- Need to fund R&D expenses

Merck's Hedging Decision

From Merck's 1995 annual report, p.36:

"A significant portion of the Company's cash flows are denominated in foreign currencies. The company relies on sustained cash flows generated from foreign sources to support its long-term commitment to U.S. dollar-based research and development. To the extent the dollar value of cash flows is diminished as a result of a strengthening dollar, the Company's ability to fund research and other dollar based strategic initiatives at a consistent level may be impaired. *To protect against the reduction in value of foreign currency cash flows, the Company has instituted balance sheet and revenue hedging programs to partially hedge this risk.*"

(Italics added)

Merck's Hedging Decision (continued)

From Merck's 1995 annual report, pp.36–37:

"The objective of the revenue hedging program is to reduce the potential for longer-term unfavorable changes in foreign exchange to decrease the U.S. dollar value of future cash flows derived from foreign currency denominated sales . . . To achieve this objective, the Company will *partially hedge forecasted sales* that are expected to occur over its planning cycle, typically no more than three years into the future . . . The portion of sales hedged is based on assessments of cost-benefit profiles that consider natural offsetting exposures, revenue and *exchange rate volatilities and correlations*, and the cost of the hedging instruments . . . *The Company manages its forecasted transaction exposure principally with purchased foreign currency put options.*"

(Italics added)

Hedging by Corporations: Empirical Evidence

From the October 1995 Wharton survey of derivatives use by non-financial U.S. firms:

- 38% of firms use derivatives
  - → 13% with market cap under $50 million
  - → 48% with market cap from $50-250 million
  - → 59% with market cap over $250 million
- Top reasons given by firms which do not use derivatives:
  - → Lack of significant exposure
  - → Expected costs exceed the benefits
  - → Concern about perception of derivatives use
- Top reasons given by firms which use derivatives:
  - → Manage foreign exchange exposure
  - → Manage interest rate exposure
  - → Manage commodity price exposure
  - → Manage equity exposure
- Frequency of FX derivative use for hedging by exposure category:
  - → Contractual commitments: 90%
  - → Anticipated transactions within 1 year: 90%
  - → Foreign repatriations: 72%
  - → Anticipated transactions over 1 year: 54%

Merck's Foreign Exchange Hedging Problem

A Simplified Example

- Suppose Merck has receivables of $1.0 billion Swiss francs in one year.
- *What is the risk in U.S. dollars if this cash flow is not hedged?*
- Because the market for Swiss franc put options is not highly liquid, Merck is considering a partial hedge of its exposure by purchasing German mark put options.
- As we'll see, the Swiss franc and German mark currencies are very highly correlated.
- In particular, Merck is considering the purchase of 0.75 billion one-year German mark put options. The current FX rates are: 0.7465 US$/SF, 0.6418 US$/DM. The cost of a one-year German mark put option with a strike of 0.635 is $0.021.
- *What is the risk in U.S. dollars if this hedging strategy is followed?*

Don't worry if the FX option terminology is somewhat unfamiliar. In the next slides we'll define the terms more precisely.

Developing a Simulation Model to Manage Foreign Currency Exposure

The current rate is $SF_0 = 0.7465$ US$/SF. If the rate does not change, the 1.0 billion SF receivable will be worth 0.7465 billion US dollars.

Let SF_1 denote the random Swiss franc rate one year from today and let R_{SF} represent the Swiss franc *return* over the year, i.e.,

$$SF_1 = SF_0 \times (1 + R_{SF}).$$

Our simulation model for R_{SF} (and hence for SF_1) is

$$R_{SF} \sim N(\mu = 0, \sigma = 0.11).$$

The most likely value for R_{SF} is 0, so the most likely value for $SF_1 = 0.7465$. A one standard deviation return of 11% corresponds to a rate change of $0.7465(0.11) = 0.0821$. There is roughly a 2/3 chance that R_{SF} will lie in $[-0.11, 0.11]$, so there is a 2/3 chance that SF_1 will lie in $[0.7465(1 - 0.11), 0.7465(1 + 0.11)]$, i.e., in $[0.6644, 0.8286]$.

A Model for the Swiss Franc Rate

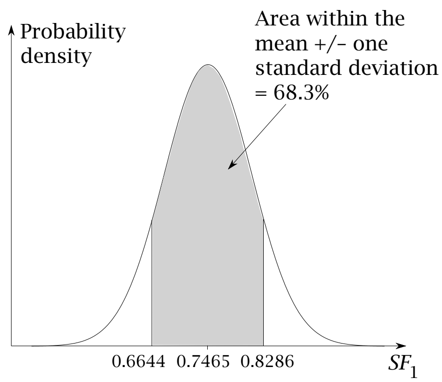
The model for SF_1 is

$$SF_1 = SF_0 \times (1 + R_{SF}),$$

where

$$R_{SF} \sim N(\mu = 0, \sigma = 0.11)$$

and where the current rate is $SF_0 = 0.7465$.



In this model, the Swiss franc rate is said to have a *volatility* of 11%.

Where does this model come from?

Historical Swiss Franc Returns

The Swiss franc model can be estimated using historical data. Eight years of (slightly hypothetical) Swiss franc rates are given in the next table:

Year	Rate ($/SF)	Return (in %)
1	0.6006	
2	0.5453	−9.21
3	0.6706	22.98
4	0.7019	4.67
5	0.6357	−9.43
6	0.7034	10.65
7	0.7830	11.32
8	0.7465	−4.66

The rates are converted to returns using:

$$\text{Return} = \frac{\text{Rate}_{i+1}}{\text{Rate}_i} - 1$$

The standard deviation of returns is 11.26% (the model uses 11%).

Although the historical mean return is 3.8%, the standard error of the estimate is so large (4.3%) that a mean of zero cannot be ruled out. The model uses a mean return of 0%, which is generally a better predictor of future FX returns than the historical estimate.

Merck's U.S. Dollar Risk Unhedged

	A	B	C	D	E	F	G
1	MERCK_U.XLS		Merck's Unhedged U.S. Dollar Risk				
2							
3	Swiss franc receivable in one year				1	(in billion SF)	
4	Current Swiss franc rate				0.7465	(in US$/SF)	
5	Swiss franc volatility				11%		
6							
7			Return	Price			
8	Swiss franc		-6.12%	0.7008			
9							
10	Revenue in one year (unhedged)				0.7008	(in billion US$)	
11							

Assumption cell C7:
Normal with mean = 0,
std dev =E5

Forecast cell E10 named
"Unhedged reveune"

Spreadsheet formulas:
Cell D8: =E4*(1 + C8), i.e., $SF_1 = SF_0(1 + R_{SF})$
Cell E10: =E3*D8

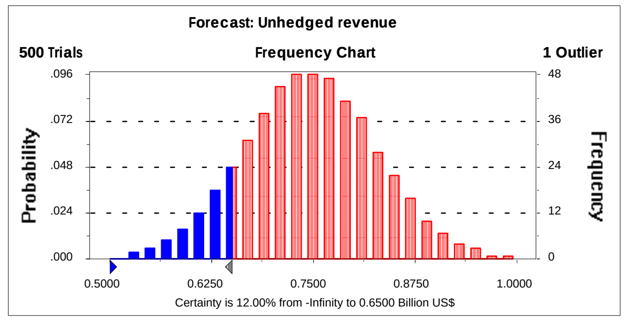
In the Crystal Ball "Run Preferences," set the maximum number of trials to 500, the random number seed to 123, and for the sampling method choose "Latin Hypercube." This sampling method requires somewhat more computer memory, but gives more accurate results. The spreadsheet is now ready to run a Crystal Ball simulation.

Merck's U.S. Dollar Risk Unhedged (continued)

If FX rates do not change, the 1.0 billion Swiss franc receivable will be worth 0.75 billion US$ one year from today. Suppose Merck is worried about a shortfall of 100 million US$ or more. What is the likelihood of this event?

The simulation output can be used to estimate

$$P(SF_1 \le 0.65).$$



After running the simulation, move the right arrow in the "Unhedged revenue" forecast window to 0.65. The certainty window reads 12%, i.e., there is a 12% chance of a shortfall of \$100 million or more. (The histogram was drawn using 25 bins.)

German Mark Put Options

Because the market for Swiss franc put options is not highly liquid, Merck is considering a partial hedge of its exposure by purchasing German mark put options. These are options to sell marks at a fixed dollar price. How do these put options work?

An option is defined by several factors:

Factor	Our option
◦ Underlying	DM rate ($/DM)
◦ Expiration	1 year
◦ Strike (K)	0.635
◦ Type	Put
◦ Cost	$0.021

The payoff of an option occurs at the expiration (or maturity) of the option. At expiration, let the DM rate be denoted by DM_1. The payoff of a German mark put option is

$$\text{Put payoff} = \begin{cases} K - DM_1 & \text{if } DM_1 \leq K \text{, or} \\ 0 & \text{if } DM_1 > K. \end{cases}$$

The payoff can be computed in a spreadsheet using the formula:

$$=\text{MAX}(K - DM_1, 0).$$

German Mark Put Options (continued)

The DM rate in one year is DM_1, in units of US$/DM. The payoff of a German mark put option is

$$\text{Put payoff} = \begin{cases} K - DM_1 & \text{if } DM_1 \leq K \text{, or} \\ 0 & \text{if } DM_1 > K. \end{cases}$$

Purchasing a put option is like buying insurance in case the DM rate declines below K.

Example 1. The current DM rate is 0.6418 US$/DM. An investor buys a put option with a strike of $K = 0.635$. Suppose that the mark *depreciates* in one year to $DM_1 = 0.600$. Then the option will have a payoff of $0.035.

Example 2. Continuing the previous example, suppose instead that the mark depreciates in one year to $DM_1 = 0.500$. Then the option will have a payoff of $0.135. The put option exactly offsets all declines in the DM rate below the strike $K = 0.635$.

Example 3. Suppose instead that the mark *appreciates* in one year to $DM_1 = 0.6580$. Then the option will have a payoff of $0.

A Model for the Deutschemark Rate

A model for the German mark rate can be estimated using historical data:

Year	DM Rate ($/DM)	DM Return (in %)
1	0.4805	
2	0.4418	−8.05
3	0.5433	22.97
4	0.5645	3.90
5	0.5286	−6.36
6	0.5576	5.49
7	0.6194	11.08
8	0.6418	3.62

The DM rates are converted to returns using:

$$\text{Return} = \frac{\text{Rate}_{i+1}}{\text{Rate}_i} - 1.$$

The standard deviation of DM returns is 9.73% (for simplicity we'll use 10% in the model). The current DM rate is $DM_0 = 0.6418$. We model the DM rate one year from today, DM_1, by

$$DM_1 = DM_0 \times (1 + R_{DM}),$$

where

$$R_{DM} \sim N(\mu = 0, \sigma = 0.10).$$

Combining the SF and DM Rate Models

Now we have models for the Swiss franc and German mark rates. But we need one more important piece of information. How do these models relate to one another?

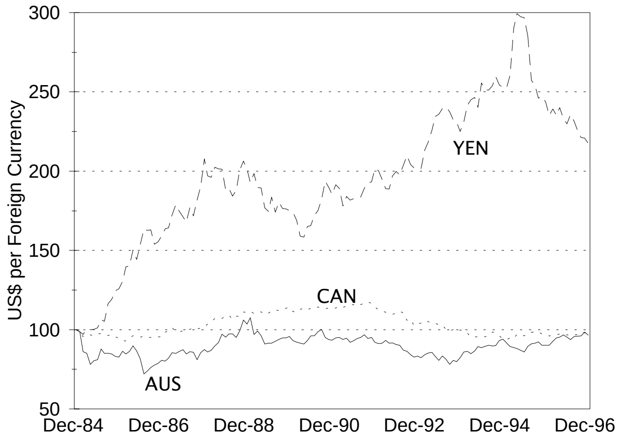
We need to specify the *correlation* between the models.

Year	SF Rate ($/SF)	SF Return (in %)	DM Rate ($/DM)	DM Return (in %)
1	0.6006		0.4805	
2	0.5453	−9.21	0.4418	−8.05
3	0.6706	22.98	0.5433	22.97
4	0.7019	4.67	0.5645	3.90
5	0.6357	−9.43	0.5286	−6.36
6	0.7034	10.65	0.5576	5.49
7	0.7830	11.32	0.6194	11.08
8	0.7465	−4.66	0.6418	−3.62

The correlation between the SF and DM returns is 94.5% (for simplicity, we'll use a correlation of 95% in the model). The correlation can be computed in a spreadsheet using the =CORREL function.

Historical FX Rates

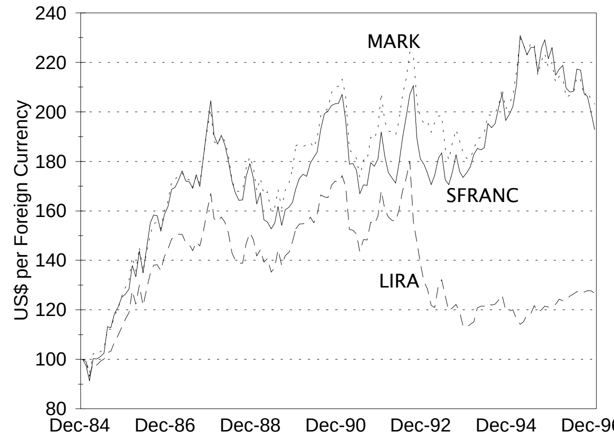
The next figure shows FX rates for the Canadian dollar, Australian dollar, and Japanese yen. The rates are scaled to 100 at the beginning of the series.



Notice the low volatility of the Canadian dollar. The correlation between Australian dollar returns and Japanese yen returns is quite low.

Historical FX Rates (continued)

The next figure shows FX rates for the German mark, Swiss franc, and Italian lira. The rates are scaled to 100 at the beginning of the series.



The correlation between German mark returns and Swiss franc returns is very high.

Merck's FX Risk Hedging Spreadsheet

Input parameters

	A	B	C	D	E	F	G
1	MERCK.XLS		Merck Hedging Spreadsheet				
2	Swiss franc receivable in one year				1	(in billion SF)	
3	Current Swiss franc rate				0.7465	(in US$/SF)	
4	Current German mark rate				0.6418	(in US$/DM)	
5	Strike of one-year German mark put options				0.6350		
6	Cost per German mark put option				0.0210	(in US$)	
7	Number of German mark put options				0.7500	(in billion)	
8	German mark/Swiss franc correlation				95%		
9	Swiss franc volatility				11%		
10	German mark volatility				10%		
11			Return	Price			
12	Swiss franc		-18.50%	0.6084			
13	German mark		-17.00%	0.5327			
14	Put option payoff				0.1023	(in US$)	
15	Revenue in one year (unhedged)				0.6084	(in billion US$)	
16	Revenue in one year (hedged)				0.6694	(in billion US$)	

Assumption cells, both normal with mean = 0, std dev from E9 and E10, and correlation E8

Forecast cells

Cell D12: =E3*(1 + C12), i.e., $SF_1 = SF_0(1 + R_{SF})$
Cell D13: =E4*(1 + C13), i.e., $DM_1 = DM_0(1 + R_{DM})$
Cell E14: =MAX(E5 − D13, 0), i.e., MAX($K - DM_1$, 0)
Cell E15: =E2*D12
Cell E16: =E15 + E7*(E14-E6)

Cell E16 is interpreted as
Hedged revenue = Unhedged Revenue
+ No. of Options × (Option payoff − Option cost).

Defining Correlated Assumptions in Crystal Ball

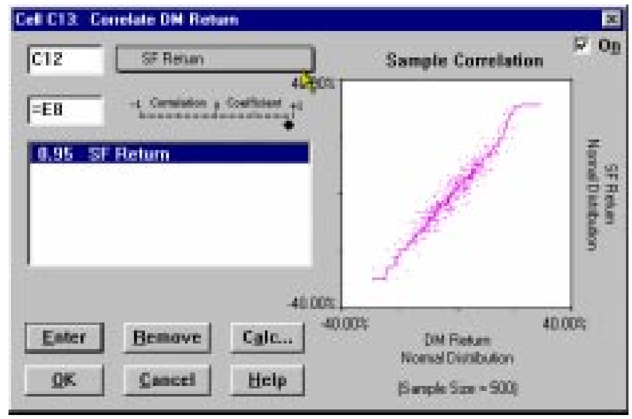
To run this simulation, follow the usual steps to define assumption cell C12 ("SF Return") to be

$$C12 \sim N(\mu = 0, \sigma = \text{Cell E9} = 0.11)$$

Then define assumption cell C13 ("DM Return") to be

$$C13 \sim N(\mu = 0, \sigma = \text{Cell E10} = 0.10).$$

In the C13 assumption cell window, click on "Correlate" to bring up the correlation window:

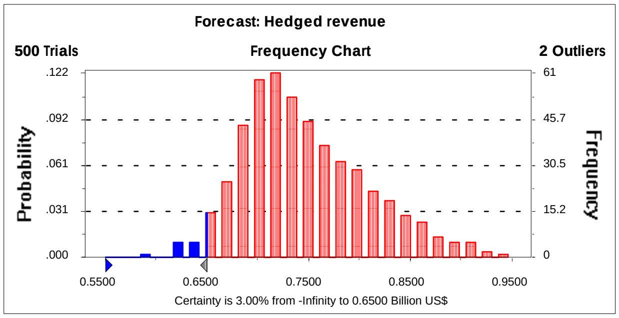


Type =C12 in the "<Select Assumption>" window and type =E8 in the correlation window. Then click on "OK."

Merck's U.S. Dollar Risk Hedged

Now define the forecast cells E15 ("Unhedged revenue") and E16 ("Hedged revenue").

In the Crystal Ball "Run Preferences," set the maximum number of trials to 500, the random number seed to 123, and for the sampling method choose "Latin Hypercube."



After running the simulation, move the right arrow in the "Hedged revenue" forecast window to 0.65. The certainty window reads 3%, i.e., there is a 3% chance of a shortfall of $100 million or more. (The histogram was drawn using 25 bins.)

Comparison of Hedged and Unhedged Risk

Selected statistics from the "Unhedged revenue" and "Hedged revenue" forecast cells:

Statistic	Unhedged Revenue	Hedged Revenue
Trials	500	500
Mean	0.7464	0.7474
Standard Deviation	0.0824	0.0633
Skewness	−0.03	0.68
$P(\text{Revenue} \le 0.65)$	0.12	0.03

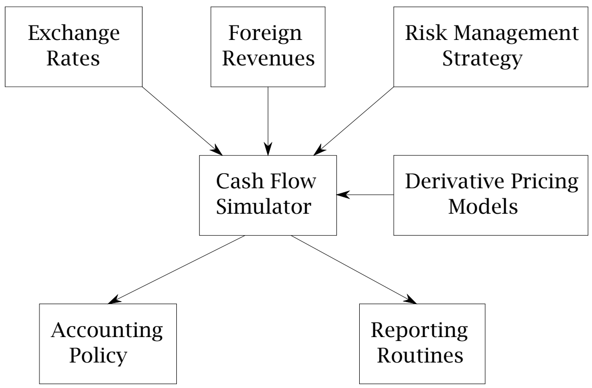
The mean of the U.S. dollar revenue is essentially unchanged whether hedged or not.

The standard deviation of the hedged revenue is reduced by about 25%; skewness increases significantly.

The risk of a shortfall of $100 million or more is reduced from 12% (unhedged) to 3% (hedged).

Merck's Monte Carlo Hedged Revenue Simulator

The following schematic summarizes the major components of Merck's financial hedging simulator:



Accounting issues are important because some financial positions qualify for "hedge accounting" where gains and losses are recorded differently than for other investments.

Derivative pricing models become necessary when, for example, the expiration of an option does not coincide with the hedging period.

Merck's Risk Management System

- Merck's financial risk management system allows them to examine the effects of various hedging strategies. With their system, they can easily compare
  - → Using out-of-the-money options, which are cheaper but offer less protection, or
  - → Using forward contracts to lock-in future exchange rates today, versus
  - → Not hedging (also called self-insurance)

For next class

- Don't forget that the "Yield Management at American Airlines" case is due March 6.