15.433 INVESTMENTS

Class 16: Risk Management

Spring 2003

Introduction

The recent, notable increase in focus on financial risks can be traced in part to the concerns of regulatory and investors about risk exposure of financial institutions through their large positions in OTC derivatives.

The dramatic increase in the availability and usage of derivative products can be traced to several developments:

- 1. Because of the rapid improvement in financial modelling and computer systems, complex derivatives can be offered at more favorable prices and liquidity.
- 2. With the liberalization of financial markets around the world, the demand for more sophisticated hedging instruments with wider coverage range has also increased.

There certainly have been periods of high volatility in the financial market, but what distinguishes the recent period from earlier periods is that investors have had lower cost access to derivatives that permit highly leveraged positions and, hence, potentially large changes in value for a given change in the value of the underlying instrument. The recent losses on derivative positions, by both financial and non-financial corporations, are clear manifestations of this effect.

Some Losses on Derivatives Position

Orange County: \$ 1.7 billion, leverage (reverse repos) and structured notes

Showa Shell Sekiyu: \$ 1.6 billion, currency derivatives

Metallgesellschaft: \$ 1.3 billion, oil futures

Barings: \$ 1 billion, equity and interest rate futures

Codelco: \$ 200 million, metal derivatives.

Proctor & Gamble: \$ 157 million, leveraged currency swaps.

Air Products & Chemicals: \$ 113 million, leveraged interest rate and currency swaps.

Dell Computer: \$ 35 million, leveraged interest rate swaps.

Louisiana State Retirees: \$ 25 million, IOs/POs.

Arco Employees Savings: \$ 22 million, money market derivatives.

Gibson Greetings: \$ 20 million, leveraged interest rate swaps.

Mead: \$ 12 million, leveraged interest rate swaps.

Figure 1: "Accidents" of the last two decades, source: Reto Gallati, Risk Management and Capital Adequacy, McGraw-Hill, New York, March 2003.

The Economics of Risk Management

The economics of risk management for financial firms is far from an exact science.

While rigorous and empirically testable models can be brought to the task of measuring financial risks, some of the benefits and costs of bearing these risks are difficult to quantify.

In a hypothetical world of perfect capital markets, adding or subtracting financial risk has no impact on the market value of a publicly traded corporation or on the welfare of its shareholders.

We can certainly agree, however, that capital markets are not perfect, and that market imperfections underly significant benefits to bearing and controlling financial risks.

It is difficult to quantify the costs and benefits in bearing/controlling risk. So, rather than a recipe providing in each case the appropriate amount of each type of risk to be borne in light of the costs and benefits, one should aim for a critical review of the nature of risks, the channels through which they can be measured and mitigated.

An appropriate appetite for risk is ultimately a matter of judgment that is informed by quantitative models for measuring risk and based on a conceptual understanding of the implications of risk.

The Leverage of Financial Firms

Compared with other types of corporations, financial firms have relatively liquid balance sheets, made up largely of financial positions.

This relative liquidity allows a typical financial firm to operate with a high degree of leverage.

For example, major broker-dealers regulated by SEC frequently have a level of accounting capital that is close to the regulatory minimum of 8% of account assets, implying a leverage ratio on the order of 12 to 1.

Ironically, in light of the relatively high degree of liquidity that fosters high leverage, a significant and sudden financial loss (or reduced access to credit) can cause dramatic illiquidity effects.

The Firm's Vulnerability to Losses

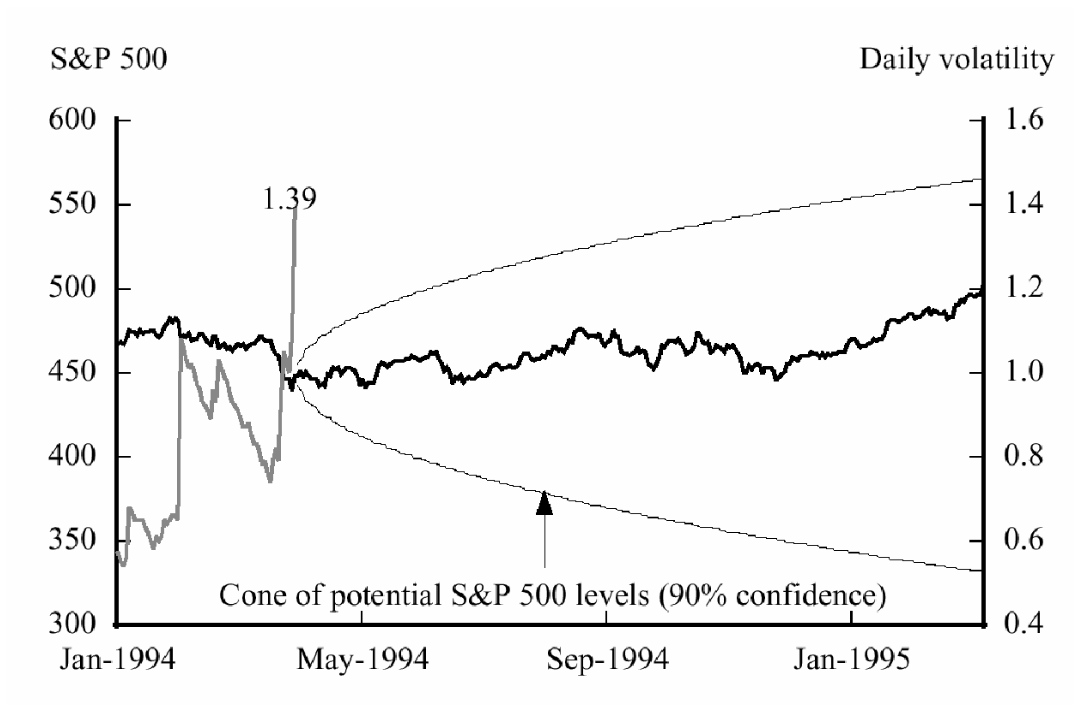

Figure 2: S&P 500 returns and VaR estimates (1.65σ)

The primary focus of risk-management teams at financial institutions is not on traditional financial risk, but rather on the possibility of extreme losses.

The benefits of this particular focus of risk management usually come from the presence of some kind of non-linearity in the relationship between the market value of the firm and its raw profits from operations.

Such non-linearity is typically associated with events that cause a need for quick access to additional capital or credit.

Capital - A Scarce Resource

If new capital could be obtained in perfect financial markets, we would expect a financial firm to raise capital as necessary to avoid the costs of financial distress.

In such a setting, purely financial risk would have a relatively small impact, and risk management would likewise be less important.

In fact, however, externally raised capital tends to be more costly than retained earnings as a source of funding.

External providers of capital tend to be less well informed about the firm's earnings prospects , charging the firm a "lemon's premium" that reflects their informational disadvantage.

They might also be concerned that the firm's managers have their own agenda, and may not use the capital efficiently.

A Brief Zoology of Risks

The risks faced by financial institutions fall largely into the following broad categories:

- Market Risk - unexpected changes in prices or rates.
- Credit Risk - changes in value associated with unexpected changes in credit quality.
- Liquidity Risk - the risk of increased costs, or inability to adjust

financial positions (for example through widening of spreads), or of lost access to credit.

- Operational Risk - fraud, systems failures, trading errors (such as deal mispricing).
- Systemic Risk - breakdown in market-wide liquidity, chain-reaction default.

Risk Management in a Non-Financial Firm, the Case of Merck

Related Materials:

- Lecture Notes: "Corporate Financial Risk Management," by Darrell Duffle, Graduate School of Business, Stanford University, Spring Quarter, 1996.

- Judy Lewent and John Kearney, "Identifying Measuring and Hedging Currency Risk at Merck," Journal of Applied Corporate Finance, vol 2, 1990, pp. 19-28.

Financial Background

As of 1994, Merck had been an extremely profitable firm with a low debt load (the debt/equity ratio is under 2%).

There is no financial distress on the horizon, essentially eliminating that as a motive for hedging.

For 1994, Merck's sales were $15 billion, of which 32% were foreign. Sales were enhanced by 1% in dollar terms in 1994 by changes in foreign exchange rates. Fluctuations in currency prices reduced earnings by 2% in 1993.

R&D expenditures in 1994 were $ 1.2 billion.

A Strong Dollar Scenario

Consider a scenario in which the U.S. dollar has strengthened dramatically, say 20%. At current levels of foreign revenue, the 20% strengthening in U.S. dollar translates into an unexpected shortfall of about $1 billion in revenues. Management is not to blame for fluctuations in foreign currency markets. Exchange rates are difficult to predict, after correcting for differences between domestic and foreign interest rates.

Managers, however, will be expected to deal with the immense amount of shortfall represented by this sort of scenario:

1. Are dividends to be cut?
2. What R&D program? How will it be funded?

Funding all positive NPV projects and at the same time maintaining stable dividends in this scenario could call for issuing new debt.

Not only are debt underwriting costs considerable, crucial information regarding the profitability of the R&D program is likely to be unknown by potential bond investors.
This means that the rate of return demanded by outside bond investors may include an extra risk premium for the information that they do not hold.

In other words, what might have been a positive NPV project, when funded with retained earnings, may now be a negative NPV project, when funded with new debt, and may therefore be dropped.

Finally, shareholders may not be aware that weak earnings are due to financial market effects beyond management control, and could inappropriately blame management.

A Program of Foreign Exchange

Quoting from the 1994 annual report, Merck claims that:

"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".

Some **Details**: The value of purchased currency options, the largest category of hedging instruments shown in Merck's disclosure under "fair value of financial instruments", was $ 42.5 million as of year-end 1994, on a notional amount of $ 1.79 billion underlying these options.

- The carrying value of these options is shown as $ 97.6 million, indicating a loss of $ 55 million, more than half of the value of the options. This is consistent with the hedging role of these options and the fact that sales were enhanced by approximately 1% (roughly $150 million) due to fluctuations in exchange rates.
- On a "delta" basis, one may therefore draw the conclusion that

Merck has hedged roughly one-third of its exposure to foreign exchange rates.

Accounting Issues

Consider a 750 million Euro put option hedge against a 1 billion Swiss franc receivable on next year's sales.

Suppose the puts expire in one year, and were purchased for about 7.5 million dollars. Suppose the market value of the options dropped to 2.5 million dollars during the next quarter because of a risk in the value of the Euro.

Since there is roughly a 90% correlation between Swiss franc price changes and Deutsch Mark price changes, it is quite likely that the market value of receivable francs has risen and at least partially offset the loss on the options.

If the put position is marked-to-market for accounting purposes, as would be required by an SEC ruling, then the 5 million dollar decline in value of the put position would show up on the balance sheet or income statement as a reduction of $ 5 million.

The receivable, however, would not typically be marked to market under current accounting standards.

Before the publication of FAS 133, if the options were written on Swiss francs rather than marks, and a number of other conditions were met, then accounting standards would allow losses or gains on the put options to be deferred until the francs are received and recorded.

This situation is often called hedge accounting. In his 1996 lecture notes, Darrell Duffie wrote: "The criteria for hedge accounting are governed by a bewildering, complicated, and quickly changing array of different accounting standards". Sure enough, we now have a new accounting rule, FAS 133 (amended by FAS 137 and 138), which is based on a non-economic separation of option time value and intrinsic value.

Futures and Basis Risk

Basis risk arises when the characteristics of the futures contract differ from those of the underlying.

For example quality of agricultural products, types of oil, cheapest to deliver (CTD) bond, etc.

$$Basis = Spot - Futures \tag{1}$$

Cross Hedging

Hedging with a correlated (but different) asset.

- In order to hedge an exposure to Norwegian Krone one can use Euro futures.
- Hedging a portfolio of stocks with index futures.

The optimal Hedge Ratio

$$\begin{aligned} \Delta S &- change\ in\ \$\ value\ of\ the\ inventory & (2) \\ \Delta F &- change\ in\ \$\ value\ of\ the\ one\ futures & (3) \\ N &- number\ of\ futures\ to\ buy/sell & (4) \end{aligned}$$

$$\begin{aligned} \Delta V &= \Delta S + N \cdot \Delta F & (5) \\ \sigma^2_{\Delta V} &= \sigma^2_{\Delta S} + N^2 \cdot \sigma^2_{\Delta F} + 2 \cdot \sigma_{\Delta S, \Delta F} & (6) \\ \frac{\partial \sigma^2_{\Delta V}}{\partial N} &= 2 \cdot N \cdot \sigma^2_{\Delta F} & (7) \end{aligned}$$

Minimum variance hedge ratio:

$$N_{opt} = -\frac{\sigma_{\Delta S, \Delta F}}{\sigma^2_{\Delta F}} = -\rho_{\Delta S, \Delta F} \cdot \frac{\sigma_{\Delta S}}{\sigma_{\Delta F}} \tag{8}$$

Hedge Ratio as Regression Coefficient

The optimal amount can also be derived as the slope coefficient of a regression $\Delta S/S$ on ΔF:

$$\frac{\Delta S}{S} = \alpha + \beta_{SF} \cdot \frac{\Delta F}{F} + \varepsilon \tag{9}$$

$$\beta_{SF} = \frac{\sigma_{SF}}{\sigma_{SF}^2} = \rho_{SF} \cdot \frac{\sigma_S}{\sigma_F} \tag{10}$$

Optimal Hedge

One can measure the quality of the optimal hedge ratio in terms of the amount by which we have decreased the variance of the original portfolio.

$$\begin{aligned} R^2 &= \sigma_S^2 - \sigma_V^2 \sigma_S^2 = \rho_{SF}^2 \\ \sigma_V &= \sigma_S \sqrt{1 - R^2} \end{aligned} \tag{11}$$

where V stands for Value including hedge.

If R^2 is low the hedge is not effective!

At the optimumum the variance of the hedged portfolio is:

$$\sigma_V^2 = \sigma_S^2 - \frac{\sigma_{SF}^2}{\sigma_F^2} \tag{12}$$

Example: An airline company needs to purchase 10'000 tons of jet fuel in 3 months. We can use heating oil futures traded on NYMEX. Notional for each contract is 42'000 gallons. We need to check whether this hedge can be efficient.

Spot price of jet fuel is \$ 277/ton. Futures price of heating oil is \$ 0.6903/gallon.

The standard deviation of jet fuel price rate of changes over 3 months is 21.17%, that of futures 18.59%, and the correlation is 0.8243.

Compute:

- The notional and the standard deviation of the unhedged fuel cost in dollars.
- The optimal number of futures contracts to buy/sell, rounded to the closest integer.
- the standard deviation of the hedge fuel cost in dollars.

Solution:

The notional is $N = \$2'770'000$, the standard deviation in dollars is:

$$\sigma(\Delta S/S) \cdot S \cdot N_S = 0.2117 \cdot 277 \cdot 10'000 = \$586'409 \tag{13}$$

The standard deviation of one futures contract in dollars is:

$$\sigma(\Delta F/F) \cdot F \cdot N_F = 0.1859 \cdot 0.6903 \cdot 42'000 = \$5'390 \tag{14}$$

The futures notional in dollars is:

$$F \cdot N_F = 0.6903 \cdot 42'000 = \$28'993 \tag{15}$$

The position corresponds to a liability (payment), hence we have to buy futures as a protection.

$$\beta_{SF} = 0.8243 \cdot \frac{0.2117}{0.1859} = 0.9387 \quad (16)$$

$$\sigma_{SF} = 0.8243 \cdot 0.2117 \cdot 0.1859 = 0.03244 \quad (17)$$

The optimal hedge ratio is:

$$HR_{opt} = \beta_{SF} \cdot \frac{N_S \cdot S}{N_F \cdot F} = 89.7,\ \ or\ 90\ contracts \quad (18)$$

$$\sigma^2_{unhedged} = \$586'409^2 = 343'875'515'281 \quad (19)$$

$$-\sigma^2_{SF}/\sigma^2_F = -(2'605'268'452/5'390)^2 \quad (20)$$

$$\sigma^2_{hedged} = \$331'997 \quad (21)$$

The hedge has reduced the standard deviation from \$586'409 to \$331'997.

$R^2 = 67.95\% \quad (= 0.8243^2)$

Term structure strategies

Bullet strategy: Maturities of securities are concentrated at some point on the yield curve.

Barbel strategy: Maturities of securities are concentrated at two extreme maturities.

Ladder strategy: Maturities of securities are distributed uniformly on the yield curve.

Example:

bond	coupon	maturity	yield	duration	convexity
A	8.5%	5	8.5	4.005	19.81
B	9.5%	20	9.5	8.882	124.17
C	9.25%	10	9.25	6.434	55.45

Portfolios:

- Bullet portfolio: 100% bond C
- Barbell portfolio: 50.2% bond A, 49.8% bond B

Dollar-duration of barbell portfolio:

$$0.502 \cdot 4.005 + 0.498 \cdot 8.882 = 6.434 \tag{22}$$

It has the same duration as bullet portfolio.

Dollar-convexity of barbell portfolio:

$$0.502 \cdot 19.81 + 0.498 \cdot 124.17 = 71.78 \tag{23}$$

The convexity here is higher!

The yield of the bullet portfolio is 9.25%.

The yield of the barbell portfolio is 8.998%.

This is the *cost of convexity*!

Stock Index Futures

A stock index tracks changes int he value of a hypothetical portfolio of stocks. The weight of a stock in the portfolio equals the proportion of the portfolio invested in the stock. The percentage increase in the stock index over a small interval of time is set equal to the percentage increase in the value of the hypothetical portfolio. Dividends are usually not included in the calculation so that the index tracks the capital gain/loss from investing in the portfolio.[1]

If the hypothetical portfolio of stocks remains fixed, the weights assigned to individual stocks in the portfolio do not remain fixed. When the price of one particular stock in the portfolio rises more sharply than others, more weight is automatically given to that stock. Some indices are constructed from a hypothetical portfolio consisting of one of each of a number of stocks. The weights assigned to the stocks are then proportional to their market prices, with adjustments being made when there are stock splits. Other indices are constructed so that weights are proportion to market capitalization ($stock\ price \cdot number\ of\ shares\ outstanding$). The underlying portfolio is then automatically adjusted to reflect stock splits, stock dividends, and new equity issues.

The following summary highlights the key differences between the most important stock indices:

- The Down Jones Industrial Average is based on a portfolio consisting of 30 blue chip stocks in the United States. The weights given to the stocks are proportional to their prices.
- The Standard & Poor's 500 (S&P500)Index is based on a portfolio

[1] An exception to this is a total return index. This is calculated by assuming that dividends on the hypothetical portfolio are reinvested in the portfolio

of 500 different stocks, 400 industrials, 40 utilities, 20 transportation companies, and 40 financial institutions. The weights in the portfolio at any given time are proportional to their market capitalizations.

- The NASDAQ 100 is based on 100 stocks using the National Association of Securities Dealer Automatic Quotations Service.

All futures contracts on stock indices are settled in cash, not by delivery of the underlying asset. All contracts are marked to market on the last trading day, and the positions are then deemed to be closed. For most contracts, the settlement price on the last trading day is set at the closing value of the index on that day. For the futures on the S&P 500, the last trading day is the Thursday before the third Friday of the delivery month.

Futures Prices of Stock indices

An index can be thought of as an investment asset that pays dividends. The asset is the portfolio of stocks underlying the index, and the dividends are the dividends that would be received by the holder of this portfolio. Often there are many stocks underlying the index providing dividends at different times. To a reasonable approximation, the index can then be considered as an asset providing a continuous dividend yield. if q is the dividend yield rate, equation **??** gives the futures price, F_0, as:[2]

$$F_0 = S_0 \cdot e^{(r-q)\cdot T} \tag{24}$$

Example: Consider a 3-month futures contract on the S&P 500. Suppose that the stocks underlying the index provide a dividend yield of

[2]For a total return index, dividends are assumed to be reinvested in the portfolio underlying the index so that q=0 and $F_0 = S_0 \cdot e^{r\cdot T}$

3% per annum, that the current value of the index is 900, and that the continuously compounded risk-free interest rate is 8% per annum. in this case, r=0.08, S_0=900, T=0.25, and q=0.03, and the futures price, F_0, is given by:

$$F_0 = S_0 \cdot e^{(r-q)\cdot T} \quad (25)$$

$$= 900 \cdot e^{(0.08-0.03)\cdot 0.25} = 911.23 \quad (26)$$

In practice, the dividend yield on the portfolio underlying an index varies week by week throughout the year.

Hedging using Index Futures

Stock index futures can be used to hedge the risk in a (usually well-diversified) portfolio or individual stocks (individual stock-futures work better for some specific stocks). We will use β as the coefficient from the CAPM and the regression. This is the slope of the best-fit line obtained when the excess return on the portfolio over the risk-free rate is regressed against the excess return on the market over the riskfree rate. When $\beta = 1.0$, the return on the portfolio tends to mirror the return of the market; when $\beta = 2.0$, the excess return on the portfolio tends to be twice as great as the excess return on the market; when $\beta = 0.5$, it tends to be half as great; and so on.

When the β of the portfolio equals 1, the position in futures contracts should be chosen so that the value for the stocks underlying the futures contacts equals the total value of the portfolio being hedge. When $\beta = 2$, the portfolio is twice as volatile as the stocks underlying the futures contract and the position in futures contacts should be twice as great. When

$\beta = 0.5$, the portfolio is half as volatile as the stocks underlying the futures contract and the position should be half as great. In general, if we define:

P portfolio value;

F value of assets underlying one futures contract.

The correct number of contracts to short in order to hedge the risk in the portfolio is:

$$\beta \cdot \frac{P}{F} \tag{27}$$

The formula assumes that the maturity of the futures contract is close to the maturity of the hedge and ignores the daily settlement of the futures contract.

Example: A company wishes to hedge a portfolio worth \$ 2'100'000 over the next three months using an S&P 500 index futures contract with four months to maturity. The current level of the S&P 500 is 900 and the β of the portfolio 1.5. The value of the assets underlying one futures contract is $900 \cdot 250 = \$225'000$. The correct number of futures contracts to short is, therefore:

$$1.5 \cdot \frac{2'100'000}{225'000} = 14 \tag{28}$$

To show that the hedge works, we suppose the risk-free rate is 4% per year and the market provides a total return of -7% in the course of the next three months. This is bad news for the portfolio. The risk-free rate is 1% per three months so that the return on the market is 8% below the risk-free rate. We therefore expect the return (including dividends) on the portfolio during the three months to be $1.5 \cdot 8 = 12\%$ below the risk-free rate, or -11%. Assume that the dividend yield on the index is 2% per annum, or 0.5% per three months. This means that the index declines by. 7.5% during the three months, from 900 to 832.5. Equation **??** gives the initial futures price as:

$$900 \cdot e^{(0.04 \cdot -0.02) \cdot \frac{4}{12}} = 906.02 \tag{29}$$

and the final futures price as:

$$832.5 \cdot e^{(0.04 \cdot -0.02) \cdot \frac{1}{12}} = 833.89. \tag{30}$$

The gain on the futures position is:

$$(906.02 - 833.89) \cdot 250 \cdot 14 = 252'455 \tag{31}$$

The total loss on the portfolio is $0.11 \cdot 2'100'000 = \$231'000$. The net gain form the hedge position is $252'455 - 231'000$ or about 1% of the value of the portfolio. This is as expected. The return on the hedged position during the three months is the risk-free rate. It is easy to verify that roughly the same return is realized regardless of the performance of the market.

Questions for Next Class

Read:

- Kritzman (1994a)
- Kritzman (1994b)
- Ross (1999), and
- Perrold (1999) regarding hedge funds.