ERM Detailed Study Guide - Sample

Financial Enterprise Risk Management
Source Author: Paul Sweeting (2017)

Chapter 9: Some Useful Statistics (Background Only)

Overview of This Reading

Even though the syllabus says this chapter "background only," it's very important to be able to describe these statistics and be able to perform calculations using them

These concepts in this chapter are the basic ingredients for more advanced correlation and copula topics covered later in readings like ERM-101

Key topics for the exam include:

- Basic univariate statistical measures
  - Location measures (mean, median, mode)
  - Spread measures (variance, range)
  - Skew measures
  - Kurtosis
- Measures of correlation between two variables
  - Pearson's rho
  - Spearman's rho
  - Kendall's tau
  - Tail correlation

Location Measures

Location measure – gives an indication of the point around which observations are based

A **mean** is the most commonly used measure of central tendency in modeling (based on first moment of distribution)

Sample mean of a set of observations:

$$\overline{X} = \frac{1}{T}\sum_{t=1}^{T} X_t$$

Population mean (μ) is usually not observable, but is calculated the same as $\overline{X}$

$$\mu = \frac{1}{T}\sum_{t=1}^{T} X_t$$

Median – measure of the mid-point of a distribution (50th percentile)

- Useful for analyzing simulated data

Mode – the most common observation

- Discrete distributions:
  1. Count the number of each observation
  2. Mode = observation with highest count
- Continuous distributions: mode = maximum of density function = point at which the first derivative = 0
  - First derivative is sometimes called the "gradient"

Spread Measures

Spread measures indicate how far away an observation may fall from a location measure

- Can help establish confidence intervals

Variance is the most common spread measure (based on 2nd moment of distribution)

Population variance:

$$\sigma^2 = \frac{1}{T}\sum_{t=1}^{T}(X_t - \mu)^2$$

- Appropriate if the dataset represents all possible observations (not likely for risk management)
- Not a good estimate of the true population variance since some observations exist in the future and cannot be known
  - Biased downwards for finite samples (i.e. it tends to underestimate the true variance)
  - Bias <u>increases</u> as the sample size <u>falls</u>

Sample variance is adjusted to reduce the bias:

$$s^2 = \frac{1}{T-1}\sum_{t=1}^{T}(X_t - \overline{X})^2$$

Range = difference between the largest and smallest value in dataset

- Alternative to variance for measuring spread
- May capture information about the effect of potential extreme events
- Straightforward to calculate, but can't be used for parametric distributions or if observations are unbounded (i.e. observations can be zero to ∞)
- For unbounded distributions, one solution is to use an inter-quartile range (e.g. 75th percentile – 25th percentile)

Skew Measures

Skew – a measure of a distribution's asymmetry (based on 3rd moment)

- Skew = 0 for perfectly symmetric distributions (e.g. normal distribution)
- **Negative skew** means left tail > right tail (positive skew is the opposite)
  - This assumes the observations are increasing (i.e. worst values on the left, best values on the right)
- Mean and variance do not capture skew

Many risk distribution are negatively skewed

- Probability of a large loss > probability large gain

Problems with ignoring skew or assuming skew = 0:

1. Underestimates risk ⇒ may result in lower-than-expected profits
2. May result in profitable projects being rejected if there is a desire for large profits

Population skew:

$$\omega = \frac{1}{T}\left(\frac{\sum_{t=1}^{T}(X_t - \mu)^3}{\sigma^3}\right)$$

- Will be biased if full distribution is not available (usually it's not available)

Sample skew mitigates the bias:

$$w = \left(\frac{T}{(T-1)(T-2)}\right)\left(\frac{\sum_{t=1}^{T}\left(X_t - \overline{X}\right)^3}{s^3}\right)$$

Kurtosis

Kurtosis indicates the likelihood of extreme observations relative to those that would be <u>expected</u> with the normal distribution

- In other words, it measures how fat the tails are ⇒ higher kurtosis = fatter tails
- Based on the 4th moment of the distribution

Types of distributions based on the kurtosis value

1. **Mesokurtic:** kurtosis = 3 (true of the normal distribution)
2. **Platykurtic:** kurtosis < 3 ⇒ distribution has thin tails relative to the normal distribution ("negative excess kurtosis")
3. **Leptokurtic**: kurtosis > 3 ⇒ has fat tails relative to the normal distribution ("positive excess kurtosis")

- If this is not accounted for, the probability of extreme events will be underestimated
- Many risk distributions are leptokurtic

Memory tip: leptokurtic means the kurtosis "leptover" 3! :)

Population measure of excess kurtosis:

$$\kappa = \frac{1}{T}\frac{\sum_{t=1}^{T}(X_t - \mu)^4}{\sigma^4} - 3$$

- Measures the kurtosis against the normal distribution (hence subtract 3)

Sample excess kurtosis corrects for bias if the full population data isn't available:

$$k = \left(\frac{T(T+1)}{(T-1)(T-2)(T-3)}\right)\left(\frac{\sum_{t=1}^{T}\left(X_t - \overline{X}\right)^4}{s^4}\right) - \frac{3(T-1)^2}{(T-2)(T-3)}$$

Correlation Measures

Correlation is important in ERM because it measures the diversification benefits of aggregating risks

Interpretation of correlation between 2 variables

1. Strong positive correlation
   - The risk of two events occurring simultaneously is high
2. Low correlation
   - The risks can diversify one another
3. Strongly negative correlation
   - Indicates an incentive to increase the level of one risk taken in order to offset the second

Three Measures of Correlation

1. **Pearson's rho**: $\rho_{X,Y}$ (a.k.a. "linear correlation coefficient")

$$\rho_{X,Y} = \frac{\sigma_{X,Y}}{\sigma_X \sigma_Y}$$

$$\sigma_{X,Y} = \frac{1}{T}\sum_{t=1}^{T}(X_t - \mu_X)(Y_t - \mu_Y) = \text{population covariance}$$

   - Attractive, widely used, easy to calculate
   - Only a valid if the data series are jointly elliptical (i.e. related to the multiple variate normal distribution)

- If not jointly elliptical, $\rho_{X,Y} = 0$ does not necessarily mean independence
- For sample populations, use:

$$r_{X,Y} = \frac{s_{X,Y}}{s_X s_Y}$$
$$s_{X,Y} = \frac{1}{T-1} \sum_{t=1}^{T} \left(X_t - \overline{X}\right) \left(Y_t - \overline{Y}\right)$$

2. **Spearman's rho:** ${}_s\rho$ (a.k.a. Spearman's rank correlation coefficient)

   For sample populations:

$${}_s r_{X,Y} = 1 - 6 \cdot \left(\frac{\sum_{t=1}^{T} (V_t - W_t)^2}{T(T^2-1)} \right)$$
$$V_t, W_t = \text{rankings of } X_t \text{ and } Y_t \text{, respectively}$$

- Equals Pearson's rho if data are uniformly distributed
- Differences from Pearson's rho:
  - Ranks can be in ascending or descending order (since rank differences are squared)
  - Spearmean's rho is independent of the statistical distribution

3. **Kendall's tau:** (τ) – compares pairs of data points
   - Suppose we have 2 observations: (X_1, Y_1) and (X_2, Y_2)
   - If $X_2 - X_1$ and $Y_2 - Y_1$ have the same sign, these pairs are **concordant**; else they are **discordant**
   - For T observations, the total number of possible pairs is

$$T\left(\frac{T-1}{2}\right)$$

   - **Sample Kendall's tau** normalizes all concordant pairs (p_c) and discordant pairs (p_d) by the total number of pairings

$$t_{X,Y} = \frac{2(p_c - p_d)}{T(T-1)}$$

   - Spearman's rho $({}_s\rho)$ and Kendall's tau (τ) are related in the following way:

$$\frac{3}{2}\tau - \frac{1}{2} \le {}_s\rho \le \frac{1}{2} + \tau - \frac{1}{2}\tau^2 \qquad \text{if } \tau \ge 0$$
$$\frac{1}{2} + \tau + \frac{1}{2}\tau^2 \le {}_s\rho \le \frac{3}{2}\tau + \frac{1}{2} \qquad \text{if } \tau < 0$$

Key comparisons among the 3 correlation measures above:

- Pearson's rho is calculated directly from the data series, while Spearman's rho and Kendall's tau are rank measures
  - **Rank measure** – a statistic calculated from the position (rank) of the observations
- Pearson's rho is only valid if the data series are jointly elliptical, but rank measures are always valid since they do not depend on the distribution's shape
- Rank measures are usually combined with copulas[1]
  - Kendall's tau has simple relationships with a number of copula functions
- Limitations of the 3 correlation measures:
  - Each describes only one aspect of the variables' relationship
  - Copulas can describe correlation relationships more accurately than any of the above measures alone

Tail Correlation

The 3 correlation measures described above imply that X and Y always have the same relationship

In extreme situations (tail events), variables' relationships can change

Tail correlation looks at the variables' relationship only in the tail (e.g. lowest and highest 10% of observations)

Key problems: Determining where the "tail" begins is subjective and can cause instability in parameterization

[1] Copulas will be covered in more detail later in ERM-101 and ERM-103. We will also see how the basic correlation measures in this chapter relate to various copula methods. Copulas identify relationships among each individual variable's distribution to create a multivariate joint distribution. Among other advantages, a copula can describe how correlations change as the value of variables change—something that is very useful for risk modeling where extreme tail events can cause variables' relationships with each other to change.

VAR Ch 7: Portfolio Risk, Analytical Methods

Source Author: Jorion (2007)

Overview of This Reading

This chapter focuses on relative VAR tools for analyzing portfolio risk.

Key topics for the exam include:

- Describe the VAR terms and apply them to numerical examples
- Identify and describe the three VAR tools:
    1. Marginal VAR
    2. Incremental VAR
    3. Component VAR

VAR Terminology Summary

One of the key takeaways from this chapter is understanding the different "VAR Terminology" presented in this reading. For your convenience, these are summarized in the table below. We will see all of these later throughout the chapter.

"VAR" Term	Notation	Definition
Individual VAR	VAR_i	The VAR of one component taken in isolation.
Undiversified VAR	$\sum VAR_i$	The sum of individual VARs. (assumes perfect positive correlation)
Diversified VAR or Portfolio VAR	VAR_p	VAR taking into account diversification benefits between components.
Marginal VAR	ΔVAR_i	Change in portfolio VAR resulting from taking an additional dollar of exposure to a given component.
Incremental VAR	$VAR_{p+a} - VAR_p$	Change in VAR owing to a new position.
Component VAR	$CVAR_i$	How much the portfolio VAR would change if the given component was deleted.

Note: For component VAR, they use the description of "how much the portfolio VAR would change (approximately) if the given component was deleted." Keep in mind this is only in an approximate sense over a small change. If you are removing a large position, the preferred way to compute component VAR is based on removing a small incremental position (e.g. remove a small amount such as $1, look at the change in VAR, and then scale by the notional) as opposed to a discrete approach (e.g. removing the entire position and looking at the change in VAR). Using this preferred approach will give more desirable features of component VAR, such as the sum of the component VARs will equal the portfolio VAR.

VAR Overview

Portfolio Construction

- A portfolio is defined by positions on a certain number of constituent assets, expressed in the base currency (e.g dollars)
- If the positions are fixed over the selected horizon, the portfolio rate of return is a linear combination of the returns on underlying assets
  - Weights are given by the relative amounts invested at the beginning of the period
- Will assume normally distributed returns

Notation Summary

Chapter 7 has a decent amount of notation. Use this section as a reference for the meaning of the key variables in this section.

- N: the number of assets
- i: index for the asset numbers (e.g. $i = 3$ is the third asset)
- $R_{p,t+1}$: the portfolio rate of return between times t and $t + 1$
- $R_{i,t+1}$: the rate of return on asset i between times t and $t + 1$
- W: total investment size
- w_i: the weight in each asset (in percentage)
- $x_i = w_i W$: investment amount in asset i (in dollars)
- Vectors:
  - w: vector containing asset weights (vertical)
  - w': vector containing the transposed asset weights (horizontal)
  - x: vector containing asset investment amounts
  - R is the vertical vector containing individual asset returns
- μ_p: portfolio mean return
- μ_i: mean return of asset i
- σ_p: portfolio standard deviation
- σ_i: standard deviation of asset i
- σ_{ij}: covariance between assets i and j
- ρ_{ij}: correlation coefficient between assets i and j
- z: the z score used for confidence level c

- $z = \alpha = \Phi^{-1}(c)$
- Example: For a confidence level of 99%, $z = 2.326$ from the standard normal table (which will be provided to you on exam day)
- The z-score is also referred to by α in this textbook

- $\sum$: covariance matrix (of size $N \times N$)

Portfolio Returns

- Can be constructed from a combination of the risks of the underlying securities
- The rate of return is defined as the change in the dollar value, or dollar return, scaled by the initial investment.
- The portfolio return is defined below:

$$R_{p,t+1} = \sum_{i=1}^{N} w_i R_{i,t+1} = \begin{bmatrix} w_1 w_2 \cdots w_N \end{bmatrix} \begin{bmatrix} R_{1,t+1} \\ R_{2,t+1} \\ \vdots \\ R_{N,t+1} \end{bmatrix} = w'R$$

Portfolio Expected Return and Variance

Note that in the equations below, the t subscript is dropped. The assumption is that the distribution of returns is stationary / unchanged over time.

$$E(R_p) = \mu_p = \sum_{i=1}^{N} w_i \mu_i$$

$$\begin{aligned} V(R_p) &= \sigma_p^2 = \sum_{i=1}^{N} w_i^2 \sigma_i^2 + 2 \sum_{i=1}^{N} \sum_{j<i}^{N} w_i w_j \sigma_{ij} \\ &= \begin{bmatrix} w_1 & \cdots & w_N \end{bmatrix} \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} & \cdots & \sigma_{1N} \\ \vdots & & & & \\ \sigma_{N1} & \sigma_{N2} & \sigma_{N3} & \cdots & \sigma_N^2 \end{bmatrix} \begin{bmatrix} w_1 \\ \vdots \\ w_N \end{bmatrix} = w' \sum w \end{aligned}$$

You can also write this either in terms of weights w or dollar exposures x:

$$\sigma_p^2 = w' \sum w$$
$$\sigma_p^2 W^2 = x' \sum x$$

Covariance and Correlation

- σ_{12} is used to denote the covariance between variables 1 and 2
- ρ_{12} is used to denote the correlation coefficient between variables 1 and 2 and is a scale-free measure of linear dependence given by:

$$\text{Correlation Coefficient} = \rho_{12} = \frac{\sigma_{12}}{\sigma_1\sigma_2} \in [-1; +1]$$

- When $\rho = 1$, then the two variables are perfectly correlated
- When $\rho = 0$, then the two variables are uncorrelated
- When $\rho = -1$, then the two variables are perfectly negatively correlated
- If two variables are independent, then they are uncorrelated $\Rightarrow$ they have a correlation coefficient of zero and a covariance of zero

Portfolio VAR for a Uniform Correlation Portfolio

Consider a portfolio with N assets. All assets are assumed to have the same standard deviation σ and the correlation between any two assets is given by the same ρ. The amount invested in each asset is equal so that $w_i = \frac{1}{N}$.

(a) Show that the portfolio standard deviation is given by:

$$\sigma_P = \sigma \cdot \sqrt{\frac{1}{N} + (1 - \frac{1}{N})\rho}$$

(b) Show how to compute σ_P for $N \to \infty$.

(c) Your new intern uses (a) to model a simplified portfolio of 10 assets with $\rho = -1$. But he notices that his Excel formula gives an error because it takes the square root of a negative number. Determine the problem and recomend a solution.

Solution:

(a) $\sigma_P^2 = \sum_{i=1}^{N} w_i^2\sigma_i^2 + 2\sum_{i=1}^{N}\sum_{j<i}^{N} w_i w_j \sigma_{ij} = \sum_{i=1}^{N} \frac{\sigma^2}{N^2} + 2\sum_{i=1}^{N}\sum_{j<i}^{N} \frac{\rho\sigma^2}{N^2} = N \cdot \frac{\sigma^2}{N^2} + N \cdot (N-1)\frac{\rho\sigma^2}{N^2}$

$= \frac{\sigma^2}{N} + \frac{N-1}{N}\rho \cdot \sigma^2 = \sigma^2 \left[\frac{1}{N} + \left(1 - \frac{1}{N}\right)\rho\right] \Rightarrow \sigma_P = \sigma \cdot \sqrt{\frac{1}{N} + (1 - \frac{1}{N})\rho}$

(b) $\sigma_P = \sigma \cdot \sqrt{\rho}$.

(c) The problem is that it is impossible for 10 assets all have $\rho = -1$ with each other. The solution is to revisit the correlation assumption and set it to a more appropriate value.

This should make intuitive sense - if A and B have perfectly negatively correlated returns and A and C have perfectly negatively correlated returns, then we would expect B and C to be positively correlated with each other. Thus B and C would not have a correlation of -1. It is beyond the scope of this reading, but as a technical note if you are curious, it must be the case that $\rho \geq -\frac{1}{N-1}$.

Portfolio VAR or Diversified VAR

Portfolio / Diversified VAR takes into account diversification benefits between components.

$$\text{Portfolio VAR} = VAR_p = z\sigma_p W$$

Individual VAR

Individual VAR is the VAR of one component taken in isolation.

$$\text{Individual VAR} = VAR_i = z\sigma_i \underbrace{|w_i|W}_{x_i}$$

Undiversified VAR

Undiversified VAR is the sum of individual VARs.

It provides an upper bound on the portfolio VAR if correlations prove unstable and all move at the same time in the wrong direction to a correlation of +1.

$$\text{Undiversified VAR} = \sum_{i=1}^{N} VAR_i \geq \text{Portfolio VAR}$$

Ashley's Portfolio - VAR Numerical Example (Part I)

Ashley puts together a portfolio of two uncorrelated assets. The first asset has a standard deviation of 5% and the second asset has a standard deviation of 12%. The dollar amounts invested are $2 million and $1 million in each asset, respectively.

Calculate the following using $c = 95\%$:

(a) Portfolio VAR

(b) Individual VAR for each asset

(c) Undiversified VAR

Solution:

(a)

$$\sigma_P^2 = w' \sum w = \begin{bmatrix} \frac{2}{3} & \frac{1}{3} \end{bmatrix} \begin{bmatrix} (5\%)^2 & 0 \\ 0 & (12\%)^2 \end{bmatrix} \begin{bmatrix} \frac{2}{3} \\ \frac{1}{3} \end{bmatrix} \approx .2711\%$$

Thus, $VAR_p = z\sigma_P W = 1.645 \cdot \sqrt{.2711\%} \cdot \$3 \text{ million} \approx \boxed{\$256,957}$

(b) $VAR_i = z\sigma_i x_i$

Asset 1: $1.645 \cdot 5\% \cdot \$2 \text{ million} = \boxed{\$165,000}$

Asset 2: $1.645 \cdot 12\% \cdot \$1 \text{ million} = \boxed{\$198,000}$

(c) Adding up the individual VARs from (b) gives: $165{,}000 + 198{,}000 = \boxed{\$363,000}$

VAR Tools

The reading mentions the following three types of VAR tools:

1. Marginal VAR
2. Incremental VAR
3. Component VAR

Marginal VAR

- The change in portfolio VAR resulting from taking an additional dollar of exposure to a given component.
- Marginal VAR measures the contribution of one security to total portfolio risk.
- Marginal VAR is also the partial derivative with respect to the component position:

$$\text{Marginal VAR} = \Delta VAR_i = \frac{\partial VAR_p}{\partial x_i} = z\frac{\text{Cov}(R_i, R_p)}{\sigma_p}$$

- Marginal VAR can be rewritten using β_i from the capital asset pricing model (CAPM)
- Beta is also called the systematic risk of security of security i for portfolio p
- Beta can be measured from the slope coefficient in a regression of R_i on R_p

$$\beta_i = \frac{\sigma_{ip}}{\sigma_p^2} = \frac{\text{Cov}(R_i, R_p)}{\sigma_p^2}$$

$$\beta = \frac{\sum w}{w' \sum w}$$

- Marginal VAR can also be calculated in terms of β_i:

$$\begin{aligned}
\Delta VaR_i &= z\frac{\text{Cov}(R_i, R_p)}{\sigma_p} \\
&= z\sigma_P\frac{\text{Cov}(R_i, R_p)}{\sigma_p^2} \\
&= z\sigma_P\beta_i \\
&= \beta_i\frac{z\sigma_P W}{W} \\
&= \beta_i\frac{VaR_p}{W}
\end{aligned}$$

- To summarize:

$$\text{Marginal VAR} = \Delta VAR_i = \frac{\partial VAR_p}{\partial x_i} = z\frac{\text{Cov}(R_i, R_p)}{\sigma_p} = \beta_i \frac{VaR_p}{W}$$

Incremental VAR

- The change in VAR owing to a new position
- It differs from the marginal VAR in that the amount added or subtracted can be large, in which case VAR changes in a nonlinear fashion

$$\text{Incremental VAR} = VAR_{p+a} - VAR_p$$

- Disadvantage of Incremental VAR
    - It requires a full revaluation of the portfolio VAR with the new trade. This can be time-consuming for large portfolios
- If incremental VAR is negative, the new trade is risk-reducing or a hedge
- **Best hedge**: The additional amount a^* to invest in an asset so as to minimize the risk of the total portfolio

$$\begin{aligned} a^* &= -W\frac{\sigma_{ip}}{\sigma_i^2} \\ &= -W\beta_i\frac{\sigma_p^2}{\sigma_i^2} \end{aligned}$$

- The best hedge amount is derived on the next page

Deriving the Best Hedge Amount

Consider the baseline portfolio p and add an investment of a to asset i to get portfolio $p+a$. The variance of portfolio $p+a$ is given by:

$$\sigma_{p+a}^2 = w_1^2\sigma_P^2 + w_2^2\sigma_i^2 + 2w_1w_2\sigma_{ip}$$

where $w_1 = \frac{W}{W+a}$ and $w_2 = \frac{a}{W+a}$

Thus,

$$\sigma_{p+a}^2 = \left[\frac{W}{W+a}\right]^2 \sigma_P^2 + \left[\frac{a}{W+a}\right]^2 \sigma_i^2 + 2\frac{W}{W+a}\frac{a}{W+a}\sigma_{ip}$$

Multiplying both sides by $(W+a)^2$ to scale in terms of dollars yields:

$$\sigma_{p+a}^2(W+a)^2 = \sigma_P^2 W^2 + a^2\sigma_i^2 + 2aW\sigma_{ip}$$

Taking the partial derivative with respect to a and setting the result to zero solves for the case where risk is minimized:

$$\frac{\partial\left[\sigma_{p+a}^2(W+a)^2\right]}{\partial a} = \frac{\partial}{\partial a}\left[\sigma_P^2 W^2 + a^2\sigma_i^2 + 2aW\sigma_{ip}\right] = 2a\sigma_i^2 + 2W\sigma_{ip} = 0$$

Rearranging to solve for a^* gives the best hedge amount:

$$\boxed{a^* = -W\frac{\sigma_{ip}}{\sigma_i^2}}$$

Component VAR

- A partition of the portfolio VAR that indicates how much the portfolio VAR would change approximately if the given component was deleted.
- By construction, component VARs sum to the portfolio VAR.

$$\begin{aligned}\text{Component } VAR_i &= VAR_p\beta_i w_i \\ &= \rho_i VAR_i\end{aligned}$$

- For large portfolios, you can show component VAR by type of currency, by type of asset class, by geographic location, or business unit.
  - This detail is invaluable for drill-down exercises, which enables users to control their VAR.

Ashley's Portfolio - VAR Numerical Example (Part II)

Recall Ashley's Portfolio that we saw earlier:

Ashley puts together a portfolio of two uncorrelated assets. The first asset has a standard deviation of 5% and the second asset has a standard deviation of 12%. The dollar amounts invested are $2 million and $1 million in each asset, respectively. VAR is calculated using a confidence level of 95%.

Calculate the following, assuming that Ashley is considering adding an additional $10,000 of Asset #1 to the portfolio for parts (c) and (d):

(a) β_1

(b) Marginal VAR for Asset #1

(c) Incremental VAR for Asset #1

(d) Component VAR for Asset #1

Solution:

(a) From Part I, we already know that $w^{'} \sum w \approx .2771\%$

$$\beta = \frac{\sum w}{w' \sum w} = \frac{\begin{bmatrix} (5\%)^2 & 0 \\ 0 & (12\%)^2 \end{bmatrix} \begin{bmatrix} \frac{2}{3} \\ \frac{1}{3} \end{bmatrix}}{.2711\%} = \begin{bmatrix} .615 \\ 1.77 \end{bmatrix}$$

Thus, $\boxed{\beta_1 \approx .615}$

(b) $\Delta\text{VAR}_1 = z\sigma_P\beta_1 = 1.645 \cdot \sqrt{.2711\%} \cdot .615 \approx \boxed{.052675}$

(c) From the Part I example, we know the baseline VAR is $256,957. The next step is to recalculate VAR with the additional position in asset #1:

$$\sigma_P^2 = w' \sum w = \begin{bmatrix} \frac{2.01}{3.01} & \frac{1}{3.01} \end{bmatrix} \begin{bmatrix} (5\%)^2 & 0 \\ 0 & (12\%)^2 \end{bmatrix} \begin{bmatrix} \frac{2.01}{3.01} \\ \frac{1}{3.01} \end{bmatrix} \approx .27\%$$

Thus, $VAR_{p+a} = z\sigma_P W = 1.645 \cdot \sqrt{.27\%} \cdot \$3.01 \text{ million} \approx \$257,485$

Thus, $\text{VAR}_{p+a} - \text{VAR}_p \approx 257,485 - 256,957 = \boxed{\$528}$

Notice that this approximately equals what we would estimate from (b):

$$10,000 \cdot \Delta\text{VAR}_1 \approx 10,000 \cdot .052675 \approx 527$$

(d)

$$CVAR_1 = VAR_p\beta_1 w_1 \approx 256,957 \cdot .615 \cdot \frac{2}{3} \approx \boxed{\$105,000}$$

Examples

Global Portfolio Equity Report

- **Hot Spots** are positions contributing to more than 5% of the total risk
- Percentage contribution to risk equals $w_i\beta_i$
- Can look at best hedges to mitigate risk

Barings

- In 1995, Barings faced $1.3 billion in losses from the trader Nick Leeson
- Lack of trader controls
- Leeson had joint responsibility for front and back office functions, and was able to hide trading losses. In July 1992, he created a "special account" numbered 88888. Losing trades and unmatched trades were parked in account 88888
- If a proper VAR system was in place, the parent company could have asked:
  - What was Leeson's actual VAR?
  - Which component contributed the most to VAR?
  - Were the positions hedging each other or adding to the risk?
- Positions changed over time, so VAR would still not have been a perfect risk measure

VAR Tools for General Distributions

The majority of this Chapter focused on the results using a normal distribution assumption. The result below holds in general:

$$\mathrm{VAR}_p = \sum_{i=1}^{N} (\Delta\mathrm{VAR}_i) \cdot x_i$$

And given a normal distribution assumption, $\Delta\mathrm{VAR}_i = z\sigma_P\beta_i$.

From VAR to Portfolio Management

Using Marginal VAR to Minimize Portfolio Volatility

- At the point where the portfolio risk has reached a global minimum, the marginal VAR of all assets will equate by using the following iterative process:
  - Positions should be cut first where the marginal VAR is the greatest, keeping portfolio constraints satisfied.
  - This process can be repeated up to the point where the portfolio risk has reached a global minimum.
- Note that Marginal VAR is best suited for small changes in the portfolio (since it is a derivative)
- Marginal VAR can help the portfolio manager decrease the risk of the portfolio.

Using Marginal VAR to Optimize Portfolio Risk/Reward Tradeoffs

- Choose a portfolio that represents the best combination of expected return and risk
- The **efficient frontier** contains the best portfolio combinations that minimize risk for varying levels of expected return.
- Sharpe Ratio: $SR_p = \frac{E_p}{\sigma_p} = \frac{E(r_p)-r_f}{\sigma_p}$
  - E_p is the expected return on the portfolio in excess of the risk-free rate
- The **optimal portfolio** has the following properties:
  - On the efficient frontier
  - Maximizes the Sharpe Ratio
  - Ratio of excess expected returns to marginal VARs must be equal for all assets i
    - $\frac{E_i}{\Delta VaR_i}$ = constant
- Let the subscript m denote the market portfolio from the Capital Asset Pricing Model (CAPM) in the equations below
- Recall from CAPM that $E(r_i) - r_f = \beta_i \cdot (E(r_m) - r_f)$.
- Thus, $E_i = \beta_i E_m$
- In the optimal portfolio, the ratio of the expected excess return and beta for each asset must be constant:

$$\frac{E_i}{\beta_i} = E_m = \text{Constant}$$

Optimal Portfolio Example

Suppose that you use two assets to construct an optimal portfolio. Given the following information below, complete the table by computing β_2.

You are also given that $r_f = 2\%$.

i	$E(r_i)$	β_i
1	10%	1.038
2	7%	?

Solution:

Remember to use excess returns in the numerators!

$$\frac{E_1}{\beta_1} = \frac{E_2}{\beta_2}$$

$$\Rightarrow \frac{E(r_1) - r_f}{\beta_1} = \frac{E(r_2) - r_f}{\beta_2}$$

$$\Rightarrow \frac{10\% - 2\%}{1.038} = \frac{7\% - 2\%}{\beta_2}$$

$$\Rightarrow \boxed{\beta_2 \approx .649}$$

Conclusion

- The VAR approach is richer than the computation of a single risk measure
- VAR tools can be used to analyze risk management frameworks
- Can be used to optimize risk/reward tradeoffs or minimize variance
- Marginal VAR can provide useful information to traders to control their risk profile
- VAR is particularly convenient when closed-form solutions exist that are easy to interpret

ERM-702: ERM for Capital and Solvency Purposes

Source Author: IAA (March 2009)

Pages 9–38 Only

Overview of This Reading

This paper provides a good general introduction to ERM from an organizational and cultural perspective

One of the most prominent themes in the paper is the importance of having an ERM culture embedded in all aspects of the organization—from the very top with the Board and CEO down to the most basic functional areas

In terms of the ERM exam, this paper (like most of the readings in Section 1) reduces to a large number of fairly dry lists that you'll need to review regularly in the final weeks before the exam

I recommend not getting too bogged down in the lists and terminology on your first pass—just make a good pass over this reading, then return to it after you've processed the rest of the syllabus

For each of the 4 key sections of the paper, the authors list "key features" for that item

Key topics for the exam include:

- Key feature 1: governance and an ERM framework
  - Introduction and overview of ERM governance
  - Board vs. management: high level view
  - Board vs. management role in risk management
  - Establishing and developing an enterprise risk function
  - Importance of a common risk language in the insurer
  - Risk management culture
  - Developing an culture implementation plan
  - Upside risk management
  - Performance management and reward systems
  - Reporting and monitoring
  - Dealing with new activities
- Key feature 2: risk management policy
  - Aspects to address in the risk management policy
- Key feature 3: risk tolerance statement
  - Strategic choices in risk tolerance statement
  - Risk tolerances vs. risk limits
  - Typical roadmap of the steps to establish risk tolerance

- Key feature 4: risk responsiveness and feedback loop
  - Nature of feedback loops
  - Emerging risks
  - Scenario planning

Governance and an ERM Framework

Key Feature 1: Overall Governance Structure

- **Insurer should operate within a sound ERM framework**
  - Appropriate to the nature, scale and complexity of its business and risks
- **ERM framework should be integrated with the insurer's business operations**
  - Reflect desired business culture and behavioral expectations
  - Address all reasonably foreseeable and relevant material risks faced by the insurer
  - ERM framework should be overseen by the board and senior management
- **Quantify risk for a sufficiently wide range of outcomes using appropriate techniques**

Introduction

An ERM framework should be proportionate to the nature, scale and complexity of the insurer

- The "concept of proportionality" for ERM is based on the idea that supervision of regulated entities should be proportionate to the nature, scale and complexity of the insurer's risks

Some aspects of ERM differ between large and small insurers

- Smaller insurers tend to have consolidated management structures and fewer resources for risk management and modeling
- Large insurers have more resources, policies, and risk management tools

An absence of a supportive ERM culture will undermine the most sophisticated of ERM frameworks

- Cultural and behavioral characteristics of risk management vary by company

Risk Management and Corporate Governance Generally

Corporate governance – the processes by which organizations are directed, controlled and held to account

Link between corporate governance and risk management: board committee and/or board charter responsibilities

- Risk management's role in corporate governance is to exercise direction, control and accountability
- Board's risk responsibilities must include all risk the insurer is exposed to

Risk Management and the Role of the Board

The board has an ultimate responsibility for the insurer's risk management framework

- Approves the insurer's overall risk management strategy/policy
- Oversees the process of ensuring the insurer's responsible persons are fit and proper
- Setting the insurer's risk appetite
- Monitoring key risks and implementing suitable internal controls

The board should establish a dedicated **risk committee**

- May include risk, audit, financial reporting, and compliance staff

Risk committee's objectives:

- Help the board exercise due care, diligence, and skill in risk management
- Verify adequacy of risk management policy and internal controls

Typical committee charter responsibilities:

- Effectiveness of the insurer's risk management framework
- Compliance with supervisory requirements
- Establish an independent risk function with the authority, standing and resources to it needs to execute its mandate
- Monitor adequacy of corporate insurance covers

Processes that enable effective discharge of charter obligations:

- Direct reporting line between the committee and the most senior risk executive in the insurer
- Regular one-on-one meetings between the committee chair and the most senior risk executive outside of formal committee meetings
- Have private meetings that exclude executive management
- Consult external experts
- Transparent reporting by the insurer's risk function (no filtering of information)

Charter objectives are more likely to be met if the culture fosters rapid escalation of significant risk issues and/or bad news

Board vs. management accountabilities:

- Should reflect natural boundaries and differences in legal jurisdictions
- Board should NOT be active in day-to-day management of insurer's risks (this is management's role)
- Board's role: oversee and monitor risk management and reporting
- Risk committees should allow people to challenge risk assessment process

Characteristics of an effective risk committee:

- Member characteristics: diverse background, inquisitive minds, objective, relevant experience
- Should question reports, not just "tick the box"
- Should have board and management buy-in
- Appropriate level and volume of reporting to risk committee
- Keep track of leading practices
- Appropriate self-assessment with SMART key performance indicators
    - SMART = Specific, Measurable, Achievable, Realistic, and Time bound

Management Commitment and Leadership

CEO = critical link between the Board and management

- If the CEO doesn't think ERM is important, it will be hard to convince other stakeholders

It's best if the CEO's job description includes ERM responsibilities

- Promotes a risk management and control framework with clear and powerful risk tolerance boundaries
- Provides periodic assurance to the Board about risk management and control effectiveness
- Avoids behavior that might compromise prudent risk management practices

It's best if the CEO promotes risk management as an insurer's core competency

Establishing and Developing an Enterprise Risk Function

Often the CEO will appoint a Chief Risk Office (CRO) as a sign of leadership and commitment to ERM

- CROs often have an actuarial or mathematical background

Good characteristics of a CRO:

- Has support of the board
- Has a good relationship with the CFO

  - Ideally, they should integrate their earnings and risk management strategies
  - Goal: generate adequate returns and provide appropriate capital to protect policyholders
- Facilitates dialogue/debate at management and board level about the insurer's risk tolerance
- High visibility and authority
- Coordinates risk activities/ measurement at the company level

Challenges faced by the CRO initially:

- Must bring together different risk functions and specialists under a common framework
- Will typically encounter a fragmented series of risk structures and "sacred cows"
  - Actuarial and/or research functions in some business units
  - Internal audit function
  - Specialist business continuity team
  - Reinsurance staff
  - Treasury and credit risk function
  - Capital management function
  - HR
  - Compliance teams
- Working with existing risk-related committees

Examples of questions the CRO should ask:

- Is there a clear, shared understanding throughout the Board and management of the insurer's risk tolerance?
- Are management's incentive arrangements aligned with prudent management of risk?
- What is the quality, health and transparency of risk information flows?
- Where are the capability gaps?
- Are there elements of the insurer's business that are destroying value on a risk adjusted basis?

Initial task for the CRO: establish whether Board-approved risk tolerance exists

- If not, make one, otherwise determine if it is understood by decision makers
- Most important: determine if it is appropriate for the insurer's strategic objectives

Management Governance – Considerations

- Oversight structures should regard the following:
  - Transparency of decision making processes
  - Size/nature of the insurer and type of insurance
  - Mix of risks faced by the insurer
- Larger insurers may have separate oversight committees for key risk areas:
  - Pricing and underwriting risk
  - Balance sheet and market risks (credit, liquidity, etc.)
  - Operational risk
- Smaller insurers are more likely to have a single committee
- The risk management structure should align with management's accountability
  - Example: "end-to-end accountability" means accountability for meeting premium growth targets and managing risks associated with pursuing growth targets
- Risk management committees should be made up of senior management from business and risk management functions

Structure of the ERM Function

- Even if it is impractical to combine all risk functions, it is important for them to act in a coordinated fashion
- Avoid risk functions that operate in isolation
- Project and change management skills are just as important as technical expertise

Importance of a Common Risk Language in the Insurer

A common risk language is essential to meet increasingly global supervisory requirements, no matter the size of the insurer

<u>Competing</u> risk language makes ERM <u>less effective</u> in a number of ways:

- Inhibits business management buy-in
- Confuses people not directly involved in developing and maintaining the methodology (prevents ERM culture from being embedded)
- Reinforces a silo approach
- Focuses on form over substance $\Rightarrow$ may fail to identify "real" risks
- Proliferates process inefficiencies and duplication
- Results in inconsistent risk measurement $\Rightarrow$ makes aggregation harder

Attributes and practices associated with a common risk management language:

- Universally understood top-down risk rating system
  - Should relate the risk rating to the management function responsible for mitigating the risk
- Standard templates and risk categories across the insurer
- Reporting and escalation thresholds

Risk Management Culture

Key question for ERM: "What are the behaviors you want people to use in relation to management of risk?"

People need to be willing and able to use the appropriate behaviors to support risk related activities

- Avoid a culture of "shoot the messenger" and "bad news travels slowly"
- ERM should be framed as **business as usual**, not with a "big launch" that employees see as a fad

It may take 3+ years before ERM is embedded in the corporate culture

Examples of ways to **proactively** embed risk management behaviors:

- Include proactive principles in the risk management strategy and policies
- Set a corporate risk goal for senior managers based on improving a "risk culture index"
- Define behaviors in roles, performance management, and succession/talent development processes
- Training programs for managers and staff

3 Aspects of Developing a Risk Behavior Model

1. Risk management is **not about eliminating risk**—it is **choosing** the risks the organization is willing to take and managing them well
2. People need to be encouraged to **speak up** in a management context
3. People need the **skills and empowerment** to undertake the behaviors necessary to manage risk situations

These 3 aspects also suppose innovation and growth

Developing an Implementation Plan

Implementing a culture component of ERM should address the following:

- Consider and develop a risk management behavioral model that suits the insurer's broader culture and operating environment

  - Describe behaviors precisely in measurable/observable terms

- Get support of senior management and develop their risk awareness
  - Use training, focus groups, education, and briefing of executive management
  - "War stories" help understanding and engagement
- Ensure that the right behaviors are embedded in the design of frameworks and processes
- Have a realistic time frame for the implementation plan
- Reinforce behaviors through multiple influencing channels
- Benchmark behaviors before starting the implementation program
  - Measure at least annually to assess progress
  - Adjust to the design and change program if required
- Link the measures to measurable business outcomes
  - The simpler, the better

Tips for Implementing Risk Culture Change Programs

- **Leverage** – Use existing organization-wide programs rather than starting new ones
  - Lessens load of managers/staff
  - Embeds it as "business as usual" faster
- **Language** – Focus on behaviors that people can change rather than intangibles
- **Change skills** – Hire people skilled in change management, learning, HR, project management, etc.
- **Embed principles** – Ensure the culture change initiatives are embedded into the people processes
- **Measures and consequences** – Benchmark the culture then measure progress
  - Ensure the Board/Risk Committees are supportive of the program
  - Reinforce good behaviors with bonuses, etc.

Upside Risk Management

Effective ERM implies an integrated assessment of adverse effects <u>and opportunities</u> ("a.k.a. upside risk")

- Insurers tend to focus much more on downside risk than upside risk (i.e. opportunities)

Practices supporting integrating upside and downside risk:

- Ensure the risk function is involved in strategic planning

- Include both risks and opportunities in reports prepared by risk functions
  - Reduce costs by removing excessive or ineffective controls
  - Use risk management controls to achieve other business goals
    - Example: utilize work from home solutions not just as a BCP risk control but also to attract/retain talent
- Use reward systems that encourage calculated risk taking
- Report on emerging, industry-wide, cross-border, and longer-term risks

Effective upside risk management views views all risks as opportunities

Performance Management and Reward Systems

ERM implementation will likely fail if the company doesn't encourage managers with incentives (bonuses, etc.)

- *Keep this in mind while studying principal-agent risk later on the syllabus*

Key considerations for encouraging risk management with reward systems:

- Ensure the size of the incentive actually motivates the targeted individuals
- Decide which individuals or groups to include (include senior management at a minimum)
- Use clear, activity-based measurements (e.g., milestone completions, financial measures, VaR, etc.)
- Link risk management performance with talent management and capability development processes
- Target appropriate staff, and avoid unintended consequences
  - Example: don't link staff incentives to the results of staff surveys (*unless you want highly biased surveys*)

Reporting and Monitoring

At the highest level risk reporting should cover:

- Current and emerging key risks in the business and within the wider environment, and changes over time (the risk profile of the insurer)
- Changes in risk indicators (measures influencing risk likelihood and/or impact)
- Capability for identifying and managing risks

Examples of information provided by risk category:

Risk Category	Information
All	Risk profile, capital adeqacy ratios, signficant losses, changes in KRIs
Underwriting	Risk aggregations by region, reserve strengthening
Market	VaR, stress scenarios
Credit	Counterparty credit risk, credit rating analysis
Liquidity	Ratio of liquid to total assets
Operational	Analysis of key risks, change in KRIs, internal audit results

A succinct **dashboard** is the most effective way to report so the information can be assessed at a glance

- Top 10 residual risks
- Key risk indicators (KRIs)
- Scoring chart for risk severity and control effectiveness
- Heatmap of all substantial inherent and residual risks
- Additional commentary section
- Significant project progress

Dashboard audience: key stakeholders

- Audit Committees – Monitoring material financial risks and mitigation of those
- Executives – Reviewing risk information for completeness
- Managers – Reviewing risk information for completeness and changes in risk profile or control effectiveness
- Risk Owners – Updating risk information and escalating changes in likelihood, impact or control effectiveness as required
- Control Owners – Updating status of treatments for controls that they are responsible for
- Internal Audit – Reviewing the effectiveness of internal control measures
- External Stakeholders – Reviews by supervisory bodies

Role of Internal Audit

Insurers often delegate the development of the insurer's risk framework to the internal audit function

Why this is a bad idea:

- Unlikely to deliver effective ERM in the long-term
- Sends a message that ERM is a compliance exercise

Best practice: clearly delineate the roles of internal audit and the function tasked with developing and maintaining an insurer's ERM framework

Dealing with New Activities

An insurer's ERM framework needs to be involved at the planning stage of new activities

- Product changes and introduction of new products
- Changes in corporate and management structures
- Major projects to build and/or upgrade computer systems and networks
- Due diligence, acquisitions, etc.
- Outsourcing and off-shoring strategies

Ways that the insurer's risk function can become involved in new activities:

- Involvement in due diligence where the skills of the actuary can be utilized to identify/assess risks
- Working with the insurer's strategy team to ensure the strategy incorporates an appropriate assessment of risks
- Preparing and/or facilitating risk assessments for major projects or new product launches
- Managing engagement with relevant supervisors
- Working with newly acquired businesses to help them adapt to the insurer's risk management framework

Risk Management Policy

Key Feature 2: Risk Management Policy

- Outline the way the insurer manages each relevant and material category of risk, both strategically and operationally
- Describe the linkage with the insurer's tolerance limits, supervisory capital requirements, economic capital, and risk modeling

Aspects to Address in the Risk Management Policy

- **Most important: state the insurer's risk appetite**
- Clear risk management philosophy: explain why risk management is important and the linkages with value creation
- Relationship between risk management and the insurer's mission, values, and strategic objectives
- How risk management is embedded in capital management, pricing, reserving, and performance management
- Scope of activities covered
  - Should be sufficiently flexible for multiple ownership structures

- Appropriate supervisory requirements and considerations
- Requirements with respect to acquisition of new businesses
- Categories of risk and risk definitions
- Definitions of risk terminology
- Governance and oversight aspects
  - Board, board committee structures, responsibilities
  - Management structures, roles, responsibilities
  - Roles and responsibilities of the various corporate and business unit risk functions
  - Role of internal and external audit
  - Compliance aspects, including consequences for policy breach
- Behavioral expectations of all staff
- Minimum process-level requirements that apply universally across the operations of the insurer
  - Risk management training, risk profiling, business process documentation, etc.
- ORSA requirements
- Specific requirements for defined risk categories
- Process for reviewing and updating the policy

Avoid writing a long policy document that is not read or understood by the wider organization

Risk Tolerance Statement

Key Feature 3: Risk Tolerance Statement

- Set overall quantitative and qualitative tolerance levels
  - Based on the insurer's strategy and actively applied within the ERM framework and risk management policy
- Defines tolerance limits for each relevant and material category of risk
  - Embedded in the insurer's ongoing operations via risk management policies and procedures

Establishing the risk tolerance involves making strategic choices

- Use the same time horizon as corporate strategy (3–5 years)
  - Don't change it every year
- Set boundaries for how much risk the insurer is prepared to accept
- Make a clear link between risk tolerances and limits

- Each insurer should develop its own risk tolerance based on its own circumstances
- Risk tolerance is about which risks to take and why, not just how much risk to take

Risk Tolerances vs. Risk Limits

"Tolerance" is more high level than "limits"

- Risk tolerance broadly considers risk exposure levels that the board deems acceptable
- Limits are narrower: more specific thresholds that can be monitored on a day to day basis
  - More transparent to business managers
  - Key risk indicators (KRIs) are becoming more common

Parameters used to describe risk tolerance:

- Lines of business that the insurer will/will not accept
- Earnings volatility
- Requirements to meet supervisory criteria including allowance for unexpected events
- Desired capital strength based on a credit rating agency
- Maintaining levels of economic capital based on a "risk of ruin"
- Maintaining a capital buffer in excess of the minimum supervisory capital
- Maximum exposure to aggregation of risk
- Dividend-paying capacity
- Maximum net loss the insurer is prepared to accept in any given year in the event of a catastrophic loss

The following should be kept in mind when settling an insurer's risk tolerance:

- Must support the achievement of business strategy
- Must be supported by appropriate policies that translate risk tolerance into operational limits

Examples of risk limits:

- Counterparty credit limits for investments and reinsurers
- Overall target for credit quality for a reinsurance buying program, usually by reference to credit rating
- Concentration limits for lines of business/products, geographies and counterparties
- Underwriting and pricing principles and limits
- Insurance reserves based on an explicitly quantified probability of adequacy

- Liquidity benchmarks

Typical Roadmap of the Steps to Establish Risk Tolerance

1. Measure current qualitative appetite at senior executive level
2. Measure current risk profile using quantitative techniques
3. Merge 1 and 2 to determine current risk appetite
4. Define and assess ongoing desired risk appetite
5. Develop metrics and framework for ongoing monitoring
6. Monitor activities relative to defined appetite

Risk Responsiveness and Feedback Loop

Key Feature 4: The insurer should incorporate a feedback loop

- Based on appropriate/good quality information, management processes and objective assessment
- Enables timely action in response to changes in risk profile

The ERM framework must be able to adapt to change

Nature of Feedback Loops

The insurer's risk profile will be influenced over time by past, present, and future influences

1. **Future:** periodic risk assessments, new initiatives/strategies, and external events
2. **Present:** movements in KRIs
3. **Past:** unexpected losses, significant control failures, and incidents
    - Incidents: customer complaints, audit findings, system failures, crisis events, etc.

The ERM framework should include formal processes to collate information from the above 3 sources

- Should include formal review of incidents to determine root cause

An effective feedback loop is underpinned by:

- Thresholds for reporting significant issues
- Protocols for escalating issues to management and supervisors, if necessary
- Risk aggregation reports that identify where limits/tolerances may have been exceeded

Emerging Risks

Emerging risks – uncertain/ambiguous risks that are difficult to quantify using traditional risk assessment techniques

Why insurers want to know about emerging risks:

- Influences the organization's strategy
- Impacts underwritten portfolios: unexpected (latent) claims / claims frequency / claims costs
- Impacts OR
- May create opportunities for new types of insurance products

Common characteristics of emerging risks:

- High uncertainty: little information available, making the frequency/severity difficult to assess
- Difficult to quantify: risk is uncertain and the risk transfer may be questionable
- No industry position: no single insurer wants to make the first move for fear of losing market share
- Difficult to communicate: danger of reacting to phantom risks
- Supervisory involvement often necessary

Emerging Risks Initiative (ERI) (founded in 2005 by the CRO Forum)

- Raises awareness about emerging risks relevant to the insurance industry
- Focus is identifying, prioritizing, and communicating information

Scenario Planning

Scenario planning can help evaluate high impact/low probability events

Uses of scenario planning:

- Augment statistical models
- Prepare for specific events
- Assess impact of internal or external shocks
- Business continuity management (BCM): run crisis simulations under a range of scenarios