QFI ADV Model Solutions
Fall 2016

1.   **Learning Objectives:**
1.   The candidate will understand the standard yield curve models, including:
- One and two-factor short rate models
- LIBOR market models

The candidate will understand approaches to volatility modeling.

Learning Outcomes:
(1i)   Explain the set up and motivation of the Lognormal Forward LIBOR Model (LFM).

(1k)   Explain the LFM drift terms and their dependence on the calibration and choice of numeraire.

Sources:
Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Sections 6.1-6.2, p.195-200.

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 6.2, p. 198-199.

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 6.3, p. 213-215.

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 6.3, p.216.

Commentary on Question:
This question tested the candidate's understanding of the change of numeraire technique in the context of the Forward LIBOR Model.

Solution:
(a)   Explain one advantage of the LFM model over a short rate model.

Commentary on Question:
The candidates performed as expected on this question. Many candidates successfully listed one advantage.

1. **Continued**

Here are some advantages of the LFM over short-rate models:
- Calibration to cap data is simplified because the model allows for simple expressions for their prices.
- The LFM pricing formula for caps coincides with Black's caps pricing formula, and provides a rigorous explanation for this formula.
- In the LFM, observable market rates such as the LIBOR can be modeled using a lognormal distribution.
- The LFM allows decorrelation which is not possible in some short rate models.

(b) Explain how the LFM model justifies this step without making a simplifying assumption.

Commentary on Question:
The candidates performed as expected on this section. Many candidates mentioned the change of measure but some did not explain how it was performed.

In the LFM derivation of the cap price, this step involves a change of measure. The new measure considered is the T_2-forward measure, which uses the bond with maturity T_2 as numeraire. Then, performing the change of measure using Fact Two of the change of numeraire technique (from the reference), we have

$$E\left[\exp\left(-\int_0^{T_2} r_s ds\right) \tau(L(T_1, T_2) - X)^+\right] = P(0, T_2)\tau E^2\left[(L(T_1, T_2) - X)^+\right]$$

where $E^2[\ ]$ denotes the expectation taken under the T_2-forward measure. Note that in the LFM derivation, the expectation at the end of this step is taken under a different measure, which is not the case in the derivation of Black's formula.

(c) Express $Z^j(t)$, the Q^{Tj}-forward measure Brownian motion, in terms of $Z(t), \mu_j(t)$ and $\sigma_j(t)$.

Commentary on Question:
The candidates performed below average on this section. Many candidates did not perform the final step which was to integrate $dZ^j(t)$.

Under the Q^{Tj}-forward measure, $F_j(t)$ is a martingale so $dF_j(t)$ has no drift. Therefore, we have

$dF_j(t) = \sigma_j(t) F_j(t) dZ^j(t)$
We also know that
$dF_j(t) = -\mu_j(t) F_j(t) dt + \sigma_j(t) F_j(t) dZ(t)$

1. Continued

Putting the two equations together, we get

$\sigma_j(t) \, F_j(t) \, dZ^j(t) = -\mu_j(t) \, F_j(t) \, dt + \sigma_j(t) \, F_j(t) \, dZ(t).$

Isolating $dZ^j(t)$ yields

$dZ^j(t) = dZ(t) - (\mu_j(t)/\sigma_j(t)) \, dt.$

To obtain $Z^j(t)$, it suffices to integrate both sides

$$Z^j(t) = Z(t) - \int_0^t \left(u_j(t)/\sigma_j(t) \right) dt$$

(since $Z^j(0)=Z(0)=0$).

(d) Explain why, from time t, it is easier to simulate values of $F_j\left(T_{j-1}\right)$ under the Q^{Tj}-forward measure than under the Q^{Ti}-forward measure.

Commentary on Question:
The candidates performed as expected on this question. Most candidates identified that the lack of the drift term made the simulation easier. Very few candidates described the distribution of the factor.

As seen in (c), under the Q^{Ti}-forward measure, $dF_j(t)$ has a drift, while it does not under the Q^{Tj}-forward measure. In fact, for $i{\neq}j$, $F_j(t)$ does not have a known transition density under the Q^{Ti}-forward measure and it needs to be simulated in multiple steps by discretizing its dynamics. However, under the Q^{Tj}-forward measure, $F_j(T_{j-1})$ follows a log-normal distribution and can be simulated directly.

2. **Learning Objectives:**
4. The candidate will understand important quantitative techniques relating to financial time series, performance measurement, performance attribution and stochastic modeling.

Learning Outcomes:
(4b) Apply various techniques for analyzing factor models including Principal Component Analysis (PCA) and Statistical Factor Analysis.

Sources:
QFIA-125-16 Market Models: A Guide for Financial Data Analysis, Chapter 6

Commentary on Question:
This question tested how to apply various techniques for analyzing factor models including Principal Component Analysis (PCA) and Statistical Factor Analysis.

Solution:
(a) Describe the empirical and theoretical advantages of using PCA on daily changes in skew deviations for modeling implied volatility smiles and skew.

Commentary on Question:
The candidates performed poorly on this section. Only few candidates mentioned that "Daily variations in fixed strike deviations from ATM vol, $\Delta(\sigma_K - \sigma_{ATM})$ are much less noisy" or "There is a linear relationship between the deviation of a fixed strike (K) volatility from ATM volatility" or "Implies that only first PC would be significant; however, it is found that the second or higher PC can also be significant factors for determining movements in $\Delta(\sigma_K - \sigma_{ATM})$" Candidates got full credit if they mentioned at least 3 of the below 5 bullet points.

Empirical Advantages
- Time series data on fixed strike or fixed delta volatilities often display very much negative autocorrelation, so the "noise" in daily changes of fixed strike volatilities is a problem for PCA
- Daily variations in fixed strike deviations from ATM vol, $\Delta(\sigma_K - \sigma_{ATM})$ are much less noisy

Theoretical Advantages
- Derman's models of skew in equity markets depend on different behaviour of ATM volatility. However, in all market regimes (trending, range-bound, or jumpy) there is a linear relationship between the deviation of a fixed strike (K) volatility from ATM volatility
- Implies that only first PC would be significant; however, it is found that the second or higher PC can also be significant factors for determining movements
  in $\Delta(\sigma_K - \sigma_{ATM})$

---

2.   **Continued**

- PCA method shown extends Derman's linear models to allow non-linear movements in fixed strike implied volatilities as underlying price changes

(b)   Estimate the implied volatility at $t+1$ for an option with strike 4825.

Commentary on Question:
The candidates performed poorly on this section. Many candidates did not write down the correct formulas to estimate the implied volatility at t+1 for an option with strike 4825 even though it was provided on the formula sheet. Some candidates did not have the correct substitutions for $w_{4825,t}\gamma_{i,t}$. Some candidates did not multiply β_t by ΔS_{t+1}. Only a few candidates received full credit.

The change of the fixed-strike volatility at 4825 can be estimated using
$$\Delta\sigma_{K,t} \approx \beta_{K,t}\Delta S_t$$
Where
$$\beta_{K,t} = \beta_t + \sum_i w_{K,t}\gamma_{i,t}$$
Hence,
$$\Delta\sigma_{4825,t+1} \approx \left(\beta_{t+1} + \sum_i w_{K,t+1}\gamma_{i,t+1}\right)\Delta S_{t+1}$$

$$\Delta\sigma_{4825,t+1} \approx \left(\beta_t + \sum_i w_{4825,t}\gamma_{i,t}\right)\Delta S_{t+1} =$$
$$= (-.00019 + 0.866 * 0.0001 + 0.017 * 0.00007 + 0.433 * 0.0001) * 100$$
$$= -0.5891\%$$
where $\Delta S_{t+1} = 5125 - 5025$

(since $E[\Delta\sigma_K] = E[\Delta\sigma_{ATM}] + E\left[\sum_i w_{K,t+1}\gamma_{i,t+1}\right]$
and $P_{i,t} = \gamma_{i,t}\Delta S + \epsilon_{i,t}$
and $\Delta\sigma_{ATM} = \alpha + \beta\Delta S + \epsilon$, where $E[\epsilon] = E[\epsilon_{i,t}] = 0$ *and α is assume to be* 0)

Hence, $\sigma_{4825,t+1} = 35\% - 0.5891\% = 34.4109\%$

(c)   Describe how historical implied volatility data for the FTSE strikes provided in Table 1 can be used by PCA to create missing historical data for implied volatility of the 5000-strike option.

2. Continued

Commentary on Question:
The candidates performed below average on this section. Candidates did not demonstrate familiarity with the PCA steps to create missing historical data for the implied volatility of the 5000-strike option. Many candidates did not use the correct data and strike prices in Step 1 and Step 2. No credit was given for Step 1 and Step 2 if:
Candidates mentioned: "Obtained factor weights w11,.....,w1m" in Step 2" and "Estimated m PC , P1, P2,..... PM in Step 1" or   Candidates mentioned: "Used 5-year data…" in Step 1 and "Used most recent 1-year of data… in Step 2".

Use daily differences/returns/log-returns to remove any trends
Let the 5000-strike series be X1 and the 5 series from Table 1 be X2… X6

Step 1. PCA on X1…X6 using the most recent 1-year of data. Obtain principal components and factor weights. Choose first m PC (m<6). Denote the factor representation as w11, …, w1m

Step 2. PCA on X2…X6 on the 5 years of history. Estimate the m PC, P1, P2…Pm, which cover 5 years of data.

Step 3. Recreate artificial data history for X1 for the 5-year period using the factor weights from Step 1 and the PC from Step 2 as:
X1* = w11*P1 + w12*P2 +…+w1mPm

Step 4. Calibrate which variables of X2…X6 to include/exclude and the number of PC to include (m) by minimizing the root-mean-square error between the estimated values for X1 from the PCA and the actual values.

3. **Learning Objectives:**
2.   The candidate will understand and be able to apply a variety of credit risk theories and models.

Learning Outcomes:
(2h)   Demonstrate an understanding of credit default swaps (CDS) and the bond-CDS basis, including the use of CDS in portfolio and trading contexts.

(2i)   Demonstrate an understanding an understanding of CDS valuations

Sources:
Handbook of Fixed Income Securities, Fabozzi, F.J, Ch. 66, 67

QFIA-104-13: Asset/Liability Management of Financial Institutions, Tilman, Leo M., 2003, Ch.9

Commentary on Question:
This question tested the candidate's knowledge and understanding of Credit Default Swaps and how these instruments can be used for 'basis' trading. Overall, candidates performed as expected on this question.

Solution:
(a)   Define the following as it relates to a Credit Default Swap (CDS):

I.   Upfront payment
II.   Par spread
III.   Flat quoted spread

Commentary on Question:
The candidates performed as expected on this section. Many candidates did not identify that the upfront premium was the difference between the pay and receive legs and relate the par spread to the upfront premium.

Par spread – the coupon that would be paid for protection on a T-year contract which has <u>no initial cost</u>.

Flat quoted spread – the level at which a flat CDS par spread curve needs to be marked in order that the model-implied upfront value <u>matches the upfront value quoted in the market</u> (e.g. the CDS equivalent of the bond yield-to-maturity.)

Upfront premium – the cost in bps (or dollars) paid by the premium leg the beginning of the contract to transfer the credit risk to the protection leg. There may or may not be a trailing premium cost along with the upfront premium.

3. **Continued**

(b) Show that the CDS running spread for the above CDS is within the range 1.00% to 1.15%.

Commentary on Question:
The candidates performed below average on this question. A few candidates answered the question from first principles instead of using a given formula - the relationship is shown in the solution below. Many candidates ignored the discounting of credit risk and discounted only for the time value of money. Some candidates calculated a 'risk-free' annuity for the denominator in the given formula instead of the correct risky annuity.

The solutions below assume that the cash flows are received at the beginning of the year. However, no candidates were penalized for assuming otherwise since the question did not address the cash flow timing.

The upfront premium (UFP) must be equal to the present value of the expected cash flows (ECF) on the premium (pay) leg of the CDS. Thus,

$$UFP = \sum_{t=0}^{4} \frac{ECF_t}{(1+i)^t}$$

The ECF at each point in time is given by
Notional x Running Spread (RS) x Probability of Surviving (PS)

Thus the UFP can be rewritten as

$$UFP = Notional \times RS \sum_{t=0}^{4} \frac{PS_t}{(1+i)^t}$$

Rearranging and solving for RS gives

$$RS = \frac{UFP}{Notional \times \sum_{t=0}^{4} \frac{PS_t}{(1+i)^t}}$$

Note that this is very similar to the formula given in the Bond-CDS Basis Handbook, Page 15, Equation 2:

$$FR = \frac{U - AI}{RA} + FC$$

Where FR = Full Running Spread, U = Upfront Premium, AI = Accrued Interest, FC = Fixed Coupon and RA = Risky Annuity.

3.   Continued

The calculations (using the above formulas) are shown in the table below:

End of year t	0	1	2	3	4
PS (given in question)	100%	97.50%	95.06%	92.69%	90.37%
Interest Rate	3.00%	3.00%	3.00%	3.00%	3.00%
Discount Factor	1.0000	0.9709	0.9426	0.9151	0.8885
Notional	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
PV (ECF)	10,000,000	9,466,019	8,960,552	8,482,076	8,029,150

Total expected cash flows = 44,937,798
Upfront premium = 460,000
Running Spread = 460,000 / 44,937,798 = 1.02%

(c)   Solve for X.

Commentary on Question:
The candidates performed poorly on this section. A few candidates who did well answered the question from first principles instead of using a given formula.

Many candidates used a simple formula that did not take into account the time value of money. (This is shown in the solution below)

The upfront premium (UFP) must be equal to the present value of the expected cash flows on the protection leg. Therefore,

$$UFP = \sum_{t=1}^{5} \frac{ECF_t}{(1+i)^t}$$

The ECF at each point in time is given by
   Notional x (1 - Recovery Ratio (RR)) x Probability of Default (PD)

Thus the UFP can be rewritten as

$$UFP = Notional \times (1 - RR) \sum_{t=1}^{5} \frac{PD_t}{(1+i)^t}$$

Rearranging and solving for RS gives

$$1 - RR = \frac{UFP}{Notional \times \sum_{t=1}^{5} \frac{PD_t}{(1+i)^t}}$$

3. **Continued**

Many candidates recognized that the probability of default was constant and attempted to use the following formula (given on the formula sheet) which does not take into account the time value of money:
$$S = PD \times (1-R)$$

The calculations are shown in the table below:

t	1	2	3	4	5
PD	2.50%	2.50%	2.50%	2.50%	2.50%
Interest Rate	3.00%	3.00%	3.00%	3.00%	3.00%
Discount Factor	0.9709	0.9426	0.9151	0.8885	0.8626
Notional	10,000,000	10,000,000	10,000,000	10,000,000	10,000,000
ECF	242,718	235,649	228,785	222,122	215,652

Total expected cash flows = 1,144,927
Upfront premium = 460,000
1 – RR = 460,000 / 1,144,927 = 40.18%
RR = 59.82%

(d) Describe how you would use each bond shown above in a negative CDS-Bond basis trade paired with the CDS from part (b). Be sure to discuss

   (i) the specific bond transaction used, and

   (ii) advantages and disadvantages of using that specific bond.

Commentary on Question:
The candidates performed as expected on this section. Some candidates selected a single bond as an investment instead of describing how they would use each bond in an investment as stated in the question. Some candidates did not qualify if their comments were an advantage or disadvantage. Some candidates also left out how they would use the bond and CDS in an investment transaction.

Bond A
- Z-spread is too low for a negative basis trade; need to consider a positive basis trade
- Basis spread = 108 – 75 = 33 bps
- Need to either short the bond, or repo it for a positive basis trade
- Will sell protection via the CDS instead of buying it (as in a negative trade)
- (adv) Default correlation is quite good so should mimic the default events of the CDS

3.   Continued

- (dis) Term and notional do not align with the CDS adding additional basis risks

Bond B
- Z-spread is nice and high can be used for negative basis trade
- Basis spread = 108 – 225 bps = -117
- Can buy bond and enter into negative basis trade
- (adv) Default correlation is not very high meaning there is a risk that default events will not happen at the same time for the Bond and CDS
- (dis) Term and notional exactly line up with the CDS which is what we want

Bond C
- Z-spread is high enough to make this a negative basis trade
- Basis spread = 108 – 180 = 72
- Can buy bond and enter into negative basis trade
- (dis) Default correlation is higher than Bond B but there is still risk that default events will not happen at the same time for the Bond and CDS
- (adv) Notional aligns exactly with the CDS which is what we want
- (adv) Term is a little long, but not significantly long so could still enter the trade

(e)   Draw a diagram showing all cash flows, over the lifetime of the strategy, for the CDS and Bond B used in the above CDS-Bond basis trade.

Commentary on Question:
The candidates performed above average on this section. A few candidates did not distinguish between the investor, bond instrument, and CDS seller; as well they did not show the cash flows taking place at t=0, t=1/2, and t=1, including the bond coupons. Other common mistakes made were calculating the coupon amount based on the price of the bond (8.5 million) instead of the notional amount (10 million) and double counting the recovery amount by applying the recovery ratio (60%) to the net amount paid by the CDS.
There were many ways to diagram the cash flows which were acceptable. One possible solution is shown below.

---

3. **Continued**
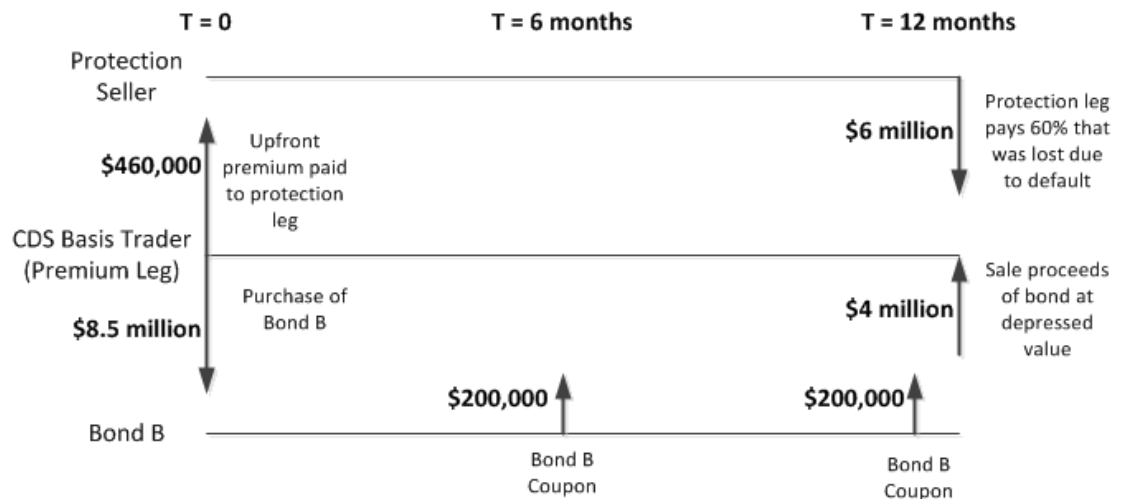
(f)   Calculate the amount earned (or lost) by entering into this CDS-Bond basis trade.

Commentary on Question:
The candidates performed as expected on this section. Many candidates used a formula given in the text, but often didn't use the appropriate variables. Candidates that did well answered the question based on first principles. Discounting the net profit/loss for time-value-of-money is appropriate for various analyses and no candidate was penalized for doing so.

T = 0
- The CDS basis trader (premium leg, aka us) will pay the protection leg the upfront premium for the deal this premium covers the life of the deal
- The CDS basis trader will purchase Bond B for $8.5 million

T = 6 months
- The bond will pay $200,000 coupon payment (4% BEY on $10 million notional)

T = 12 months
- The bond pays the $200,000 coupon and then defaults
- 40% of notional, or $4 million, is recovered by the CDS basis trader
- The protection leg of the CDS must pay the CDS premium leg the $6 million lost due to default

3. **Continued**

The total amount earned by the CDS Basis Trader is:

CDS Premium paid	-460,000
Funds to purchase Bond B	-8,500,000
Total coupons received	400,000
Sale proceeds on default	4,000,000
Protection leg payment	6,000,000
Total earnings	**1,440,000**

4.

Learning Objectives:
3.   Candidate will understand the nature, measurement and management of liquidity risk in financial institutions.

Learning Outcomes:
(3b)   Measure and monitor liquidity risk, using various liquidity measurement tools and ratios.

(3d)   Understand liability termination provisions such as book-value surrender and the impact on a company's overall liquidity risk.

(3g)   Understand and apply techniques to manage street liquidity risk.

Sources:
QFIA-105-13: Report of the Life Liquidity Work Group of the American Academy of Actuaries to the Life Liquidity Risk Working Group of the NAIC

Liquidity Risk Management, CRO Forum 10/2008

Commentary on Question:
This question tested the candidate's knowledge and understanding of specific liability termination provisions, and how it pertains to a company's overall liquidity risk assessment.

Solution:
(a)   Identify key features of each of these two products that could potentially impact RMK's liquidity risk profile:

        (i)   Benefit-responsive GIC

        (ii)   COLI with no deferral options

        Commentary on Question:
        The candidates performed below average on this section.
        Most candidates identified some features of these products, however the linkage between these features and liquidity risk profile was weak or missing.

        (i)   Benefit-responsive GIC
- GICs used for DC pension plans
- Commonly allows payments at book value for individual plan participants
- Could result in large payments during layoffs or early retirement programs
- Surrender of entire contract typically subject to market value surrender penalty
- This still may not prevent large cash demands in times of stress

4. **Continued**

    (ii)   COLI with no deferral options
- Funding vehicle used by large corporations to fund employee benefit plans and other liabilities
- Potential for entire groups of individual policies to surrender at the same time
- No deferral option being included - could result in large cash demands on short notice
- May be side agreements that allow contract holder to surrender w/o penalty in certain circumstances – such as credit rating downgrade of the insurer
- Tax consequences of withdrawal may reduce the likelihood of surrender

(b)   Critique the pricing actuary's COLI pricing assumptions with respect to:

    (i)   Investment strategy

    (ii)   The additional required capital to account for the liquidity risk

Commentary on Question:
The candidates performed as expected on this section.
Many candidates identified the liquidity concern in the Investment Strategy and explained why the additional required capital is not appropriate to account for the liquidity risk.

    (i)   Investment Strategy
- From maximizing the crediting rate perspective, the investment strategy is valid.
- The investment strategy is heavily allocated to commercial mortgage and real estate, which are illiquid but historically had better returns than the other permitted asset classes listed.
- This higher return partially attributes to their long term nature, which matches well with the long-term nature of COLI product.
- This higher return also requires expertise. Life insurers are major players in these areas.
- However, the heavy allocation in illiquid assets may bring in liquidity issues.
- RMK Financial may find it difficult in meeting large cash demands especially given no deferral option.
- The high credited rate may attract new business, which helps liquidity in normal scenario.
- But the new business may substantially decrease or even dry up in stress scenario such as RMK Financial is downgraded.

4. **Continued**

- Downgrade of RMK Financial may trigger large withdrawal of existing COLI client.
- The high credited rate may help decrease withdrawal or transfer to some extent, but disintermediation could happen depending on a number of factors when interest rate soars rapidly.

(ii) The additional required capital to account for the liquidity risk
- The additional required capital to account for the liquidity risk is inappropriate.
- The presence of the liquidity risk should not lead to an additional capital requirement.
- Liquidity risk is a risk to be managed at all times – before, during and after any stress event.
- No amount of capital can replace comprehensive liquidity risk management

(c) Determine if the company can meet its minimum coverage ratio requirement in each scenario.

Commentary on Question:
The candidates performed as expected on this section.
Many candidates did not use cumulative cashflows to calculate the coverage ratio or simply calculated the ratio in the third month.

- Use the **cumulative** cash flows to calculate the coverage ratio since the question specifically gives cash flows by period (month) which are not cumulative.

$Millions	Cumulative Cash Flows	1st Month	2nd Month	3rd Month
Baseline Scenario	Sources	7,000	10,500	19,000
	Needs	1,000	5,500	10,000
	Coverage Ratio	7.00	1.91	1.94
Stress Scenario	Sources	6,500	9,700	17,200
	Needs	3,000	8,000	14,200
	Coverage Ratio	2.17	1.21	1.21

- RMK Financial passes liquidity test in both scenarios (but barely)

4. **Continued**

(d) Recommend three derivatives that could help mitigate the Stress Scenario liquidity risk.

Commentary on Question:
The candidates performed as expected on this section.
Many candidates identified appropriate derivatives, but some candidates failed to explain how those derivatives can help mitigate the Stress Scenario liquidity risk.

The three derivatives to manage the stress liquidity risk
- Purchase credit derivatives that will pay in the event of a downgrade or spread widening of the company or the sector of the financial services industry the company is in.

- Purchase equity puts that would theoretically pay off in a company specific stress scenario or industry specific scenario.

- Purchase liquidity option from an investment dealer that will pay in liquidity stress scenario.

5. **Learning Objectives:**
1.   The candidate will understand the standard yield curve models, including:
    - One and two-factor short rate models
    - LIBOR market models

    The candidate will understand approaches to volatility modeling.

Learning Outcomes:
(1l)   Define and explain the concept of volatility smile and some arguments for its existence.

(1n)   Compare and contrast "floating" and "sticky smiles.

(1p)   Identify several stylized empirical facts about smiles in a variety of options markets.

(1q)   Describe and contrast several approaches for modeling smiles, including: Stochastic Volatility, local-volatility, jump-diffusions, variance-gamma and mixture models.

Sources:
Rebonato, R, Volatility and Correlation, 2nd Edition, Section 7.2.1, p.203-4.

Rebonato, R, Volatility and Correlation, 2nd Edition, Section 7.3, p.206-208.

Rebonato, R, Volatility and Correlation, 2nd Edition, Section 8.1-4, p.237-43.

Rebonato, R, Volatility and Correlation, 2nd Edition, Section 6.4-5, p.178-184.

Rebonato, R, Volatility and Correlation, 2nd Edition, Section 6.5, p.181-2.

Rebonato, R, Volatility and Correlation, 2nd Edition, Section 6.6, p.182-3.

Commentary on Question:
This question tested the concept, stylized empirical fact, and the modeling of volatility smile.

Solution:
(a)   Describe two approaches to obtain direct static market information that can be useful for modeling the equity volatility surface.

   Commentary on Question:
   The candidates performed below average on this section.

5. **Continued**

Static information about the smile surface can be obtained by observing its behavior for a fixed maturity as a function of strike, or its dependence on the time to expiry for a fixed strike (term structure of smiles). Partial credit was given to candidates who mentioned "observe volatility across different maturity/strike". In principle, a better set of co-ordinates than the strike could be the in-the-moneyness although it is not straightforward to define. Or the smile surface at time t is a function that associates to a strike K and maturity T.

$$\sigma_t^{impl} = \sigma_t^{impl}(K, T)| \qquad\qquad (7.1)$$

Another important static information is conveyed by a comparison of at-the-money (ATM) volatilities, risk reversals, straddles for each maturity.

The risk-reversal statistics, $RR(t, T)$, for a given maturity is defined as the difference between the 25-delta implied volatility for calls and puts of the same maturity:
Or: $RR(t, T) = \sigma impl(t,K25\_p, T) - \sigma impl(t,K25\_c, T)$ (7.3)
where $K25\_p$ ($K25\_c$) is the strike that gives a 25-delta to the put (call).

Risk reversal gives an indication about the asymmetry of the smile for a given maturity.

The straddle $ST(t, T)$ is calculated as
$ST(t, T) = \sigma impl(t,K25\_p, T) + \sigma impl(t,K25\_c, T) - 2 \sigma impl(t,KATM, T)$ (7.4)
where $\sigma impl(t,KATM, T)$ is the at-the-money implied volatility.

Straddle gives information about its average curvature around the ATM level.

(b)   Describe four categories of models that account for the smiles.

Commentary on Question:
The candidates performed above average on this section. Most of the candidates listed the 4-5 categories and described the models. Many of the candidates described the type of smiles that each model can create, which is was not asked for in this question.

5. **Continued**

The following 4 models are the categories described in the syllabus.
i)   Fully-stochastic-volatility models: An example of Fully-stochastic-volatility model is as follow:
$$dS = \mu_S(S,V,t)dt + \sigma_S(S,V,T)dz_t$$
$$dV = \mu_V(S,V,t)dt + \sigma_V(S,V,t)dw_t$$
$$V = \sigma^2$$
$$E[dwdz] = \rho dt$$
The model which posits the dynamics of the underlying with two stochastic processes, one given to the underlying and the other given to the volatility of the underlying.
ii) Local-volatility (restricted-stochastic-volatility) models:
$$dS_t = rS_t dt + \sigma(S_t,t)dz$$
Or the models describe the stochastic evolution of the underlying with only one stochastic process, by means of a volatility term which is a deterministic function of the underlying S_t .
iii) Jump-diffusion models:
In this model, the stock price is not only affected by a Brownian diffusion but also by jumps which are discontinuous moves whose magnitudes do not scale with time.
iv) Variance-gamma (pure jump) models:
It describe the process for the underlying purely in terms of discontinuous jumps, and no continuous Brownian component at all.
v)   Mixing Processes:
The combination of jump-diffusions and stochastic volatilities, or variance-gamma model and stochastic volatility have all been combined by certain scholars. Often the combined model would provide 1) sharp short maturity smiles over intermediate maturities.

(c)   Identify which model category this model belongs to and explain why.

Commentary on Question:
The candidates performed as expected on this section. Most candidates stated it is local volatility model, but only a few were able to identify this model as CEV.

Local-Volatility-Model is a stochastic process where the volatility is a deterministic function of the underlying . $dS_t = rS_t dt + \sigma (S_t, t)dz$.
CEV model is a special case of the local-volatility-model.
In CEV, the volatility term is a function of the underlying $f^\beta \sigma(t)$.

5. Continued

(d)   Discuss the parameters of the model in terms of the sticky smile and floating smile.

Commentary on Question:
The candidates performed as expected on this section. Most candidates described the sticky smile and floating smile. Many candidates got the γ wrong.

When γ = 1, it describe a sticky smile, where the volatility does not change with the underlying.
When γ ≠ 1, it describe a floating smile, where the volatility does change with the underlying.

6. **Learning Objectives:**
2.   The candidate will understand and be able to apply a variety of credit risk theories and models.

Learning Outcomes:
(2b)   Demonstrate an understanding of the basic concepts of credit risk modeling such as probability of default, loss given default, exposure at default, and expected loss.

(2c)   Demonstrate an understanding of credit valuation models.

Sources:
QFIA-122-16: Recent Advances in Credit Risk Modeling
Commentary on Question:
This question tested the candidate's knowledge of the recently added study note regarding credit risk modeling. Overall, the candidates performed as expected on this question. Candidates who were successful were able to identify the reasons why the Black model cannot be applied for credit index options.

Solution:
(a)   Calculate the distance to default 3 years ahead using the information above.

Commentary on Question:
The candidates performed above average on this section.

Distance to default –

$$DD_T = \frac{\ln \frac{V}{D} + \left(\mu - \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}},$$

Calculation –

μ = .03
sigma = 0.2
T = 3
V/D = (100/50) = 2

DD(t) = [Ln (2) + (.03 – ½*(.2)^2)*3]/(.2*sqrt(3))
DD(t) =0.72315/0.34641

DD(t) = 2.08755

6. Continued

(b) Describe a drawback of distance to default that makes it difficult to use for regulatory purposes.

Commentary on Question:
The candidates performed poorly on this section. Most candidates did not identify that the main drawback of using distance to default as a metric for regulatory intervention is that intervention must happen at some point <u>before</u> the default.

Distance to default measures may understate the likelihood the institution may be required to take action by regulators. Thus the distance to default measure may be considered a bridge too far for regulatory intervention.
Usually regulators would like to intervene with capital measures at some point before the default occurs. However, the distance to default usually does not give regulators that luxury. However, alternative models are and variations are available.

(c) Describe the differences between structural and reduced form models, giving examples of each.

Commentary on Question:
The candidates performed above average on this section. Many candidates successfully identified the difference between structural and reduced form models.

Main definition

The reduced form approach assumes that the timing of default relies on exogenous stochastic process and the timing of default is not linked to any observable characteristics of the firm.
Structural models believe that default occurs when a firm is unable to service its debt, say because of economic reasons related to its business cycles.

Dependence on firm characteristics

Structural models assume that defaults depend on characteristics of the firm, whereas reduced form models relate the defaults to some exogenous stochastic factors.

Structural models assume that the modeller has the same information as the firm's managers and hence can reliably estimate default. The reduced form models on the other hand assume that the modeller has the same information set that the market has, incomplete knowledge of firm's financial health, which makes it difficult to nearly impossible to predict default time.

6. Continued

(d)   Describe a credit index option including the front end protection offered.

Commentary on Question:
The candidates performed as expected on this section. Many candidates were successful in defining the credit index and the front end protection provided by it.

The credit index
Option on the spread of a credit index that consists of a standardized portfolio of credit default swaps.

The credit index allows the investor to enter the forward credit index at a pre specified spread and to receive upon exercise of this option a front end protection corresponding to index losses from option inception to option expiry. A payer credit index option at inception (time 0) with strike K and exercise Ta and written on an index with maturity Tm allows the buyer the right (not obligation) to enter into the index at Ta with final payment at Tm. The buyer pays a fixed K which gives him the right to receive protection between Ta and Tm. Additionally, the buyer receives front-end protection from losses between 0 and Ta.

(e)   Explain why the Black model is not a useful method of pricing credit index options.

Commentary on Question:
Most candidates performed poorly on this section. Many candidates explained why Black Scholes is not a good model for pricing derivatives in general but did not specifically explain the main reasons as to why Black Scholes cannot be applied to credit index options.

Some shortcomings it suffers from –

1. The front end protection cannot be separated from the price of the call on spread as the front end protection is an integral part of the investor's decision to exercise an option.
2. Index spread does not take into account the front end protection in moments of stress in financial markets
3. Market practice to compute index spread does not consider all states of the world.

Hence the black formula to price the index option is not justified.

6. **Continued**

    (f)   Describe the issues faced historically with modeling default recovery rates.

        Commentary on Question:
        The candidates performed above average on this section.

        1. Very little literature on recovery rates
        2. Most estimates rely on industry sources
        3. Pre default debt and CDS prices are used to estimate recovery rates

7. **Learning Objectives:**
1.   The candidate will understand the standard yield curve models, including:
   - One and two-factor short rate models
   - LIBOR market models

   The candidate will understand approaches to volatility modeling.

Learning Outcomes:
(1f)   Explain how deterministic shifts can be used to fit any given interest rate term structure.

(1g)   Demonstrate an understanding of the CIR++ model.

Sources:
Brigo, D and Mercurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 4.1, p.138.

Brigo, D and Mercurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 3.9, p.102-103.

Brigo, D and Mercurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 3.8, p.95-98.

Brigo, D and Mercurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 4.2.2, p.145-146.

Commentary on Question:
This question tested the candidate's understanding of one- and two-factor versions of the CIR++ short-rate model, specifically, the shift function.

Solution:
(a)   Describe conditions under which it would be reasonable to use a one-factor short rate model (CIR++), rather than a two-factor model (CIR2++).

         Commentary on Question:
         The candidates performed as expected on this section. Many candidates described the motivation for the CIR2++ model and correctly identified multiple situations in which that motivation is not relevant. Many candidates however only described one particular situation.

         Situations where a one-factor approach is reasonable include:
- Pricing a financial instrument whose payout depends solely on a single rate of the whole interest-rate curve
- Pricing a financial instrument whose payout depends on a set of rates on the interest-rate curve that are very close together (since those rates would likely be very highly correlated anyway)

---

7.   **Continued**

- When performing risk-management approximations over relatively short time horizons and a high degree of precision is NOT needed
- Pricing a financial instrument where correlations between interest rates of different tenors don't need to be reflected (i.e. caplets).

(b)   Describe the following related to the CIR++ model:

(i)   The advantages of using CIR++ over CIR2++

(ii)   The limitations of using CIR++ over CIR2++

(iii)   The purpose of the $\varphi(t)$ function.

Commentary on Question:
The candidates performed above average on this section. Many candidates included multiple advantages and limitations in their responses. Most candidates provided reasonable descriptions of the purpose of the φ function. Some candidates only provided one advantage/disadvantage (sometimes stating multiple equivalent formulations of the same point).

(i)   advantages of using a one-factor approach over a two-factor one include:
- Analytical tractability – the one-factor short-rate model CIR++ admits an analytical solution, while the two-factor short rate model CIR2++ only allows for an analytical solution under the unrealistic assumption of zero correlation between the 2 factors.
- Computational efficiency – a one-factor approach requires half as much simulation and half as many parameters to estimate.

(ii)   limitations of using a one-factor approach over a two-factor one include:
- Assuming overly high levels of correlation between all points on the yield curve
- Less precision in the model's projected values/distribution

(iii)   in the CIR++/CIR2++ short-rate models, the φ function is a deterministic shift that is added to the CIR short rate in order to calibrate the model to exactly fit the currently observed term structure of instantaneous forward rates for all future maturities.

(c)   Show that $\varphi(t)$ is the difference between the market forward curve and the CIR forward curve i.e. $\varphi(t) = f^M(0,t) - f^{CIR}(0,t)$, without using the closed-form solution for the CIR bond price.

7.   Continued

For $\phi(t)$ to be the yield term-structure fitting function, we must have the
relationship: $P^M(0,T) = P^{CIR++}(0,T)$.

The zero-coupon bond price under CIR++ is given by:

$$P^{CIR++}(0,T) = \mathbb{E}^Q\left[e^{\left(-\int_0^T (x(s)+\varphi(s))ds\right)}\right] = e^{-\int_0^T \varphi(s)ds}\,\mathbb{E}^Q\left[e^{-\int_0^T x(s)ds}\right]$$

We are allowed to pull the integral involving φ outside of the expectation
operator, because φ is the deterministic shift function. After removing that
integral, we can recognize the remaining expectation as the market price of the
zero coupon bond:

$$P^{CIR++}(0,T) = e^{-\int_0^T \varphi(s)ds}\,P^M(0,T)$$

Next, in order to convert the bond price relation into a relation between forward
rates, we will need to take the logarithm of the expression and then differentiate
with respect to T (at T = t).

$$\ln P^{CIR++}(0,T) = -\int_0^T \varphi(s)ds + \ln P^M(0,T)$$

$$\frac{d\ln P^{CIR++}(0,T)}{dT} = -\varphi(t) + \frac{d\ln P^M(0,T)}{dT} \quad \Rightarrow \quad f^{CIR++}(t) = -\varphi(t) + f^M(t)$$

Rearranging the last equation proves the result: $\varphi(t) = f^M(t) - f^{CIR++}(t)$

(d)   Write down the formula for $f^{CIR}(0,t)$ using the parameters implied by the CIR++
model above.

7. Continued

Per formula (3.77) on the formula sheet, $f^{CIR}(0, t; \alpha)$ is given by:

$$f^{CIR}(0, t; \alpha) = \frac{2k\theta(\exp\{th\} - 1)}{2h + (k + h)(\exp\{th\} - 1)} + x_0 \frac{4h^2 \exp\{th\}}{[2h + (k + h)(\exp\{th\} - 1)]^2}$$

where $h = \sqrt{(k^2 + 2\sigma^2)} = 0.5431$.

Substituting in the model parameters for k, θ, and σ, we obtain:

$$f^{CIR}(0, t; \alpha) = \frac{0.0125(\exp\{0.5431t\} - 1)}{1.0862 + 1.0431(\exp\{0.5431t\} - 1)} + 0.0075 \frac{1.18 \exp\{0.5431t\}}{[1.0862 + 1.0431(\exp\{0.5431t\} - 1)]^2}$$

(e)   Determine if zero is accessible to the process $x(t)$.

Commentary on Question:
The candidates performed below average on this section. Some candidates recalled and correctly applied the Feller condition for strict positivity. Most candidates failed to demonstrate that the CIR process had been well-defined.

For a square-root diffusion process to remain strictly positive, the Feller condition must hold: $2k\theta > \sigma^2$. For the given parameters, we have:

$$2k\theta = 2(0.5)(0.0125) = 0.0125 < 0.0225 = (0.15)^2 = \sigma^2$$

Because the Feller condition for strict positivity does not hold, we can conclude that zero is accessible for the given square-root diffusion process.

8.   **Learning Objectives:**
6.   The candidate will understand and be able to describe the variety and assess the role of alternative assets in investment portfolios. The candidate will demonstrate an understanding of the distinguishing investment characteristics and potential contributions to investment portfolios of the following major alternative asset groups:
- Real Estate
- Private Equity
- Commodities
- Hedge Funds
- Managed Futures
- Distressed Securities
- Farmland and Timber

Learning Outcomes:
(6a)   Demonstrate an understanding of the types of investments available in each market, and their most important differences for an investor.

(6c)   Demonstrate an understanding of the investment strategies and portfolio roles that are characteristic of each alternative investment.

Sources:
QFIA-112-13: Commercial Real Estate Analysis & Investments, Ch. 12, Section 12.3, p. 276-285.

Commentary on Question:
This question tested the candidates' understanding of REIT concepts.

Solution:
(a)   Describe each of the four terms within the above two equations as they relate to a REIT.

  Commentary on Question:
  The candidates performed above average on this section. Candidates generally provided more comprehensive definitions for IV and MV and less comprehensive definitions for NAV per share and share price.

  NAV per share is the estimated private market value of the REIT's properties (less the value of debt employed to finance the properties) per share. It is based on a static portfolio of existing assets and estimates the liquidation equity value.

  Share price is the price at which parties transact in public stock markets, reflecting the market's assessment of both the existing asset values and value of future growth opportunities. The share price only provides indirect indication about the underlying property valuation since the properties themselves do not trade in the REIT market.

8. **Continued**

IV$_R$ is the investment value of a property for a given REIT, i.e. the value the individual REIT shareholders put on the property as a long-term holding.

MV$_P$ is the market value of the property in the private property market, i.e. the expected price at which a property can be sold in the current market.

(b) Critique the relationships your colleague provided, taking into consideration the validity of each equation under varying market conditions.

Commentary on Question:
The candidates performed below average on this section. Most candidates gave conditions for the equation either being true or being false and received partial credit accordingly. Very few candidates described the conditions behind the equations being true in some circumstances and false in others.

i) NAV per share = share price

The equation holds true if there is no valuation differential between the REIT and private property markets at the micro-level. In that case, REITs can generally purchase/sell properties at prices equal to prevailing market values in the private property markets without causing changes in REIT share prices.

However, valuation differentials do exist in practice when the markets believe the value of a REIT's existing assets and future growth opportunities differs from its liquidation value. In such cases, the equation will not hold true.

ii) IV$_R$ = MV$_P$

The equation is expected to hold true in efficient markets when positive-NPV opportunities do not exist and REITs are not intramarginal participants in the property market. The existence of valuation differentials implies positive-NPV opportunities for REITs based on investment value, but these differentials would be arbitraged away by multiple investors seeking these opportunities.

However, real estate markets are not always efficient and if positive-NPV opportunities exist then the equation would not hold true, e.g. if market conditions presented structural differences

(c) Identify the advantages of a REIT in generating future cash flows from a given property as compared to a private property owner.

8. Continued

Commentary on Question:
The candidates performed as expected on this section. Some candidates did not identify advantages as they relate to cash flow generation and instead listed advantages of investing in REITs as an asset class which was not asked for in the question. In such cases, the candidates did not receive any credit for points that did not relate to cash flow generation.

REIT could obtain greater future cash flows as a result of:
- Superior property management ability
- Economies of scale that allows for savings on operating expenses
- Name recognition or brand identity among potential tenants that allows it to generate greater revenue
- Synergistic or spillover effects on REIT's other property holdings that cause incremental cash flows for the REIT

(d) Compare and contrast the opportunity cost of capital between the REIT and private property markets and its impact on valuations within these markets.

Commentary on Question:
The candidates performed below average on this section. Many candidates listed several similarities and/or differences in OCCs between the 2 markets, but did not receive full credit because they either did not describe the drivers behind the similarities/differences or describe their impacts on valuations.

In an efficient capital market, we would not expect significant sustained differences in OCC or valuation differentials between the REIT and private property markets. The risk premium within the OCC is the risk in the subject asset's cash flows, i.e. risk resides in the asset, not in the investor. Capital markets are substantially integrated and seamless and positive-NPV opportunities are quickly arbitraged away.

However, capital markets are neither perfectly efficient nor completely seamless in the real world. OCC is determined by investors' expectations about individual risk/return performance and not solely on the fundamentals of the underlying physical asset. REIT markets differ in structure and functioning from private property markets and this may allow for systematic differences in OCC between the two markets. REIT and private property investor populations also have different risk preferences for the same assets, e.g. different liquidity needs, tax circumstances, etc. Thus, systematic differences in both OCC and valuation differentials between the REIT and private property markets do exist even in the long run.

8. **Continued**

(e)   Assess the amount REIT A should be willing to pay to invest in the property.

Commentary on Question:
The candidates performed as expected on this section. Many candidates did not do the math to relating REIT A and B's offers to the market value/investment value which was expected in an assessment. However many candidates received partial credit for recognizing that REIT A should offer the market value/investment value even if its cost of capital could seemingly warrant a higher offer.

NPV(market) = $51 x (1-1.08^-20)/.08 = $500M
NPV(A) = $51 x (1-1.06^-20)/.06 = $585M

REIT B is willing to pay the investment value of the property. REIT A should also offer $500M. If REIT A pays more than the investment value of $500M (even if it has a lower cost of capital), its stock price will be diluted.

9. **Learning Objectives:**
4. The candidate will understand important quantitative techniques relating to financial time series, performance measurement, performance attribution and stochastic modeling.

Learning Outcomes:
(4a) Understand the concept of a factor model in the context of financial time series.

(4b) Apply various techniques for analyzing factor models including Principal Component Analysis (PCA) and Statistical Factor Analysis.

(4h) Understand and apply various techniques of adjusting auto correlated returns for certain asset classes.

Sources:
QFIA-110-13, CAIA Level II, Advanced Core Topics in Alternative Investment, 2nd Edition, 2012, Ch. 16

QFIA-119-14: Analysis of Financial Time Series, Tsay, 3rd edition, Ch. 9
Commentary on Question:
The question tested the candidate's understanding of Principle Component Analysis and real estate price smoothing.

Solution:
(a) Explain why reported real estate prices are generally smooth.

Commentary on Question:
The candidates performed as expected on this section. Most candidates provided at least one reason why prices may be smooth.

Property prices are based on most recent transaction price that might be stale.
Appraiser/buyer/seller might exhibit anchoring and are reluctant to large change in price
Transaction price might signal lagged price response
There is a delay between the transaction and the reporting of the price

(b) Describe the data problem(s) you might encounter in PCA statistical factor analysis and how the problem(s) can be addressed.

Commentary on Question:
The candidates performed below average on this section. Many candidates did not specify that the price formula exhibits autocorrelation. Many candidates incorrectly identified collinearity as a problem.

9. **Continued**

The reported price exhibits autocorrelation with the previous 2 periods. Statistical Factor Analysis for PCA assumes zero autocorrelation. Remove the autocorrelation and analyze the residual series.

(c) Using the PCA results above:

(i) Construct a reasonable and efficient orthogonal factor model.

(ii) Calculate the factor loadings.

Commentary on Question:
The candidates performed above average on this section. Most candidates identified that two to three components explain most of the variance.

(i) Sum of eigenvalues $= 24.0054 + 4.0984 + 1.7366 + 1.4829 + 0.8052 = 32.1285$

Proportion of variances is 75%, 13%, 5%, 5%, 3%

So we can ignore factor 3, 4, 5 since they only contribute 13% of the total variance.

(ii) The factor loadings are

$$\hat{\beta} = \left[\sqrt{\hat{\lambda}_1}\, \hat{e}_1 \middle| \sqrt{\hat{\lambda}_2}\, \hat{e}_2 \right]$$

β1	-1.96	-2.27	-2.39	-2.26	-2.04
β2	-0.71	-0.61	-0.79	0.97	1.28

(d) Explain why the factor loadings are hard to interpret and describe how you can improve their meaning.

Commentary on Question:
The candidates performed below average on this section. Many of the candidates did not mention that principle components and their factors are not observable and also failed to mention how to improve their meaning.

PCA method produces estimated factor loadings. Since the choice of factors are unobservable, it is hard to interpret the resulting factor loading in a meaningful sense.

9. Continued

We can improve the meaningfulness of the result by performing a factor rotation. The communalities and specific variances remain unchanged under factor rotation. So the rotated factor loadings still account for the same variance and have a potentially useful interpretation.

(e) Explain how you can apply PCA techniques to this problem.

Commentary on Question:
The candidates performed below average on this section. Some candidates did correctly mention Asymptotic PCA as a solution, however most candidates did not identify the fact that the number of assets exceeded the number of time periods.

Since the number of assets is much larger than the number of time periods we cannot use PCA. However, we can use asymptotic PCA.

10. Learning Objectives:
2. The candidate will understand and be able to apply a variety of credit risk theories and models.

Learning Outcomes:
(2l) Understand and apply various approaches for managing credit risk in a portfolio setting.

Sources:
QFIA-101-13: Managing Credit Risk: The Great Challenge for Global Financial Markets, Caouette, John B., et. al., 2nd Edition, 2008, Ch. 20, *page 401-402*

QFIA-101-13: Managing Credit Risk: The Great Challenge for Global Financial Markets, Caouette, John B., et. al., 2nd Edition, 2008, Ch. 20, page 376-377

QFIA-101-13: Managing Credit Risk: The Great Challenge for Global Financial Markets, Caouette, John B., et. al., 2nd Edition, 2008, Ch. 20, page 390-397

Commentary on Question:
This question tested the candidate's understanding of credit risk capital and various approaches for managing credit risk

Solution:
(a) Outline four shortcomings of BIS I (Basel I) with respect to credit risk requirements and how BIS II (Basel II) attempted to rectify them.

Commentary on Question:
The candidates performed above average on this section. Most candidates correctly identified the different credit quality allowed by BIS II and understood the main differences between BIS II and BIS I.

BIS II (Basel II) has attempted to rectify some of the shortcomings in BIS 1 (Basel I) by recognizing following:
* Risk differences between obligors – BIS II (Basel II) allows for an internal ratings based on approach which can stratify the borrowers in terms of credit quality. It is no longer the case that 8% capital ratio is needed for all corporate borrowers regardless of credit quality.
* Credit migration vs. default/no default (or credit migration) – BIS II (Basel II) recognized that credit migration can occur.
* Correlation effects on the portfolio
* Basing the capital needed on unexpected loss

10. Continued

- BIS (Basel II) assumes that the portfolio is already highly diversified and the only risk it is subject to is the systematic risk

- BIS (Basel II) offers banks the option to use its own models for deriving the capital requirements as long as it is found satisfactory by the regulators

(b) Calculate the portfolio's required economic capital at 99.8% confidence interval.

Commentary on Question:
The candidates performed below average on this section. Many candidates correctly calculated the change in the portfolio value (=2.88*3) for the confidence interval, however often this amount was often added to the 52. Some candidates did not discount the loss to calculate required economic capital or discounted incorrectly.

The outcome of all the Monte Carlo simulations leads to the value distribution of the portfolio. The value distribution minus the initial portfolio value is the loss distribution. MKMV defines capital as the amount needed to set aside at the analysis date to absorb losses x% of the time where x is the confidence level desired. As such, it measures a point on the horizon loss distribution discounted back to the analysis date.

Value at 99.80 loss distribution is mean + N(-1)(99.8%) * sigma since the loss follows a normal distribution

The normal distribution table shows N(2.88) = 0.9980

Value at 99.80 loss distribution is 52 - 2.88 * 3 = 43.37M

Discounted value at analysis date is 43.37/(1+2%+.5%) = 42.31

Required Economic Capital at 99.80 Confidence Interval is 50 - 42.31 = 7.69

(c) Calculate the portfolio's risk-reward ratio based on Altman's optimization approach.

Commentary on Question:
The candidates performed below average on this section. Most candidates correctly identified the formulas for portfolio expected annual return, standard deviation, and risk award ratio. However, many candidates failed to calculate expected annual loss correctly.

10. Continued

For bond 1, the expected annual loss or annualized cumulative loss is 1.21%.

Cumulative mortality (default) losses is calculated by
(1 – prior year cumulative losses) * marginal losses + prior year cumulative losses

Annualized cumulative mortality (default) losses is calculated by
1 – (1- cumulative losses) ^ (1/year)

	1	2
Cumulative Mortality (default) Losses	0.23%	2.41%
Annualized Cumulative Losses	0.23%	1.21%

For bond 2, the expected annual loss or annualized cumulative loss is 1.53%.

	1	2	3
Cumulative Mortality Losses	0.67%	2.07%	4.52%
Annualized Cumulative Losses	0.67%	1.04%	1.53%

For bond 1, the expected annual return
EAR = YTM (Yield-to-Maturity) – EAL (Expected Annual Loss)
= 5% - 1.21% = 3.79%
For bond 2, the expected annual return
EAR = YTM (Yield-to-Maturity) – EAL (Expected Annual Loss)
= 5.76% - 1.53% = 4.23%

The portfolio expected annual return is (15/50) * Bond 1 EAR + (35/50) * Bond 2 EAR = 4.1%

The bond 1 allocation is 15/50 = 0.3, and bond 2 is 0.7

The portfolio standard deviation is
Sqrt (0.3^2 * Bond 1 variance + 0.7^2 * Bond 2 variance ^2 + 2 * 0.3 * 0.7 * 0.6* sqrt (Bond 1 variance * Bond 2 variance)) = sqrt (.3^2 * .04 + 0.7^2 * .05 + 2 * 0.3 * 0.7 * 0.6 * sqrt(.04*.05))
=sqrt(3.94%) = 19.8%

The portfolio risk reward ratio = EAR/ Std Dev = 20.65%

11. **Learning Objectives:**
4.   The candidate will understand important quantitative techniques relating to financial time series, performance measurement, performance attribution and stochastic modeling.

Learning Outcomes:
(4i)   Demonstrate an understanding of the general uses and techniques of stochastics modeling.

Sources:
QFIA-124-16 Stochastic Modeling, Theory and Reality from an Actuarial Perspective, sections I-4,5,20-24

Commentary on Question:
This question focused on the general use and techniques of stochastic modelling. It tested the candidate's ability to decide when stochastic modelling is appropriate for different situations. It then tested the candidate's understanding of the general steps of stochastic modelling. Lastly, the candidates had to simulate stock prices using a Regime Switching Lognormal model.

Solution:
(a)   Outline three alternative non-stochastic approaches that could be used when it would be impractical to build the scenarios needed for stochastic modelling.

Commentary on Question:
The candidates performed below average on this section. Few candidates retrieved or provided reasonable alternatives to receive full credit.

Stress testing/scenario testing: Represent extreme scenarios, and gauge sensitivity of outcome to certain assumptions.
Static factors (or "load factors"): Based on previously developed or commonly used load factors to account for risk.
Ranges: To account for uncertainty of a "best" estimate. e.g. 90% to 110% of the point estimate of the assumption.

(b)   Critique Bob's methodology, including considerations he may have failed to identify and any steps that should have been done differently.

Commentary on Question:
The candidates performed below average on this section. Few candidates provided all considerations, with most common ones missed being focus on fixed income risk and not challenging the use of 1,000 scenarios.

11. Continued

> Stochastic modelling may not be the only way to understand the cost of minimum interest rate guarantees.
> Bob did not determine what projection/simulation technique should be used.
> The risk metric chosen is not appropriate, because Bob's goal is to understand the economic cost.
> RBC is based on prescribed factors that are not tailored to the risk of the specific block of business under consideration.
> Economic risk metrics such as CTE (95) could be used.
> The risk factor to be modeled stochastically is S&P returns, this is not appropriate.
> The main risk is fixed account interest rate risk, not equity risk.
> Bob should have used an interest rate model to look at interest rate scenarios.
> Blindly using 1,000 scenarios is not appropriate.
> Bob should perform several runs with different number of scenarios in each run, and determine the number of scenarios necessary to reach the point at which additional iterations provide no additional information about the shape of distribution.

(c)   Simulate the price at time 1 using the RSLN parameters above.

Commentary on Question:
The candidates performed as expected on this section. Candidates generally determined that it is in regime 1 and provided the calculations correctly.

Using this formula $\pi_{1,0} = \frac{p_{21}}{p_{12}+p_{21}}$, $\pi_{1,0} = \frac{15\%}{5\%+15\%} == 0.75$
Since, $0.3 < 0.75$. the first regime is Regime 1.
Simulate the return using $\ln(S1/S0) = \mu1 - \sigma1\char`\^2/2 + \sigma1 * Z$
$\ln(S1/S0) = 15\% - 10\%\char`\^2/2 + 10\%*(-0.1)$
$S1 = S0e\char`\^13.5\% = 57.23$

So the simulated price is $57.52 at time 1.

(d)   Calculate the unconditional probability of being in Regime 2 at $t = 1$.

Commentary on Question:
The candidates performed as expected on this section. Candidates understood the concept and determined the unconditional probability of being in Regime 2 at t = 1.

11. Continued

It can calculated as $\pi_{1,0} \times p_{12} + \pi_{2,0} \times p_{22}$

$\pi_{1,0} = \frac{15\%}{5\%+15\%} == 0.75$ $\pi_{2,0} = \frac{5\%}{5\%+15\%} == 0.25$

$p_{22} = 1 - p_{21} = 1 - 0.15 = 0.85$

Therefore, the answer is $0.75 * 0.05 + 0.25 * 0.85 = 0.25$

Alternatively, full marks will be given if candidates show understanding that under the invariant distribution, each transition returns the same distribution, that is $\pi P = \pi$.

Hence the answer is $\pi_{2,0} = \frac{5\%}{5\%+15\%} == 0.25$

12. Learning Objectives:
2.   The candidate will understand and be able to apply a variety of credit risk theories and models.

Learning Outcomes:
(2c)   Demonstrate an understanding of credit valuation models.

(2d)   Demonstrate an understanding of Merton asset value models in the context of credit risk.

Sources:
–Bluhm, An Introduction To Credit Risk Modeling 2nd Ed Ch 3.
Pg 152 - 153
Pg 162 - 169
Pg 162 - 169
Pg 162 – 169

QFIA-122-16: Recent Advances in Credit Risk Modeling Pg 5

Commentary on Question:
This question tested the candidate's understanding of Merton's Asset Model and its application to credit risk modeling.

Solution:
(a)   Determine what additional assumptions must be added in order to use Merton's asset model to value the bond.

Commentary on Question:
The candidates performed as expected on this question. Some candidates simply listed all the assumptions for Black Scholes model, which is similar but not exactly the same as the Merton model as such they did not receive full credit

Candidates needed to state at least four assumptions of the Merton model in order to get full credit.

Underlying assets are tradable continuously
Frictionless market
No transaction cost
No tax
No bankruptcy cost
Bankruptcy only occurs at year end

---

12. Continued

(b) Identify the positions of the equity holder and the bond holder in terms of options.

Commentary on Question:
The candidates performed brilliantly on this question. Most candidates identified the correct type of option (call or put) and position (long or short). Some candidates did not mention bond holder's position in a risk free bond.

The equity holder owns a call option on the Asset value at strike of $80.
The bond holder has a risk free bond maturing in 1 year with par value of $80, and a short put with strike price of $80.

(c) Calculate the value of ABC's bond at time 0.

Commentary on Question:
The candidates performed above average on this question. Many candidates were able to arrive at the correct price for the risky bond. Some candidates arrived at the same solution by subtracting equity from asset value, and calculated equity as price of a call. Some candidates used simple interest to discount components of the Black-Scholes formula, instead of using continuous interest rates.

A	100
K	80
R	4%
Σ	30%

$$d_1 = \frac{ln\left(\frac{A}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)}{\sigma} = 1.0271$$

$$d_2 = \frac{ln\left(\frac{A}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)}{\sigma} = 0.7271$$

$$Put = K * N(-d_2) * e^{-r} - A * N(-d_2) = 2.74$$
$$Risky\ bond = Risk\ free\ bond - Put\ option$$
$$= 80 * e^{-0.04} - 2.74$$
$$= 74.13$$

(d) Determine ABC's credit spread.

Commentary on Question:
The candidates performed as expected on this question. Some candidates solved for the probability of default, which was not needed in this case.

---

12. Continued

$$Bond\ price\ = 80 * e^{-(r + credit\ spread)}$$

$$Credit\ spread = \ln\left(\frac{80}{Bond\ price}\right) - r$$

From part C, we know bond price = 74.13 and r = 4%. Substitute in these values to arrive at

$$Credit\ spread = 3.62\%.$$

13.

Learning Objectives:

7. The candidate will understand various investment related considerations with regard to liability manufacturing and management.

Learning Outcomes:

(7d) Demonstrate understanding of Target Volatility funds and their impact on option costs.

(7e) Demonstrate an understanding of how differences between models of markets and actual market and policy-holder behaviors affect the risks associated with equity linked guarantees.

Sources:

QFIA-120-15 Guarantees and Target Volatility Funds

Commentary on Question:

This question tests knowledge of using the EWMA estimator for hedging VA guarantees and how model volatility assumptions can impact market consistent estimates of VA product guarantee cost.

The formula for the EMWA formula that appeared in the Fall 2016 exam contained a typographical error. The correct formula should have been

$$\left(\hat{\sigma}_t^{equity}\right)^2 = \lambda \left(\hat{\sigma}_{t-\Delta t}^{equity}\right)^2 + (1-\lambda)\frac{1}{\Delta t}\left(ln\left(\frac{S_t}{S_{t-\Delta t}}\right)\right)^2$$

Students were given credit for answering the question consistent with how the formula was provided in the exam or with the correct formula as it appeared in the study material.

Solution:

(a) Describe the impact λ has in estimating future equity volatility in the EWMA calculation.

Commentary on Question:

Candidates performed brilliantly on this section

Lambda (λ) controls rate of exponential decay

Higher values of λ corresponding to slower rates of decay [alternatively, lower values of lambda correspond to faster rates of decay]

---

13. Continued

(b)   Recommend one of these values for λ. Justify your answer.

Commentary on Question:
Candidates performed below average on this section. Most candidates were able to identify .98 as the recommended value. However, to receive full credit candidates also needed to identify how the two different choices translated to an average number of days in the EWMA and that the .85 assumption that led to too few trading days for consideration

The average age of data used to calculate volatility when $\lambda=0.98 = \Delta t/(1-\lambda)=1/0.02 = 50$ days or about 0.2 years.
Average age of data when $\lambda=0.85=\Delta t/(1-\lambda)=1/0.15=6.67$ days

Large drop in average age of the data from 50 days to 7 days.

0.85 likely needs to be rejected because 7 trading days is too short. 0.98 is a more appropriate number because it averages volatility over 50 days.

(c)   Explain why the models produce different estimates of market consistent guarantee costs.

Commentary on Question:
Candidates performed below average on this section. Most candidates were able to identify that the SVJD model assumes jumps in equity return and that the EMWA estimator will over or understate volatility at times.

However, to receive full credit candidates needed to identify over or underestimating the volatility estimator translated to an incorrect volatility in the managed fund and that leads to a larger market consistent cost for target vol fund guarantees than models that do not have jumps

Almost no candidates commented on the assumption of daily vs monthly rebalancing and that there would be no material difference between the two assumptions

SVJD has jumps.

When there is a jump in equity returns (SVJD vs Heston), the EWMA estimator will pick that up after the jump and we will then underweight equity. Before jumps, estimates of volatility are too low because estimate of volatility is coming from a period without jumps so that we are invested too high in equities before the jump.

---

13. Continued

EWMA estimator does not have a way to account for jumps. The implied volatility on our fund will end up being higher than our target volatility. This will lead to a larger market consistent cost for target vol fund guarantees than models that do not have jumps

No impact from Daily vs Monthly rebalancing. Implied volatilities are relatively insensitive to rebalancing frequency

14.

Learning Objectives:

2.   The candidate will understand and be able to apply a variety of credit risk theories and models.

Learning Outcomes:

(2e)   Demonstrate an understanding of the term structure of default probability.

Sources:

Quantitative Credit Portfolio Management, Ben Dor et al, Ch 1, page 30-31

Quantitative Credit Portfolio Management, Ben Dor et al, Ch 1, page 4, 22-25, 30,32

Quantitative Credit Portfolio Management, Ben Dor et al, Ch 1, page 4,32

Quantitative Credit Portfolio Management, Ben Dor et al, Ch 1, page 20-22

Commentary on Question:
This question tested the candidate's understanding and application of the concepts of Duration Times Spread (DTS).

Solution:

(a)   Explain why DTS is better than the current approach to control risk.

   Commentary on Question:
   The candidates performed poorly on this section. Most candidates were able to identify stability as a reason why DTS is better than the current approach, but did not provide any further details or reasons.

   - Contribution to Duration Times Spread (DTS) is computed as the product of market weight, spread duration, and spread.
   - DTS would exhibit more stability over time and allow better forward looking risk forecasts.
   - Partition by quality would no longer be necessary to control risk, and each sector can be represented by a single risk factor.
     - Allows managers to express more focused views
     - Allows for smaller positions in risky assets
     - Opens up possibility of "core plus" portfolios that combine investment grade and high yield assets.

(b)   Calculate the percentages of the portfolio's market value that can be invested in each of the assets before they breach XYZ's credit limit.

---

14. Continued

Percentage limit of portfolio market value = DTS Limit / (Duration * Spread)
Bond 1: 3 / (8 * 150) = 0.25%
Bond 2: 3 / (5 * 75) = 0.80%
Bond 3: 3 / (9 * 120) = 0.278%

(c)   Calculate an approximate volatility of excess returns for Bond 1.

Volatility of excess returns for Bond 1:
σ_{return} = Duration * $\sigma_{(absolute\ spread)}$ = 8 * 0.25 = 2

(d)   Identify one disadvantage of issuer limits based on spreads and recommend one solution to avoid this issue.

A possible disadvantage of the DTS-based issuer cap is that it allows for large positions in low spread issuers and potentially exposes the portfolio to "credit torpedoes".

A solution would to include a market weight issuer cap in addition to the DTS-based issuer cap. Another solution would be a single issuer exposure limit.

(e)   Critique this hedge strategy.

Neutralizing dollar duration suggests a long position in Bond 1 and a short position in Bond 3. The lower duration for Bond 1 indicates long more of Bond 1 and short less of Bond 3.

14. Continued

Since Bond 1 trades at a wider spread than Bond 3, using DTS would indicate that a better hedge against market-wide spread changes would be obtained by using more of Bond 3, i.e. short more Bond 3, so as to match the contributions to DTS on the two sides of the trade.

(f)   Evaluate the impact of the downgrade on the spread volatility of Bond 1.

Commentary on Question:
The candidates performed above average on this section. Many candidates correctly explained the relationship between expected spread volatility and spread and described the impact of that a downgrade would cause. A few candidates performed a calculation without explaining the purpose of the calculation or how it related to the question.

There is a linear relationship between the expected spread volatility and spread level. The downgrade increases the spread on Bond 1. As a result, spread volatility would increase as well.

15.

Learning Objectives:

1.   The candidate will understand the standard yield curve models, including:
   - One and two-factor short rate models
   - LIBOR market models

   The candidate will understand approaches to volatility modeling.

Learning Outcomes:

(1a)   Identify and differentiate the features of the classic short rate models including the Vasicek and the Cox-Ingersoll-Ross (CIR) models.

(1b)   Understand and explain the terms Time Homogeneous Models, Affine Term Structure Models and Affine Coefficient models and explain their significance in the context of short rate interest models.

Sources:

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 3.1, p.57.

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 3.2.1, p.58-59.

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 3.2.3, p.64-66.

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 3.5, p.83.

Brigo, D and Mecurio F, Interest Rate Models – Theory and Practice, 2nd Edition, Section 3.2.4, p.68.

Commentary on Question:
This question tested the candidates' basic knowledge of two classic short rate models: CIR and Vasicek. Candidates also had to show that they understood what an affine model is, how the previously mentioned models were considered affine and to correctly use a practical application of that affine features.

Solution:

(a)   Compare and contrast Vasicek models and Cox-Ingersoll-Ross models.

   Commentary on Question:
   The candidates performed above average on this section. The candidates were expected to list the key similarities and differences among the 2 models. Most candidates produced a comprehensive and correct list for both interest rates models, although they sometime got the distribution for the CIR model wrong.

15. **Continued**

Model	Cox-Ingersoll-Ross (CIR)	Vasicek
Affine?	Yes	Yes
Mean reverting	Yes	Yes
Type	One factor short rate model	One factor short rate model
Distribution	Non-central X^2	Normal
other	Dynamics imply positive values for r(t)	Can never obtained some shapes, like inverted, because it has only 3 parameters

(b)   Explain this analytical tractability and identify consequences of its absence.

Commentary on Question:
The candidates performed as expected on this section. Many candidates did not correctly identify the consequences and implications of a model that is not analytically tractable.   The key element for a perfect score was to explain that the expectation for the price of a bond can be obtained from the distribution.

- -An analytical formula does exist for the price of discount bond or for option on bonds.
- The bond price, or other financial value, can be computed by getting the expectation of the price distribution.
- If not analytically tractable, the pricing of financial instruments must be performed through numerical procedure, or stochastic.
- If not analytically tractable, when using a tree to price an option on a zero-coupon bond, one has to construct the tree until the bond maturity, which is usually longer than the maturity of the option.

(c)   Calculate the risk neutral probability that short rate at time $t = 2$ is between 0.04 and 0.10.

Commentary on Question:
The candidates performed above average on this section. Most candidates recognized this was a Vasicek model and the short rate is normally distributed. A few candidates miscalculated the standard deviation with the new parameter.

1st: calculate the mean:

$$E\{r(t)|\mathcal{F}_s\} = r(s)e^{-k(t-s)} + \theta(1 - e^{-k(t-s)})$$
$$E\{r(2)|\mathcal{F}_0\} = 0.04$$

15. Continued

2nd: calculate the standard deviation:

$Var\{r(t)|\mathcal{F}_s\}$ with σ_0 is 0.02^2 at $t = 2$

$$Var\{r(2)|\mathcal{F}_0\} = 1.5^2 0.02^2 = 0.0009$$

Thus, $Stdev\{r(2)|\mathcal{F}_0\} = 0.03$

3rd : P[0.04 < r(2) < 0.10]

$$= N\left(\frac{0.10-u}{s}\right) - N\left(\frac{0.04-u}{s}\right)$$

$$= N\left(\frac{0.10-0.04}{0.03}\right) - N\left(\frac{0.04-0.04}{0.03}\right)$$

$$= \quad 0.97725 - 0.5$$
$$= \quad 0.47725$$

(d) Calculate $P(0.15, 2, 3)$. Show your work.

Commentary on Question:
The candidates performed above average on this section. The candidates that realized A(T-t) and B(T-t) are constant as long as T-t is the same did well. A few candidates did not recognize that A and B are dependent on T-t and also made minor calculation errors. Some candidates provided a long and detailed solution by solving for A(1) and B(1), however the shorter and faster way to get to the solution is shown below.

1- This is CIR model
2- Thus it is an affine model and the expectation for the price of a bond can be expressed as:
$$P(r(t), t, T) = A(T - t)e^{-B(T-t)r(t)}$$
3- Where A(T-t) and B(T-t) are constants and stay the same whenever the difference between T and t is the same, and here T-t is 1 for all 3 given cases.
4- Which means that $P(0.5;0;1) = 0.9372$ can be simplify as $Ae^{-0.05B}$ and $P(0.10;1;2) = .9011$ can be simplify as $Ae^{-0.10B}$.
5- Finally, $P(0.15;2;3) = Ae^{-0.15B} = Ae^{-0.20B} \, xAe^{+0.05B}$
$P(0.15;2;3) = Ae^{-0.10B} \, xAe^{-0.10B} \, /Ae^{-0.05B}$
$P(0.15;2;3) = 0.9011 \, x \, (0.9011/0.9372) = 0.8664$

16. **Learning Objectives:**

6. The candidate will understand and be able to describe the variety and assess the role of alternative assets in investment portfolios. The candidate will demonstrate an understanding of the distinguishing investment characteristics and potential contributions to investment portfolios of the following major alternative asset groups:
    - Real Estate
    - Private Equity
    - Commodities
    - Hedge Funds
    - Managed Futures
    - Distressed Securities
    - Farmland and Timber

Learning Outcomes:

(6b) Demonstrate an understanding of the benchmarks available to evaluate the performance of alternative investment managers and the limitations of the benchmarks.

(6d) Demonstrate an understanding of the due diligence process for alternative investments.

Sources:

QFIA-111-113: Maginn & Tuttle, Managing Investment Portfolios, 3rd Ed. 2007, Ch. 8, p. 478 – 498

Commentary on Question:

This question focused on the role of alternative assets in investment portfolios. The candidates were tested on real estate benchmarks and impacts on a company selling MYGA business. In aggregate, the candidates performed above average on this question. The candidates were successful in performing the calculation parts. The candidates were not as successful in the part e where the candidates were asked to justify the position of the CRO.

Solution:

(a) Identify the common features of alternative investments.

Commentary on Question:
The candidates performed brilliantly on this section. Most candidates listed 3 to 4 features.

(1) Relative illiquidity;
(2) Diversifying potential relative to a portfolio of stock and bonds;
(3) High due diligence costs;
(4) Difficult performance appraisal because of the complexity of establishing valid benchmarks.

16. Continued

(b)   Describe the benchmarks available and their respective limitations for direct and indirect real estate investments.

Commentary on Question:
The candidates performed below average on this section. The candidates were successful listing the name of the benchmarks, however most candidates missed the limitations for direct and indirect.

Direct:
Benchmarks:
National Council of Real Estate Investment Fiduciaries (NCREIF) Property Index is the principal benchmark used to measure performance of direct real estate. NCREIF includes subindices grouped by real estate sector (apartment, industrial, office, and retail).

Limitations:
Real estate properties change ownership relatively infrequently; *(found in section 3.2.1)*
Underestimate volatility in underlying values

Indirect:
Benchmarks:
NAREIT is the principal benchmark used to represent indirect investment in real estate.
NAREIT is a real-time, market-cap weighted index of all REIT's actively traded on the New York Stock Exchange.

Limitations:
Significant measurement issues

(c)   Justify the decision to add real estate to the strategic asset allocation.

Commentary on Question:
The candidates performed above average on this section. A few candidates did not use the Sharpe ratio in their justification.

Expected return is higher which supports the overall investment objective.
The Sharpe ratio of 80/10/10 bonds/stock/real estate allocation at (4.43 - 1.50)/7.80 = 0.375 is greater than that of the current 90/10 bond/stock allocation at (4.07 – 1.50)/7.20 = .356

16. Continued

(d)   Calculate the pricing spread with the 80/10/10 strategic asset allocation.

Commentary on Question:
The candidates performed above average on this section. Some candidates missed the crediting rate often by not adding in the spread to the risk free rate.

Bond Return = 3.60
Stock Return = 8.25
Real Estate Return= 7.25
80/10/10 Return = 80% * 3.60 + 10% * 8.25 + 10% * 7.25
                = 4.43
Crediting rate = 1.50 + 1.00 = 2.50
Pricing spread = 80/10/10 Return less Crediting rate
                = 4.43 – 2.50 = 1.93

(e)   Justify the position of your CRO.

Commentary on Question:
The candidates performed below average on this section. Most of the candidates identified real estate as an illiquid investment. Many candidates commonly missed on relative liquidity, duration and allocation.

Real estate is an illiquid investment;
Securitized (indirect) real estate is more liquid than direct real estate;
Duration is greater than MYGA (3 years):

20% allocation to illiquid assets (real estate plus equity) backing liquid liabilities is not prudent.