

VALUE AT RISK:
The New Benchmark for
Managing Financial Risk
THIRD EDITION

Answer Key to End-of-Chapter Exercises

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Chapter 1: The Need for Risk Management

1. A depreciation of the exchange rate, scenario (a), is an example of financial market risk, which can be hedged. Scenario (2) is an example of a business risk, because it could have been avoided by better business decisions. Scenario (3) is a broader type of risk, which is strategic.

2. This is incorrect. Financial risks are related. An increase in oil prices could push down the stock prices of companies that are hurt by higher oil costs.

3. This is incorrect. Casinos *create* risk. Financial markets do not create risk. Instead, market prices fluctuations are coming from a variety of sources, including effects of company policies, government policies, or other events. In fact, financial markets can be used to hedge, transfer, or manage risks.

4. A derivative contract is a private contract deriving its value from some underlying asset price, reference rate, or index, such as stock, bond, currency, or commodity. For example, a forward contract on a foreign currency is a form of a derivative. Derivatives are instruments designed to manage financial risks efficiently.

5. Exchange-traded instruments include interest rate futures and options, currency futures and options, and stock index futures and options. OTC instruments include interest rate swaps, currency swaps, caps, collars, floors and swaptions.

6. Derivatives are typically leveraged instruments. In most cases, they require minimal or no cash outlay. As a result, their risks are more difficult to assess.

7. This is incorrect. Notional amounts do not reflect the potential losses, which are instead changes in market values. These are much smaller than notional amounts. Also, many counterparties are using these markets to hedge their risk, making the financial system safer.

8. VAR describes the quantile of the projected distribution of gains and losses over the target horizon. Intuitively, it summarizes the worst loss over a target horizon with a given level of confidence. VAR is measured in currency units (e.g., dollar, euro, yen), which makes it more intuitive to understand. VAR is also based on the current positions, so is a forward-looking measure of risk.

9. No. The original purpose of VAR systems was to quantify market risk. It applies to any financial instruments. Now it is being extended to credit risk and operational risk.

10. The loss can be expected to be at least \$2.5 million in $N = 5$ out of next 100 days, where $N = (100\% - 95\%) \times 100 = 5$.

11. No. A 95% confidence level means that we expect to have a greater (not worse) return than VAR in 95% of cases.

12. No. Derivatives pricing needs to be precise, at least down to the level of bid-ask spreads. In contrast, risk management attempts to give an idea of the size and probability of losses. It also applies at a much broader level and requires many more assumptions.

13. Market risk, liquidity risk, credit risk, and operational risk.

14. Directional risks refer to exposures to the direction of movements in financial variables, such as stock prices, interest rates, exchange rates, and commodity prices. It is measured by beta, duration or delta. Nondirectional risks consist of nonlinear exposures and exposures to hedged positions or to volatilities. It can be measured by convexity, gamma, basis risk, or volatility risk.

15. No. Generally, credit risk can be defined as the potential loss in mark-to-market value that could arise from a credit event, such as a credit downgrade.

16. Settlement risk occurs during the process of settling trades, e.g., payment in one currency against another. This is different from pre-settlement risk, which involves the possibility of default during the life of an obligation.

17. The default from Bank C for Bond A is an example of settlement risk. The default on Bond B is an example of pre-settlement risk, or the usual credit risk.

18. This is incorrect. Credit and legal risk, for instance, interact with each other (see the swap example).

19. The notional provides a poor measure of market risk, as it does not differentiate between investments with no risk or high risk (for example cash versus 30-year bonds). Duration accounts for the severity but not the probability of losses. Leverage does not take into account portfolio diversification effects. VAR takes into account potential losses on the total portfolio, so is the best measure compared with other three. In practice, VAR should be augmented by stress tests. Limits on notionals are still useful against flaws in the VAR model.

Chapter 2: Lessons from Financial Disasters

1. S&L were making long-term loans for residential housing that were funded by short-term deposits. As short-term interest rates zoomed up in the early 1980s, S&Ls were squeezed in a *duration gap*. Their costs went up more than their revenues.

2. The \$30 billion cumulative loss seems large, but less so when related to notional amounts of around \$100,000 billion at the time. This is only 0.3 percent of notionals, which is also much less than the mark-to-market value of around 4%. Finally, these losses could have been due to hedging activities, which then should involve a gain somewhere else (as in the case of MG).

3. The cost of financial insolvencies is much higher than derivatives losses. Banking systems typically fail because of bad risk management practices, or government intervention.

4. Market risk and operational risk.

5. Certainly not. This would set a bad example. Other banks could take on too much risk, knowing they would be rescued anyway.

6. To hedge against the possibility of oil price increases, MGRM should have entered long-term forward contracts on oil, matching the maturity of the contracts and of the commitments. In the absence of a viable market for long-term contracts, however, MGRM turned to the short-term futures market and implemented a *rolling hedge*. In this strategy, the long-term exposure is hedged through a series of short-term contracts, with maturities around 3 months, which are rolled over into the next contract as they expire. *Basis risk* is the risk that short-term oil prices temporarily deviate from long-term prices. The large drop of cash prices from \$20 to \$15 in 1993 led to about a billion dollars of margin calls that had to be met in cash. Thus, this was a mix of market risk and liquidity risk.

7. The losses on the Orange County Investment Pool can be traced to the interest rate hikes that started in February 1994. The losses were caused by market and liquidity risk.

8. Operational risk, or, in this case, fraud.

9. Barings and Daiwa involved a mix of market and operational risks. Traders committed fraud, but this was also a failure of the systems and people who should have supervised them.

10. First, a tabular presentation of expected cash flows and contract terms summarized by risk category; second, sensitivity analysis expressing possible losses for hypothetical changes in market prices; third, value-at-risk measures for the current reporting period, which are to be compared to actual changes in market values.

11. No. Derivatives have been booming since 1997.

12. No. Companies should set up risk systems anyway to control their risks. The question is whether the new rules create unnecessary requirements.

Chapter 3: Regulatory Capital Standards with VAR

1. Externalities and deposit insurance. Unlike the case of airlines, the failure of a bank could endanger other banks. Also, bank deposits are insured by the government, which has an incentive to ensure that banks do not take too much risk.

2. The objective functions may not be the same as those of the government. The shareholders of a bank may not worry about systemic risk. Also, they may have incentives to take on too much risk because part of this risk is borne by others (e.g., the deposit insurance).

3. Moral hazard arises when people do not bear the cost of their actions fully. In the context of automobile insurance, the driver could drive less carefully, for example. This is like having a fixed insurance premium that does not reflect the risks of the driver. Risk-sensitive capital requirements create an incentive to pay attention to risks.

4. This increases the cost of business, reducing the return to investors in the banking business, making the cost of banking services more expensive to customers. Or, it could create incentives to move operations to other countries.

5. Tier 1 capital includes paid-up stock issues and disclosed reserves, most notably from after-tax retained earnings. At least 50% of the capital charge must be covered by tier 1 capital.

6. Tier 2 capital includes perpetual securities, undisclosed reserves, subordinated debt with maturity greater than 5 years, and shares redeemable at the option of the issuer.

7. A weight of zero is assigned to U.S. Treasuries, and a weight of 100% is assigned to claims on corporations, including loans, bonds, and equities.

8. Eight percent.

9. Mainly, the rules are not credit-sensitive. They do not take diversification effects into account. They could also lead to regulatory arbitrage, which may have the effect of increasing the risk of banking institutions.

10. Government debt has a weight of zero. Corporate loans have a weight of 100%. Hence, the CRC is a minimum of \$8 million, of which \$4 million should be in tier 1.

11. Highly-rated sovereign debt still has a weight of zero. For A-rated debt, the weight is now 50%, so the capital charge is halved under the standardized approach. In addition, however, there is an operational risk charge.

12. Market risk.

13. The horizon is 10 days, with a 99 percent confidence interval. In addition, the observation period must be based on at least a year of historical data and updated at least once every quarter.

14. The minimum value is 3.

15. The market risk charge is much smaller than the credit risk capital requirement.

16. There are no additional costs; the system uses the most advanced rules; the system takes into account diversification effects.

17. No. Components of the bank's internal credit risk systems can be used, however, such as estimates of default probabilities and loss given default.

18. Portfolio risk is overestimated because diversification benefits are ignored.

19. See Table 3-5. The goals are, respectively: (a) safety and soundness, protecting the deposit insurance fund, (b) protecting customers, protect integrity of securities market, (c) protecting claimants, (d) protecting retirees and the pension insurance fund. Note that these goals may not be consistent with each other.

20. This is also the moral hazard problem. With fixed insurance premiums, there is an incentive to take on additional risks. This could be solved with risk-sensitive capital requirements, i.e., charging a premium that depends on the risk of the pension plan.

Chapter 4: Tools for Measuring Risk

1. This portfolio is exposed to interest rate and currency risks. The portfolio could lose value if interest rates move up or if the value of the yen falls relative to the dollar.

2. From Figures 4-1 to 4-4, stock markets typically have a volatility of 20 percent per annum, followed by exchange rates at 12 percent.

3. The mean is a measure of central tendency, not dispersion. The standard deviation is a measure of dispersion. A distribution with higher standard deviation has greater dispersion of outcomes and is more risky.

4. The cumulative probability is $(1 + 2 + 3 + 4)/36 = 10/36$, or 27.8%.

5. The cumulative probability of observing 2 or less is $1/36 = 0.0277$. The probability of observing 3 is $2/36 = 0.0555$; the associated cumulative probability is 0.0833. Hence, 2 is the desired quantile because its cumulative probability is just below 0.05.

6. The potential for loss derives from two sources. The exposure to interest rates, which is under the control of the manager, and the movements in the risk factors, which are outside his control.

7. In the fixed-income market, exposure to movements in interest rates is called duration. In the stock market, this exposure is called systematic risk, or *beta*. In derivatives markets, the exposure to movements in the value of the underlying asset is called *delta*.

8. Convexity measure the linear exposure to movement in interest rates. Gamma is the second-order exposure for options.

9. From Figure 4-8, the former is riskier.

10. The mean is \$1.22 and the standard deviation is \$0.32. This is obtained as $\mu = 0.05 \times 1.0 + 0.2 \times 1.1 + 0.4 \times 1.2 + 0.2 \times 1.3 + 0.15 \times 1.4 = 1.22$. The variance is $\sigma^2 = 0.05(1.0 - 1.22)^2 + 0.2(1.1 - 1.22)^2 + 0.4(1.2 - 1.22)^2 + 0.2(1.3 - 1.22)^2 + 0.15(1.4 - 1.22)^2 = 0.102$ and $\sqrt{0.102} = 0.32$.

11. VAR=\$2; ETL=\$2.8. The mean is \$10 since the distribution is symmetrical. The probability that the price will be strictly greater than \$8 is 96%, so \$8 is the cutoff price. Therefore, VAR is \$10-\$8=\$2. The ETL is then computed using probability weights, or $0.01 \times \$5 + 0.03 \times \$8 = \$0.29$, which normalized by 0.04 or the total probability of being in the tail, gives \$7.25. The deviation from the mean is then \$10-\$7.25, or \$2.75.

12. The ETL will change, but not the VAR.

13. The 99% VAR is 2.326, with ETL of 2.665. From Table 4-3, the quantile and ETL are 3.143 and 4.033 for the Student t distribution.

14. The distribution cannot be strictly normal because this would involve the possibility of negative prices. Because of limited liability, prices cannot turn negative.

15. The approximation works better for shorter horizons because the dispersion is less, leading to a negligible probability of prices turning negative.

16. High kurtosis means that the tails of the probability density function are *thick*, which means there is a high probability of large movements, which could generate large losses.

17. The standard errors are in Equations (4.34) and (4.35), with $T = 120$. This gives a t -statistic of $-0.2/0.22 = -0.89$ and $(3.5 - 3)/0.34 = 1.12$. So, we cannot reject that the skewness and kurtosis are in line with a normal distribution.

18. Large kurtosis is associated with fatter tails.

19. As n tends to infinity, the distribution tends to a normal distribution. This implies the kurtosis tends to 3. The skewness is always zero, because the Student distribution is symmetric.

20. The log return over long horizons is the sum of daily log returns. As a result, due to the Central Limit Theorem, the sum of i.i.d. variables should tend to the normal distribution.

21. The adjustment of volatility to different horizons is based on a square root of time factor.

22. Trending markets involve positive autocorrelation, in which case the usual square root of time underestimates risk.

23. Following Equation (4.40), the 2-month risk is given by $\sigma\sqrt{(2 + 2\rho)}$. For $\rho = 0.0$ and 0.5, this gives 1.41 and 1.73, respectively.

Chapter 5: Computing Value at Risk

1. $\text{VAR} = \alpha(\sigma W) = 2.326(0.0157 \times \$10) = \$0.365$ million.

2. From Table 5-2, the ratio of MaxVAR to VAR is 1.107. This gives a MaxVAR of \$0.404 million.

3. MaxVAR should decrease because some drawdowns followed by recoveries might be missed.

4. From the discussion of Table 4-3, the multiplier for the Student t with $n = 6$ is $\alpha = 2.57$ instead of 2.33. VAR is then \$0.403 million.

5. A decrease in the horizon, a decrease in the confidence level, or a decrease in the volatility, will result in a decrease in VAR. A lower sized position will reduce VAR as well.

6. The Basel Committee requires VAR to be calculated with a 99 confidence level, a 10 trading day horizon, at least one year of historical data, and a quarterly update for VAR calculations.

7. This is the maximum of the previous day's VAR and the VAR average of the last 60 days, multiplied by a specific factor k , plus a specific risk charge.

8. Because the safety factor k has to be equal to or greater than 3, the capital charge has to be equal to or greater than 3 times \$320,000, which is also \$960,000. The current VAR is \$293,000 and is thus not binding.

9. Measurement error can arise from (a) normal sampling variation due to a limited sample size, (b) different methodologies used to calculate VAR, and, more generally, (c) model risk.

10. In absolute terms, the expected tail loss must be greater than VAR.
11. For capital adequacy purposes, a long term horizon is advisable. Institutions will want to have enough capital to cover their losses while they take corrective action as problems start to develop.
12. For capital adequacy purposes, a high confidence level is advisable. Most institutions will want to hold enough capital to cover losses in a high proportion of situations.
13. Backtesting is better with a greater number of comparisons, or shorter horizons, using confidence levels that are not too high. For capital adequacy, on the other hand, longer horizons and high confidence levels are advisable.
14. VAR is proportional to the square root of time horizon. The square root of 10 is 3.16. Hence VAR increases by 3.16 times.
15. $\text{VAR} = 1.645 \times 0.0126\sqrt{5} \times 10,000,000 = \$463,469$.
16. The standard error is $\$1/\sqrt{2 \times 500} = 0.0316$, which gives a total value of 14,565. So, the interval is [434,157–492,782].
17. No. The confidence interval around a sigma-based VAR is tighter than for a sample quantile.
18. The general/non-parametric approach, the parametric approach, and EVT. The first approach is based on the empirical distribution and its sample quantile. The second measures VAR from the standard deviation obtained by fitting a parametric distribution such as the normal distribution to the data. The parametric approach is more precise if the distributional assumption is correct. On the other hand, the distribution may not be correct. The general approach, however, is more imprecise. EVT is a semi-parametric method, and is more precise than the non-parametric approach.
19. For the normal distribution, the tail parameter ξ is zero. Typically, it is positive, which reflects fatter tails than the normal.
20. From Equation (5.21), we have $2 + (0.6/0.2)[(1000/50)(1 - 0.99)]^{-0.2} - 1$, or 3.14% for the 99% VAR and 5.56% for the 99.9% VAR..
21. No. EVT provides a smoother distribution than the sample quantile but still relies on historical data. If this does not contain a sufficient number of extreme observations, EVT will not pick up extreme losses.

Chapter 6: Backtesting VAR Models

1. Backtesting is a statistical process that compares the number of observed exceptions to their expected number. An exception is defined as a case where the trading loss is worse than VAR. If there are too many exceptions, the model is probably wrong.
2. No. The failure must be due to other factors in the actual P&L, such as fee income, which are not captured by VAR.
3. A type 1 error is the error of rejecting a correct model, while a type 2 error is the error of not rejecting an incorrect model. A type 1 error means rejecting a correct risk model. A type 2 error is failing to catch a bank that has a wrong risk model. Both types of errors should be avoided, but there is tradeoff between these two errors.
4. The decision rule should be designed so as to use *powerful* tests. For instance, the confidence level for VAR should not be too high, because this decreases the power of the tests. Also, a greater number of observations increases the power of the test.

5. On average, the number should be about 2.5. This higher number could happen either because of bad luck or because of a wrong risk model. It is unlikely, however, that this outcome is due solely to bad luck.

6. The z-test is $(0.01 \times 252 - 9)/\sqrt{0.99 \times 0.11 \times 252} = -4$. This is greater than 2 in absolute value, making the model seem erroneous.

7. VAR measures assume that the current portfolio is frozen over the horizon. In fact, the trading portfolio evolves dynamically during the day. Thus the actual portfolio is contaminated by changes in its composition. This contamination is minimized by a shorter horizon. Also, a shorter horizon increases the number of observations, which increases the power of the tests.

8. When the bank passes the test, the value of k is 3. For 10 or more exceptions, this increases to 4.

9. Typical backtests focus on the average bias, or unconditional coverage. Conditional coverage instead also looks at the bunching of exceptions. If there is too much bunching, models may need to be modified to allow for time-variation in risk.

10. We build an exception table as in Table 6-5.

		Day Before		Unconditional
		No Exception	Exception	
Current day	No exception	244	2	246
	Exception	2	4	6
Total		246	6	252

The fraction of exceptions is $6/252=2.4\%$, compared to the target of 1% . Using Equation (6.3), we find $LR_{uc} = 3.498$, which is less than the chi-square cutoff point of 3.84, so we do not reject the hypothesis that there is no bias. From Equation (6.4), $LR_{ind} = 25.837$, which is too high. So, it seems that there is bunching.

11. One explanation is that the models are too simple. For example, risk managers could have added up the capital charge across business lines without taking into account diversification benefits. Another is that actual returns are used instead of hypothetical returns and that positions change during the day to lower risk. Alternatively, banks may not want to be bothered by regulators asking many questions when too many exceptions arise. In such situations, the banks may want to provide high VAR numbers to avoid regulatory intrusion.

Chapter 7: Portfolio Risk: Analytical Methods

1. The marginal VAR measures the change in VAR for a small change in an asset's position.

2. Scenarios (a), (c), and (d) increase risk. Increasing the number of assets decreases risk.

3. There is no diversification effect. The risk is the sum of the two risks.

4. The risk is the sum of the two risks.

5. From Equation (7.10), this will tend to $\sigma\sqrt{\rho} = 0.10\sqrt{0.2} = 0.045$ percent.

6. Non-coherent means that the risk of two assets can be greater than the sum of the risks of the two individual assets. For a normal distribution, however, the volatility of a

sum is less than the sum of volatilities (or at worst equal). Because VAR is proportional to volatility, VAR is coherent in this case.

7. The component VAR for Asset 2 is negative, meaning that it is a hedge.

8. By ignoring second-order and higher order terms, incremental VAR can be reported as, approximately, marginal VAR vector multiplied by the new position vector, which is much faster to implement than a full revaluation of the portfolio VAR.

9. There is no general relationship for each asset. On average, however, component VAR is likely to be less than individual VAR, unless some are negative and large. Individual VARs add up to more than the total VAR because of diversification effects. Component VARs, in contrast, add up to the total VAR. Hence, component VARs is less than individual VARs, on average.

10. We find the component VAR by multiplying the dollar position by its corresponding marginal VAR.

11. Marginal VAR describes the largest effect on the portfolio VAR for an equal change in the positions on the risk factors. This is the appropriate risk measure for this purpose.

12. The best hedge is the position in each asset that minimizes the total risk.

13. At the optimum, all marginal VARs should be the same, as in Equation (7.35).

14. At the optimum, all marginal VARs should be proportional to expected returns, as in Equation (7.38).

15. (a) The portfolio variance is obtained from $x'\Sigma x$, or

$$[\$100,000 \quad \$100,000] \begin{bmatrix} 0.05^2 & -0.50 \times 0.05 \times 0.2 \\ -0.50 \times 0.05 \times 0.2 & 0.2^2 \end{bmatrix} \begin{bmatrix} \$100,000 \\ \$100,000 \end{bmatrix}$$

which gives 325,000,000. Taking the square root, we get a volatility of \$18,028 and diversified VAR of \$29,656. Note that the individual VARs are \$8,225 and \$32,900, for a total undiversified VAR of \$41,125.

(b) The marginal VARs are obtained from

$$\Delta \text{VAR} = \frac{\text{VAR}}{x'\Sigma x} \Sigma x = \frac{\$29,656}{325,000,000} \begin{bmatrix} 0.0025 & -0.0050 \\ -0.0050 & 0.0400 \end{bmatrix} \begin{bmatrix} \$100,000 \\ \$100,000 \end{bmatrix} = \begin{bmatrix} -0.0228123 \\ +0.3193715 \end{bmatrix}$$

The component VARs are obtained by multiplying these by the size of the positions. This gives -\$2,281 and \$31,937, which indeed add up to \$29,656. The component VAR for CGB is negative, indicating that it lowers the portfolio risk.

(c) When the CGB position is set to zero, the risk becomes the individual VAR for the other asset, or $1.645 \times 20\% \times \$100,000 = \$32,900$. The incremental VAR is therefore $\$32,900 - \$29,656 = \$3,244$. Note that decreasing the position in CGB leads to higher risk.

Chapter 8: Multivariate Models

1. A large number of factors will increase the size of the covariance matrix, which can cause computational problems.

2. This can happen when two series are identical or when $T < N$.

3. (a) The matrix is not positive definite. Its determinant is $1 \times 1 - 1 \times 1 = 0$. Alternatively, the correlation coefficient is unity.

(b) This means that the two series are basically identical, or represent the same risk factor.

(c) A position of $(-1, +1)$ has zero risk. Computing Σx gives a column of zeroes, therefore the variance is zero.

4. The variance of stock A is $(0.8 \times 0.15)^2 + (0.12)^2 = 0.0288$, or volatility of 0.1697. The variance of stock B is $(1.2 \times 0.15)^2 + (0.20)^2 = 0.0724$, or volatility of 0.2691. The covariance is $(0.8 \times 1.2 \times 0.15^2) = 0.0216$, and the correlation is $0.0216 / (0.1697 \times 0.2691) = 0.473$.

5. We can verify that the volatility of any asset is unity. So, the correlation between asset i and j is also the covariance, or $\text{Cov}(R_i, R_j) =$

$$\text{Cov}[\sqrt{0.2} R_m + \sqrt{1 - 0.2} \epsilon_i, \sqrt{0.2} R_m + \sqrt{1 - 0.2} \epsilon_j] = 0.2 \sigma_m^2 = 0.2.$$

6. A yield level variable and the slope of the term structure can explain 97.9% of all return variation. The third factor appears less important.

7. Duration assumes that the yield volatility is the same across maturities and that the coefficients that link the different maturities to the duration factor are the same.

8. The VARs are as follows for the two portfolios. For portfolio (1), \$6.582, and \$6.584 million, respectively, for the 1-factor and 2-factor models. For portfolio (2), \$0.128, \$0.895 million. For the first portfolio, the 1-factor or 2-factor models are similar. For the second portfolio, the exposure to the first factor is close to zero, so it is important to have a second factor.

9. If the portfolio uses long and short position and the net investment is zero, index mapping predicts zero risk, which is misleading.

10. A one-factor model would erroneously report a zero beta and zero risk. In this case, specific risk is likely to be important because the portfolio only has a few stocks. Hence, a more detailed model is required.

11. This is incorrect. The number of risk factor depends on the trading strategies. For instance, if the portfolio is immunized against level and slope risk, the third and higher order factors are important.

12. PCA has shown that there is one major principal component for each bond market (or maybe two). In addition, the dollar/euro currency is a source of risk, which is not much related to the bond first factors. So, there will be probably 3 factors (or 5).

13. No. The copula solely reflects dependencies, so should only have correlations as parameters.

14. As seen in Figure 8-2, the multivariate Student density generates most joint losses.

15. Yes. The normal copula imposes a simple, constant, correlation coefficient. Other copulas can represent more complex relationships.

15. The shape of the copula will determine the probability of joint defaults and the shape of the left tail of the losses on the CDO. If joint defaults happen frequently, then the senior tranches are more likely to experience losses as well.

Chapter 9: Forecasting Risks and Correlations

1. First, the actual distribution could have fatter tail than the normal distribution. Second, the distribution could exhibit time-variation in risk, which can also induce more extreme observations that cluster when risk is high.

2. One drawback of the moving average method is that it gives the same weight to recent and older observations. Older observations, however, may no longer be relevant. The second drawback is the *ghosting* effect. Say that the window length is M . If there was a large return

M days ago, dropping this return as the window moves one day forward will substantially affect the volatility estimate.

3. The MA(20) is more volatile because each daily observation has higher weight in the estimate.

4. By setting $E(r_{t-1}^2) = h_t = h_{t-1} = h$, we find $h = \alpha_0 / (1 - \alpha_1 - \beta)$.

5. The sum $\alpha_1 + \beta$ must be less than unity.

6. The EWMA is a special case of GARCH, where α_0 is set to 0 and $\alpha_1 + \beta$ sum to unity.

7. The scaled residual could be taken from a distribution with fatter tails, such as the Student t distribution.

8. The simple rule overestimates risk because it assumes that the current variance will stay high. In fact, future variance will move down to the long-run value.

9. The weight is $1 - 0.94 = 0.06$ for the previous day, and 0.06×0.94 for the day before.

10. For the MA, the average life is half the window. For an MA(60), half the weight is put on the last 30 observations, for example. For the EWMA, the weights on older observations decay at an exponential rate. For instance, if we continue to expand the weights from the previous question and compute the cumulative sum, we have 0.524, or more than 50% of the total weight, on the last 12 observations only.

11. The updated volatility can be computed from the square root of $h_t = \lambda h_{t-1} + (1 - \lambda)R_{t-1}^2 = 0.94x(1)^2 + (1 - 0.94)x(2)^2 = 1.180$. This gives $\sigma_t = 1.09$ percent, a bit higher than the starting value of 1 percent.

12. This is the same because the EWMA has full persistence.

13. Normally, if the model was well specified, the same decay of 0.94 should apply to all time intervals. So, the daily and monthly models are internally inconsistent.

14. Theoretically, GARCH could be extended to estimate all covariances and correlations. The number of parameters to estimate, however, increases exponentially with the number of series. This explains why simplifications must be used.

15. Because the model has one parameter only, it can be easily extended to more dimensions.

16. This is indeed simpler. The problem with modeling one time series only is that this does not allow the risk manager to evaluate the effects of varying weights on risk. Reestimating the GARCH model for different weights could also cause inconsistencies in the results.

17. Historical models are backward-looking and cannot anticipate regime or structural shifts in volatility.

18. The ISD is a forward-looking measure because it is based on option prices. These reflect the market opinions about future volatility. Empirically, the ISD has been found to contain more information than historical models for future risks.

Chapter 10: VAR Methods

1. The goal of a risk management system is to provide a useful estimate of risk at a reasonable cost. For some applications, speed is important. The delta-normal method is fast. MC simulation is more accurate, but slower.

2. Monte Carlo. Options have nonlinear components and should use full valuation over a large set of realizations for the risk factors.

3. The Delta-normal method. Local valuation should be sufficient because there are no options in the portfolio. Also, the method is fast, allowing intraday estimates of VAR. Finally, at the 95 percent confidence level, the normal distribution is usually a decent approximation to the distribution of financial risk factors.

4. The delta-normal method is more appropriate over short horizons because distributions are close to the normal distributions over short intervals and also because nonlinearities are less marked.

5. No. Options involve second-order, non-linear effects that have to be analyzed with either quadratic local valuation or full valuation methods.

6. True. With a monotonic function, there is a one-to-one relationship between the risk factor and the value of the instrument. The VAR of the instrument can be found from the initial valuation and a second valuation at the worst move of the risk factor.

7. The VAR is obtained from two full valuations and is $\$3.89 - \$0.38 = \$3.51$.

8. The method is slow to process, may be difficult to implement, creates sampling variation, and has model risk.

9. Managers could compute the residuals for the risk factors, scaled to the historical volatility. They could then sample from these scaled residuals and multiply the values by the current volatility to generate hypothetical scenarios.

10. Monte Carlo or historical simulation. This is because these methods allow full revaluation, which is important with options.

11. It only uses a short sample path and can be imprecise.

12. Not really. It assumes that the historical data is representative of the future.

13. Not necessarily. Because options are highly non-linear, we cannot use the square root of time rule to extrapolate risk.

14. As the number of replications in the simulation increases, the Monte-Carlo VAR should converge to the delta-normal VAR.

15. The function values are interpolated from a small set of full valuation estimates, which saves on the number of function valuations.

16. The standard error shrinks at a rate given by the square root of $1,000/10,000$, which is 0.316. This gives \$3 million times 0.316, or \$0.95 million.

17. The linear VAR is $\Delta WVAR_S = 0.5 \times \$1,000,000 \times 0.08 = \$40,000$. When second-order terms are considered, the option VAR must be less. Positive gamma reduces risk.

18. In Equation (10.11), positive gamma decreases VAR. Positive gamma creates positive skewness, or shorter left tails, which lowers risk.

19. The VAR of the asset is $VAR = 1.645 \times \$400 \times 0.30 \times \sqrt{2/52} = \38.71 . The linear VAR for the option is $0.569 \times \$38.71 = \22.03 . The gamma adjustment is $(0.5) \times 0.01 \times (\$38.71)^2 = \$7.49$. Subtracting from \$22.03, we get \$14.50.

20. By now, many institutions are using historical simulation over a window of 1 to 4 years, duly supplemented by stress tests.

Chapter 11: VAR Mapping

1. Mapping simplifies the portfolio. Also, some positions may not have a complete history or may have a risk profile that changes over time.

2. These stocks should be included in the risk measurement, but do not have a history. Instead, they could be replaced by positions on equivalent securities.

3. The portfolio will have some remaining risk, but these are not captured by the risk system. Some specific risk will remain, such as default risk.

4. Seven. The primitive risk factors include movements in government bond yields with three different maturities and credit spreads for four different ratings.

5. It only uses the maturity of the principal payment, and ignores the intervening coupon payments. Duration mapping is much better.

6. The duration model assumes parallel moves in the term structure. All yields are assumed to have the same volatility and are assumed to be perfectly correlated with each other.

7. Pricing is straightforward for a zero-coupon bond. Modified duration is $D^* = T/(1 + y) = 3/1.04 = 2.88$. Price is $P = \$100/(1 + y)^T = \$100/(1.04)^3 = \$88.90$. Dollar duration is $D^*P = \$256$. DVBP is $D^*P \times 0.01\% = \$0.0256$.

8. The dollar duration is $(\$100 \times 5,000 \times 13.84 + \$100 \times 5,000 \times 7.44) = \$10,640,000$. Multiplied by 0.0029, this gives \$30,856.

9. The 95 percent VAR for yield changes over a month is $0.01 \times \sqrt{1/12} \times 1.645 = 0.00475$. Multiplying this by 7.44 and \$100 million gives a VAR of \$3.53 million.

10. The duration is now lower, at $(7.44 - 1)$, because of the floating rate leg. This gives a VAR of \$3.06 million.

11. No. Duration hedging only provides a first approximation to interest rate risk. A finer decomposition of the index by maturity is desirable to minimize relative market risk.

12. The original VAR is $100 \times 0.9\% \times 1.645 = \1.48 million. Define x as the amount of the 5-year note to sell. The variance of the hedged portfolio is $(\$100 \times 0.9\%)^2 + (x \times 0.5\%)^2 - 2(\$100 \times 0.9\%)(x \times 0.5\%) \times 0.97$. To find the optimal amount, we take the derivative with respect to x and set to zero. The derivative is $2(x \times 0.5\%) - 2(\$100 \times 0.9\%)0.5\% \times 0.97$. Setting to zero gives $x = \$175$ million. We then replace in the formula for the variance and find $\sigma_p^2 = 0.0479$. Taking the square, this gives \$0.22 and a VAR of $1.645 \times \$0.22 = \0.36 million. Thus, there was a sharp drop in VAR.

13. A portfolio can have a return of 10%, but if the benchmark return is 20%, it would still have relative risk.

14. The exporter either sold the yen and the dollar went up, or the yen depreciated. This creates a gain per long yen position of $S \exp(-r^*t) - K \exp(-rt) = (1/130) \exp(-5\% \times 7/12) - (1/124.27) \exp(-6\% \times 7/12) = -0.000299$. See Equation (11.9). Since the U.S. exporter is short Y125 million, we multiply by $-125,000,000$ to find a gain of \$37,356.

15. They tend to move together generally in the same direction and by the same amount. In other words, basis risk is generally low.

16. With currency futures or forwards, basis risk arise from variations in the differential between domestic and foreign interest rates.

17. Basis risk is large when the underlying and hedging asset are very different, in which case the correlation is low and the residual risk high.

18. The current value is $V = S(\$/\text{euro}) \times \text{PV}(1 \text{ euro}) - F \times \text{PV}(\$1) = 1.05 \times 0.97561 - 1.06 \times 0.94787 = +0.0197$.

19. This is $[\$1.4 - (\$1.3861 - \$1.4703)] \times BP1,000,000 = \$1,484,200$.

20. There are three risk factors, the spot price and the two interest rates. The spot price has highest volatility and is the main determinant.

21. Natural gas is expensive to store and transport, so should be more affected by local demand and supply conditions, which create more volatility.

22. With a delta of 0.5, VAR is given by $0.5 \times \$1,000,000 \times 20\% \times \sqrt{1/252} \times 1.645 = \$10,362$.

23. If the option has maturity of 3 months, gamma is low. As a result, the first order approximation is better than for a short-term option.

Chapter 12: Simulation Methods

1. The MC method assumes that the risk factors follow pre-specified probability distributions.

2. The HS method samples from the recent empirical observations and assumes the risk factors have an empirical distribution represented by recent data.

3. With N variables, numerical integration requires a number of operations that increases geometrically with N . This generates far too many computations. In contrast, MC simulation utilizes random samples to generate an average that converges to the true value.

4. This decreases at the rate of $1/\sqrt{K}$.

5. The Monte Carlo method suffers from *model risk*, or risk that the pre-specified distributions are not correct. In addition, it creates sampling variability and requires long computer runs.

6. Dependencies may be introduced in the price process if the cycle is too short, which may lead to a limited range of portfolio values. This yields incorrect measures of risk.

7. We generate draws from the uniform, then use the inverse of the cumulative distribution function for the Student t to transform the original draws into random numbers with the appropriate distribution.

8. The bootstrap approach can generate fat tails, jumps, or other departure from the normal distribution.

9. Not directly. The bootstrap resamples data at random assuming that returns are independent. Hence, any pattern of time variation would be broken, which is incorrect. This can be handled by fitting a model to the time variation and sampling from the errors.

10. To compute VAR using a simulation method, one needs to compute the mean and the appropriate quantile of the simulated portfolio distribution.

11. Yes. This requires a model such as GARCH for time variation in the volatility.

12. Pricing methods obtain the correct prices by assuming investors are risk-neutral. This involves using a risk-neutral distribution and discounting at the risk-free rate. Risk measurement, in contrast, requires the actual or physical distributions.

13. We need to multiply $K = 1,000$ by 4 squared, which gives 16,000.

14. The error in the 95 percent quantile should be less than for the 99 percent quantile, all else equal. Lower quantiles are estimated more precisely.

15. From Table 12-3, this is more than 10,000, which is 40 years. Negative skewness will increase this number further, because the left tail where VAR is estimated is very long.

16. Stratified sampling generates more observations in the zones around VAR, requiring fewer data points overall.

17. The first variable is $\epsilon_1 = \eta_1$. Then compute $\sqrt{1 - \rho^2} = \sqrt{1 - 0.6^2} = 0.8$. The second variable is $\epsilon_2 = 0.6\eta_1 + 0.8\eta_2$. Each variable has volatility of one. The two variables have correlation of $\text{Cov}(\epsilon_1, \epsilon_2) = \text{Cov}(\eta_1, 0.6\eta_1) = 0.6$.

18. A correlation of unity implies that there is only one relevant risk factor.
19. No. The samples are not truly random, unlike in MC simulation, but depend on previous values.
20. Not really. The prices of default-free bond converge to their face value at expiration, which create patterns that are not consistent with a random walk.
21. *Arbitrage models* take the current term structure as an input and fit the stochastic process accordingly, whereas *equilibrium models* generate a term structure based on a stochastic process for some risk factors.

Chapter 13: Liquidity Risk

1. Liquidity risk includes asset liquidity risk and funding liquidity risk. Asset liquidity risk refers to the risk that liquidation value of the assets differs significantly from the current mark-to-market value, due to the price impact of the liquidation. Funding liquidity risk refers to the risk that an institution could run out of cash and is unable to raise new funds to meet its payment obligations, which could lead to default.
2. VAR does not specifically account for liquidity risk. After a forced sale, liquidation values could differ significantly from their initial market values.
3. Liquidity risk arises when selling assets, for example. The sale price is a function of the demand curve for the asset. Such demand curves are useful to evaluate a potential liquidity loss.
4. A *deep* market means that positions can be offset with very little price impact.
5. *Normal market sizes* represents the number of shares for which the bid-ask spread is valid. Beyond, there is a further price impact.
6. Asset liquidity risk has traditionally been controlled through position limits, i.e., by limiting the exposure to a single instrument in order to avoid a large market impact in case of forced liquidation, and by diversification.
7. One half of the bid/ask spread is $\$0.20 \times 1,000,000$, or $\$200,000$ which has to be incurred on the entire position. This leaves 900,000 beyond the NMS. The drop in price is $\$0.5 \times 9 = \4.5 per share. Multiplying by 900,000 shares gives an additional loss of $\$4,050,000$. The total cost is $\$4,250,000$, or 4.25% of the original amount.
8. If the sale is spread uniformly over 10 days, the sale each day is within the NMS. So, the total cost is $\$200,000$, or 0.20%. If the sale is spread over 5 days, the price impact is $\$0.50$ for each additional block of 100,000 sold daily. This gives $\$200,000 + 5 \times \$0.50 \times 100,000 = \$450,000$, or 0.45%.
9. Holding the position over ten days increases the volatility of 1% by the square root of time, or 3.1%. The risk of liquidating all is zero. Using Equation (13.7), the risk of liquidating uniformly over 10 days is 1.69%. The risk of liquidating over 5 days is 1.10%.
10. Immediate liquidation decreases the volatility but creates losses due to market impact.
11. Funds that are too big have to face liquidity risk. Bid/ask spreads are larger for high-yield bonds, so the optimal size should be less for high-yield hedge funds.
12. Because high-yield bonds are less liquid, hedge funds that invest in them are more likely to use lockup periods, in order to avoid having to sell them at distressed prices.
13. Borrowing creates a possibility that creditors could ask for their funds back. Equity holders could also ask their money back, but this is easier to control. Potential demands on

cash arise due to margin requirements, mismatches in the timing of collateral payments, or changes in collateral requirements.

14. No. There is no debt nor equity holders who could pull out their funds.

15. A haircut is the amount of excess collateral required by brokers over and above the cash loaned. This is designed to provide a buffer against decreases in the collateral value, or potential credit exposure.

16. Credit triggers are offered by companies that issue debt in exchange for a lower cost of capital. The problem, however, is that these triggers could create claims on the company's cash, precisely after the company has been downgraded. As a result, these credit triggers are not good ideas because they can precipitate bankruptcy.

17. Treasury bills have the lowest spreads, on the order of 0.003% to 0.02%.

18. Spreads arise from order-processing costs, asymmetric information costs, and inventory-carrying costs.

19. LVAR is constructed from VAR by adding an additional term representing liquidity risk, $1/2(WS)$, where W is the initial wealth and S is the bid-ask spread.

20. The liquidity term in LVAR grows linearly with the size of the portfolio. The risk factor, in contrast, does not grow as quickly due to diversification effects. So, for large portfolios, the liquidity term may be more important than the risk term.

21. *Cash liquidity* is defined as the ratio of cash equivalent over the potential decline in the value of positions that may create cash-flow needs.

22. LTCM leveraged its balance sheet through sale-repurchase agreements (repos) with commercial and investment banks. Under repo agreements, LTCM sold some of its assets in exchange for cash and a promise to purchase them back at a fixed price at some future date.

23. Market risk and asset liquidity risk.

24. Not necessarily. Most of the positions lost money when volatility went up in August 1998.

Chapter 14: Stress Testing

1. VAR numbers only indicate the minimum loss in a small fraction of days, but do not indicate how bad a loss can be. This is the goal of stress testing. In addition, the recent history on which VAR is based may not contain enough relevant scenarios that could cause large losses.

2. *Backtesting* uses a large number of past observations and is used to check if VAR models are appropriately calibrated. In contrast, *stress testing* uses a small number of extreme movements in market variables.

3. This is not necessarily true because stress testing can be used to identify conditions that the VAR model based on historical data could miss. For instance, a type of shock may not have occurred in the past, or there could be structural breaks in the financial series.

4. It does not account for correlations. That is why multidimensional scenarios are valuable.

5. Historical scenarios may not have some events that are important for the portfolio, yet are still probable in the future.

6. Scenarios must be worked through all the risk factors in a consistent fashion. This may be difficult to do if there are many risk factors. In additions, constructing conditional

forecasts relies on estimated correlation coefficient, which may change under stress conditions.

7. SPAN provides a series of scenarios where the underlying price and implied volatility move in fixed increments. For each scenario, the portfolio is marked-to-market. The margin is then set at the worst loss across all scenarios.

8. The losses are \$200, \$250, \$350, and \$300 million. The \$350 million loss accounts for a positive correlation between the two stock markets. Because this is typically the case, the scenario is most realistic.

9. The slope coefficient of 0.9 would lead to a forecast loss on Japanese stocks of $0.9 \times (-20\%) = -18\%$. This generates a total loss of \$200 plus \$180 million, or \$380 million. In practice, the relationship could be nonlinear, leading to an even greater fall in the Japanese market.

10. The 1987 equity crash is most widely used. According to the BIS report on stress tests, banks use scenarios based on an equity crash 74% of the time.

11. It would be incorrect to ignore this event. The normal distribution is not appropriate. Other events could happen, creating trading volumes that overwhelm the exchange.

12. The trading positions could be cut to reduce the severity of loss to an acceptable level, or the position could be hedged with another instrument. Alternatively, the institution could increase the amount of capital that it holds.

Chapter 15: Using VAR to Measure and Control Risk

1. VAR initially was devised as a method to measure and report financial risks, as well as to facilitate communication to top management and shareholders.

2. Initially, VAR was devised as a passive method to report risk. In the second stage, VAR began to play a defensive role as a risk control tool. In the last stage, VAR played an active role in the management of risk and return for the institution, for evaluating performance and allocating economic capital.

3. There are two main driving factors. First is the increase in sources of risks, second is the greater volatility of new products.

4. Institutions that would benefit from such system are those that: (a) are exposed to a diversity of financial risks, (b) undertake proprietary trading, and (c) deal with complex instruments.

5. JPM Chase is likely to rely more on VAR because it is exposed to many types of risks. Thus diversification effects are important for this institution. FNMA relies more heavily on duration and convexity measures, because it is mainly exposed to U.S. interest rate risk.

6. JPM Chase is likely to rely more on VAR due to the need to measure and control risk for proprietary trading portfolios. Merrill has less trading risk. Proprietary trading desks can benefit from global risk management systems because they are exposed to a diversity of financial risks, they can take aggressive proprietary positions, and they can deal with complex products.

7. For nonfinancials, VAR concepts can be extended to the so-called cash flow at risk (CFAR). This is the worst loss in cash flows over the horizon at some confidence level.

8. Derivatives can be used to hedge unfavorable movements in cash flows due to financial market variables.

9. CFAR is more complex because the exposures are more difficult to measure. VAR is based on directly observable positions. For CFAR, quantities such as payments in various currencies, are more uncertain. Also, companies have strategic options to manage their cash flows, which can reduce risks.

10. Toyota suffers economic losses when the value of the Japanese yen appreciates relative to the dollar. This could be hedged by selling the dollar forward against the yen or borrowing in dollars. Both financial transactions will generate a gain if the dollar weakens, providing some offset to the loss on exports to the U.S.

11. This is the probability that a standardized normal variable is less than -10 percent (margin) divided by 10 percent (volatility), or about 16 percent.

12. Zero, because revenues in dollars are fixed.

13. Now that companies cannot smooth earnings so easily with earnings management, they will have to increase their use of financial derivatives.

14. Such disclosure provides investors, shareholders, creditors and counterparties with useful information, which can be used to impose strong market discipline. Additionally, such transparency can lead to more financial market stability.

15. Reporting data at the end of the period only could lead to *window-dressing*, or artificially improving the reported results, which is misleading.

16. In practice, the industry often fails to make voluntary disclosures, even when these are beneficial for the industry as a whole. This can be due to a number of reasons. First, if only one company discloses, analysts may not have the knowledge to understand the disclosure or be able to place it in the context of other firms. This creates a rationale for having many companies disclose at the same time. Second, some companies are afraid that disclosures could reveal sensitive information about proprietary positions. In fact, however, VAR is an aggregate measure of risk that does not reveal too much information about positions.

17. Yes. Firms with greater VAR numbers have bigger swings in trading revenues.

18. This can arise either because markets are more volatile, or because the bank is increasing the size of its bets.

19. The risk limit at higher levels can be lower than the sum of risk limits for individual units due to diversification benefits.

Chapter 16: Using VAR for Active Risk Management

1. These measures ignore differences in the risk of business lines.

2. Risk capital is the economic capital required to support a financial activity. VAR can be viewed as a measure of risk capital because it measures the aggregate capital against unexpected losses.

3. The choice of the confidence level should be based on the choice of the optimal capital structure, which reflects a balance between the marginal benefits of increased leverage with the marginal costs of increased default probability. A higher confidence level is safer but creates lower returns on capital.

4. Credit ratings agencies report average default rates over one year for different credit ratings. Setting the confidence level equal to one minus the default rate should lead to the desired credit rating.

5. This corresponds to an Aa credit rating.

6. VAR is $\alpha\sigma W = 2.33 \times \$10 \times 0.12 = \$2.8$ million. RAPM is the ratio of profit over VAR, which is equal to 36% in this case.
7. Without this adjustment, revenues will be too high.
8. Traders are long options because of the bonus, which cannot be negative. Risk managers have little upside, on the other hand.
9. *Earnings-based* VAR is measured from historical movements in earnings.
10. *Position-based* VAR provides forward-looking measure of risk, whereas earnings-based VAR measures historical risks.
11. Position-based VAR provides structural information that is more helpful to understand risk.
12. The *Sharpe ratio* is the ratio of average return in excess of the risk-free rate divided by the total volatility of returns. RAPM can be viewed as a generalization of the Sharpe ratio, using risk capital in the denominator.
13. The *Treynor ratio* emphasizes beta risk rather than total risk. It is the ratio of excess return divided by the contribution of this asset to the portfolio's total risk, which is measured by the asset beta.
14. The conventional RAPM fails to account for diversification effect. The trader's risk is only one component of the bank's total risk. Applying VAR separately to each unit overstates their combined risk.
15. The marginal RAPM can be obtained by dividing the profit for security i by marginal VAR for this security. Similarly, the component RAPM can be obtained by dividing the profit for security i by component VAR for this security.
16. Frictions in capital markets; financial market imperfections; liquidity constraints.

Chapter 17: VAR and Risk Budgeting in Investment Management

1. No. Compared to bank trading portfolios that have high leverage, pension funds do not allow much leverage. Hedge funds, however, may have high leverage.
2. Changing positions and complex financial instruments.
3. As seen in Box 17-1, losses can be greater than the notional. Also, these limits do not take hedging or diversification into account.
4. Relative risk is the risk of a dollar loss in a fund relative to its benchmark. It is defined as the dollar difference between the fund return and that of a like amount invested in the benchmark. Relative risk is important for managers because their performance is compared to that of a passive index.
5. More risk, because the cash position increases the tracking error risk. Deviating from the benchmark creates relative risk, even if absolute risk is lowered.
6. Not necessarily. If there is negative correlation between the policy mix VAR and active management VAR, the fund's total VAR will be lower than the sum of these two components.
7. Most of the downside risk of a fund is due to policy mix VAR. Asset allocation is the most important investment decision.
8. Funding risk is the risk that the value of assets will not be sufficient to cover the liabilities of the fund, which are the promised pension fund benefits. For a pension fund, funding risk is of paramount importance.

9. Since the funding risk is determined by both asset side and liabilities side, decreases in interest rate may lead to increased value of liabilities, and therefore lead to a decrease in the plan's funding ratio.

10. The change in asset value is \$22.1 billion. The change in liabilities is an increase of $15 \times 0.0124 \times \$90 = \$16.7$ billion. The new surplus is $\$10 - \$22.1 - \$16.7$ or $\$77.9 - \106.7 , which is a deficit of \$28.8 billion. The return is $-\$38.8/\$100 = -39\%$.

11. Using Equation (17.3), the variance is $0.15^2 + (15 \times 0.01 \times 90/100)^2$. Taking the square root gives 20.2%, or a 99 percent VAR of 47%. This is on the order of the actual loss of -39% .

12. Negative correlation would increase risk. When stock fall, bonds go up in value, increasing the value of liabilities and squeezing the surplus further.

13. This is partially true. If distributions are close to normal, VAR is proportional to a forward-looking tracking error volatility.

14. This can happen: (a) when all managers increase their allocation to a particular sector, (b) because of more volatile markets, or (c) because a trader deviates from the guidelines.

15. The portfolio is exposed to fixed-income and credit risks (from the corporate bond investments), equity and currency risks (because the portfolio is unhedged).

16. Using a short window will provide a better forecast of short-term risk. However, this will create wider swings in VAR measures. Managers could then hit their limit if markets become more volatile. This would force them to sell.

17. The manager should choose the asset with the lowest marginal VAR. This would help him lower the overall risk of the portfolio.

18. Risk budgets are similar to individual VAR, and add up to more than the total diversified risk.

19. The IR are $(13 - 10)/6 = 0.5$ and $(14 - 10)/5.7 = 0.7$. The second is best.

20. The variance is $0.17^2 + 0.17^2 + 2 \times 0.7 \times 0.17 \times 0.17 = 0.0983$. This gives a total VAR of $2.33 \times 0.313 \times \$100 = \$36.52$ million.

21. The \$50 million manager allocations can be scaled using $\$50 \times (35/36.5) = \48 million each. The remainder, or $\$100 - \$48 - \$48 = \4 , can be invested in cash.

22. The investments should be proportional to the information ratios. Hence, \$70 million should be allocated to the second.

Chapter 18: Credit Risk Management

1. *Credit risk* is the risk of financial loss due to counterparty failure to perform their obligations.

2. Banks may have concentrations of credit risk due to lack of diversification in their loan portfolios.

3. Because credit events occur with low frequency, it is harder to quantify default probabilities, their correlations, and recovery rates. Legal issues are very important for evaluating credit risk, whereas they are not applicable for evaluating market risk. In addition, credit risk models are based on longer horizon, which makes it difficult to backtest, or to compare risk forecasts with their realization.

4. With a bond, the best that can happen is repayment, which is limited upside. The downside is potential loss of entire notional. So, there is an asymmetry in the distribution

of payoffs. Similarly, for derivatives, the exposure is the positive value; negative exposures are not considered.

5. From Equation (18.2), this is given by d_2 in $(1 - c_2) = (1 - c_1)(1 - d_2)$. Hence, the solution is $1 - (1 - 0.1433)/(1 - 0.0624) = 8.6\%$.

6. The cumulative probability cannot go down because it is a sum of positive numbers. Over time, the marginal probability increases for high credits and can decrease for low credits.

7. Bank loans have average recovery rates of 62%, greater than senior secured bonds, senior unsecured bonds, and other subordinated bonds.

8. From Equation (18.7), this is $(11 - 5)/(1 - 0.37) = 9.52\%$.

9. In Table 18-2, the first-year default rate for B credits is 6.24%. The number found in the previous question is higher; this is a risk-neutral probability, however. Differences could be due to systematic risk, tax effects, or liquidity effects.

10. In the Merton model, equity can be viewed as a call option on a firm's asset value, with an exercise price given by the face value of debt. In this model, a firm defaults if the asset value is less than the promised payments. Thus, stock prices reflect a forecast of default probability.

11. In large portfolios, the volatility converges to the average volatility times the square root of the average correlation coefficient. Thus, the correlation coefficient is a major driver of portfolio risk.

12. This could be understated if the correlation is too low, or if the joint distribution has fatter tails and/or more dependent tails (such as the Student t).

13. The credit exposure of defaultable bond is determined by the market value of the bond. It is the principal at expiration.

14. The exposure arises because that the rate on the fixed payments may differ from prevailing market rates. Exposure, however, is only the positive part of the swap value.

15. The former. The risk profile of an interest rate swap is a combination of two factors, the amortization effect and the diffusion effect. The risk is zero at maturity because there are no remaining coupon payments, nor an principal payments. In contrast, a currency swap involves the exchange of notionals.

16. Zero, because the market value is negative.

17. The net loss with the netting agreement is the positive sum of the market value of all contracts, which is always less than the sum of all positively valued contracts.

18. The worst credit exposure is the largest credit exposure at some level of confidence c . Expected credit exposure is the expected value of the asset replacement value x , if positive, on a target date.

19. No. The credit reserve should be based on the present value of *expected* credit losses.

20. This approach does not account for diversification effect across time and counterparties.

21. The expected credit loss (ECL) is $\$100 \times 0.32 \times (1 - 0.45) = \17.6 million.

22. The ECL is typically 100 times lower for a swap than for a bond with otherwise identical characteristics.

23. As seen in Chapter 5, applications of VAR for economic capital require long horizons and high confidence levels.

24. Multiplying the two entries in each row gives a dollar incremental risk of \$100, \$100, and \$140, respectively. Hence, credit C has the highest dollar incremental risk.

25. As shown in Table 18-9, portfolio credit risk models indicate that the sum of expected and unexpected loss is about 8% of notional.

26. Portfolio invariance means that the risk charges depend on the individual credit alone and not on the portfolio. In general, this is not the case. For asymptotic single risk factor models, however, this may be a good approximation. The Basel II capital charges are based on this model.

27. They force banks to pay attention to, measure, and manage their risks. As a result, the banking system is more diversified and safer.

Chapter 19: Operational Risk Management

1. Operational risk is the risk of losses resulting from failed or inadequate processes, systems, people, or from external events.

2. Commercial banks are exposed first to credit risk, then market risk and operational risk. Asset-management firms are mainly exposed to operational risk.

3. Critical self-assessment, key risk indicators, and formal quantification.

4. Bottom-up models are more useful to understand sources of operational risk and therefore to identify potential failures and associated losses. In contrast, top-down models are easier to apply because they estimate risk from firm-wide data.

5. Losses due to operational risk are determined by the loss frequency and the loss severity. The loss frequency describes the number of loss events over a fixed interval of time. The loss severity describes the size of the loss once it occurs.

6. The expected annual loss is \$300 million. As a result, the expected severity is $\$300/60 = \5 million.

7. The loss distribution has a long, or heavy, left tail, due to large losses, such as trading fraud, that occur infrequently, but can be very large.

8. The challenge comes from the collection of relevant data. The drivers of operational risk are internal to the firm and depend on the quality of the control systems. The banks need to have a system in place to collect occurrences of operational losses. In addition, these need to be combined with external data, for which large losses are relatively infrequent and may not be relevant to the bank.

9. Historically, trading has caused very large losses because of the size and complexity of the trades, which has allowed rogue traders to commit unauthorized trades.

10. From Equation (19.6), the worst loss is given by $y = -b \ln[1 - F(y)] = -0.75 \ln[1 - 0.999] = 5.18$. Taking the exponent and adding \$1 million gives \$179 million.

11. Purchasing insurance to cover operational risk allows the bank to hold less capital (either economic or regulatory, up to some extent). The downside is that the insurance payment may take time and may be subject to legal challenge. In addition, this creates a potential credit exposure against the insurance company.

12. The AMA approach to regulatory capital is based on the bank's internal estimate of its one-year, 99 percent VAR for operational risk. It should be superior to the standardized approach because it allows for diversification effects and the purchase of insurance. Also, in theory, the bank's internal model should be more finely tuned to the actual risks of the bank.

Chapter 20: Integrated Risk Management

1. Financial risk includes market, credit, and operational risk. Business risk refers to other risks that corporations willingly assume to create value for shareholders.
2. Legal risk is the risk of losses due to fines, penalties, and legal settlements. It is part of operational risk. Standardized contracts help to reduce the uncertainty in language and enforceability of contracts. As a result, they lower legal risk.
3. This is an example of reputational risk. The direct loss is \$100 million.
4. The loss due to market risk is due to the devaluation of the peso, or 30 percent of \$100 million, which is \$30 million. The credit loss is \$80 million, or 80 percent of the other \$100 million. There is no other loss category.
5. Operational risk involves rare but very severe events. The probability density function thus has fat tails, or high kurtosis.
6. Both credit and operational risk have negative skewness, reflecting the possibility of large losses but limited gains.
7. The hybrid VAR provides the closest approximation to an integrated VAR.
8. Larger size usually creates exposures to more sources of risk, which creates benefits from diversification effects. However, reputational and liquidity risk mitigate the benefits of size.
9. Such trade is indeed a wrong-way trade. The company produces gas, so should hedge by *selling* gas at a fixed price, to protect against falls in gas prices. Instead, the company is paying a fixed price for gas, which is speculation. If gas prices go down, the swap will lose money. In addition, the company will lose money on its operations.
10. The brokers' operating business benefits from high volatility. Option values benefit from increasing volatility. To create a hedge, brokers should be *short* options.
11. The combined coverage provides a maximum payout of \$10 million, versus \$20 million for the separate coverage. The former is cheaper.
12. Integrated risk-management systems help institutions discover natural hedging, take advantage of diversification benefits, and reduce separate insurance costs against each type of risk.
13. Hedging keeps the mean unchanged but lowers the volatility, or narrows the distribution of cash flows.
14. Hedging can lower the volatility of cash flows or firm values, therefore reduce financial distress cost, the tax expenses, lower agency costs, and facilitate optimal investment.

Chapter 21: Risk Management: Guidelines and Pitfalls

1. *Marking to market* (mtm) measures the current value of assets and liabilities, or the value that could be obtained from selling the positions. Changes in mtm values provide the best measure of risk. Because derivatives are generally liquid instruments, they can be value using market prices. There is no reason to use historical cost information to value the positions.
2. All financial risks (market, credit, and operational) should be considered jointly because of possible interactions.
3. The Barings failure brought to attention *reputational* risk, defined as the risk to earnings arising from litigation or financial loss due to negative public opinion.
4. Credit exposure should account for current and also *potential* exposure, using liquidation-based estimates of exposure.

5. Assumptions behind underlying risk models always need to be examined closely. Risk managers also need to run stress tests to identify risks that could be missed by conventional VAR systems.

6. VAR does not provide a measure of the absolute worst loss. It is an estimate of losses at a certain confidence level, so there will be situations where VAR is exceeded.

7. The assumption of constant position in measuring VAR ignores the possibility that trading positions may change over time in response to changing market conditions. This could understate or overstate risk.

8. VAR models based on historical data may be inaccurate with the occurrence of one-time events or structural changes.

9. Estimation risk is the risk of imprecision in reported numbers due to sampling variation.

10. The *Black-Scholes* model, which assumes geometric Brownian motion for the underlying price process, is appropriate for stock options, because stock prices approximately behave as Brownian motions. This model, however, is not appropriate for pricing options on short-term interest rate instruments, which needs to model an interest rate process first. This is model-selection risk.

11. The option requires a more complex model for the exchange rate, which could create more errors. So, the knockout option is more likely to have model risk.

12. NatWest incurred a loss due to model risk and suffered further from reputational risk.

13. Some argue that VAR gives a false impression of accuracy that may lull portfolio managers into taking bigger positions than they might otherwise consider.

14. A VAR system could induce traders to conduct VAR arbitrage by moving into markets or securities that appear to have low risk for the wrong reasons. For instance, as of 2005, the Chinese currency was fixed to the U.S. dollar, with very low historical risk. A short position in the yuan would have low reported VAR. There is an economic risk, however, of currency appreciation.

15. An exogenous shock in volatility could increase VAR close to VAR limits, forcing banks to sell assets. The sale pushes prices down, increasing the volatility further, which creates a vicious circle. In practice, however, the trading revenues of banks do not have high correlation, which suggest that the positions are not similar. This hypothesis is not supported by the empirical data, as of this writing.

16. The answer is (c). All the other factors had some role in the failure of LTCM.

17. The hedged portfolio is exposed to twists in the yield curve and changes in corporate spreads. The portfolio is only hedged against parallel moves in the yield curve. Other types of moves, such as twists in the yield curve or movements in credit spreads will create risk.

18. Historical data will not pick up the risk of a devaluation. The riskiest position is (c), as the currency could fall, creating losses in the long position.