UNIVERSITY OF CHICAGO
Booth School of Business

Bus 35120 – Portfolio Management Prof. Lubos Pastor

Final Exam
(Solutions)

Spring 2016

Name:

Section (circle one): Fri 1:30-4:30 Fri 6-9 Sat 9-12

Instructions:

1. You have 3 hours to complete this exam.
2. Total points: 180. Partial credit will be given.
3. You may use the basic math functions of a calculator. No smart-phones.
4. You may use both sides of a 8.5" by 11" sheet of paper with anything written on it.
5. Be clear and brief. Vagueness and unnecessary wordiness may be penalized. Underline or circle your numerical answers.
6. Read the following statement and sign below to acknowledge it:

   "I pledge my honor that I have not violated the Honor Code during this examination."

   Sign here:

7. Do not turn the page until instructed to do so.
8. Good luck!

1. **(6 points)**. In early April 2016, one of the most crowded hedge fund trades was

   (a) Long Herbalife, short Allergan

   (b) Long Allergan, short Herbalife

   (c) Long Pfizer, short Allergan

   (d) Long Allergan, short Pfizer—CORRECT

   Many hedge funds, such as Paulson & Co., Third Point, and Elliot Management,

   (a) made

   (b) lost—CORRECT

   money on this trade because . . . the stock price of Allergan dropped sharply when the Obama administration announced a crackdown on tax inversion deals.

   Circle the best answers and provide a brief explanation of the second answer.

2. **(6 points)**. Which of the following help explain why convertible bond arbitrage hedge funds underperformed the average hedge fund during the financial crisis of 2008? Circle the THREE best answers and briefly explain in the space provided.

   (a) Leverage because . . . Convertible bond arbitrage hedge funds tend to be more highly levered than the average hedge fund. High leverage amplifies losses not only directly but also indirectly, by inducing deleveraging when funds lose capital.

   (b) Volatility because . . .

   (c) Liquidity because . . . Convertible bonds tend to be less liquid than the underlying stocks. The strategy earns a liquidity premium and it loses money when liquidity evaporates, as it did in 2008.

   (d) Bernie Madoff because . . .

   (e) Funds of funds because . . .

   (f) The short-sale ban in September 2008 because . . . Convertible bond arbitrage tends to short stocks. After the ban was announced, hedge funds had to buy back the stocks they had shorted. To do so, they had to sell illiquid convertible bonds at large discounts.

3. **(6 points)**. You are forming a fund of hedge funds. You would like to pick two out of three hedge funds: A, which specializes in shorting growth stocks that seem overvalued to A's principals, B, which specializes in buying growth stocks that seem undervalued to B's principals, and C, which is a long-short (mostly long) fund that specializes in value stocks. The correlation matrix of the funds' returns looks as follows:

	A	B	C
A	1	-0.9	-0.1
B	-0.9	1	0.5
C	-0.1	0.5	1

State below which funds you would or would not put together and why.

Best combination: A and C. Brief explanation: They follow different strategies with little if any overlap. Their low negative correlation highlights the diversification benefits of putting them together.

Worst combination: A and B. Brief explanation: They are likely to have some counterbalancing bets, where A is shorting the same stocks that B is buying.

4. **(3 points)**. Consider a market-neutral hedge fund with expected return of 4% and 10% volatility. The risk-free rate is 1%. The market's expected return is 6%. Then the fund's information ratio is

   (a) greater than the fund's Sharpe ratio
   (b) equal to the fund's Sharpe ratio—CORRECT
   (c) lower than the fund's Sharpe ratio
   (d) none of the above, given the information provided

   Circle the right answer and justify it.

   (b). For any market-neutral strategy ($\beta = 0$), the information ratio and the Sharpe ratio are equal. No need for any calculations.

5. **(6 points)**. Which of the following would reduce the funding levels of defined-benefit pension plans? In each line, circle ONE of the two options provided. Briefly explain.

   (a) The stock market goes DOWN.
   Reason: A significant part of pension fund assets is invested in stocks.

   (b) Interest rates go DOWN.
   Reason: The present value of pension fund liabilities goes up. Assets also go up but pension liabilities generally have longer duration.

6. **(6 points)**. Consider a private equity (PE) fund holding a portfolio of illiquid assets. The portfolio's value is determined each month by an internal appraisal procedure that considers both recent comparable sales and past appraised values. As a result, the PE fund's returns tend to exhibit positive autocorrelation. Assume for simplicity that the fund's reported returns r_t^* follow an AR(1) process:

$$r_t^* = a + br_{t-1}^* + \epsilon_t \ ,$$

where b is the autocorrelation coefficient, $0 < b < 1$, and ϵ_t is i.i.d. with mean zero. A natural way to "unsmooth" the PE fund's returns is by removing the serial correlation:

$$r_t = \frac{1}{1-b} r_t^* - \frac{b}{1-b} r_{t-1}^* \ ,$$

where r_t is the PE fund's true unobserved return. In each of the three questions below, circle the correct answer (i.e., circle one and only one of the three signs: greater than, equal to, or smaller than). No need to explain.

(a) The expected value of r_t^* is $=$ the expected value of r_t

(b) The volatility of r_t^* is $<$ the volatility of r_t

(c) The Sharpe ratio of r_t^* is $>$ the Sharpe ratio of r_t

7. **(5 points)**. Which of the following does David Swensen view as non-disruptive sources of liquidity for an endowment? Circle all that apply. No need to explain.

(a) Sales of stocks and/or bonds

(b) Sales of real assets

(c) Dividends generated by stock investments

(d) Interest generated by bond investments

(e) Using bonds as collateral in repurchase agreements—CORRECT

(f) Using stocks for security lending—CORRECT

(g) Withdrawals from hedge fund managers

(h) Sales of private equity stakes

(i) External borrowing by issuing commercial paper—CORRECT

(j) External borrowing by issuing taxable bonds—CORRECT

8. **(9 points)**. The case studies on Dimensional Fund Advisors (DFA) and Grantham, Mayo, and Van Otterloo (GMO) point out some similarities and differences between DFA and GMO. In the following table, mark an "X" wherever appropriate.

   (For example, in the first row, if DFA believes markets are efficient but GMO doesn't, mark an "X" in the DFA column but not in the GMO column. If both believe in market efficiency, mark an "X" for both; if neither believes in it, don't mark anything.)

	DFA	GMO
Believes markets are efficient	X	
Believes markets are inefficient		X
Believes in value investing	X	X
Believes in growth investing		
Adds value mostly via active management		X
Mostly demands liquidity		X
Mostly provides liquidity	X	
Uses mean-variance optimization		X
Builds on findings from academic research	X	X

9. **(6 points)**. Different financial entities pay different kinds of fees to index providers such as S&P. In the following table, mark an "X" wherever appropriate.

	Licensing fee	Subscription fee	Performance fee
ETFs that track the index	X		
Passive funds that track the index	X		
Active funds that use the index as a benchmark		X	
Derivatives tied to the index	X		
Broker-dealers that trade on index information		X	
Distributors of index information		X	

10. **(5 points)**. Which of the following were significant risks in the investment strategy of Mr. Franey from the Fixed Income Arbitrage case study? Circle all that apply. No need to explain.

    (a) market risk

    (b) credit risk

    (c) interest rate risk

    (d) liquidity risk—CORRECT

    (e) inflation risk

11. Bill Miller, the legendary manager of the Legg Mason Value Trust, outperformed the S&P 500 index for 15 years in a row (1991–2005).

(a) **(6 points)**. Suppose that $N = 10,000$ money managers follow random uncorrelated strategies, each of which has a 50% probability of beating the S&P 500 index every year. What is the probability that at least one of the 10,000 managers will beat the S&P 500 for 15 years in a row simply by chance?

The probability that any given manager beats the S&P for 15 years in a row is

$$p = (0.5)^{15} = 0.000030518 = 0.0030518\%$$

The probability that at least one of $N = 10,000$ managers will do it is

$$P = 1 - (1-p)^N = 0.2630 = 26.3\%.$$

(b) **(6 points)**. Now suppose that $N = 3,000$ managers follow value strategies like Bill Miller does. (These strategies are still completely random and uncorrelated.) Given the value effect in stock returns, each strategy has a 60% probability (instead of 50% as in part (a)) of outperforming the S&P 500 each year. What is the probability that at least one of the 3,000 managers will beat the S&P 500 for 15 years in a row simply by chance?

The probability that any given manager beats the S&P for 15 years in a row is

$$p = (0.6)^{15} = 0.00047018 = 0.047018\%$$

The probability that at least one of $N = 3,000$ managers will do it is

$$P = 1 - (1-p)^N = 0.7561 = 75.61\%.$$

(c) **(5 points)**. How many managers do we need (N =?) if we want the answer in part (b) to be 50%?

With $p = (0.6)^{15} = 0.00047018$, we need N such that

$$\begin{aligned} 1 - (1-p)^N &= 0.5 \\ (1-p)^N &= 0.5 \\ Nlog(1-p) &= log(0.5) \\ N &= log(0.5)/log(0.999530) \approx 1,474. \end{aligned}$$

12. You are a manager of a \$50 million small-cap equity portfolio P whose benchmark B is the Russell 2000 index. A regression of your portfolio's excess monthly returns on the benchmark's excess monthly returns yields the following results:

$$R_{P,t} - R_f = 0.25\% + 0.8(R_{B,t} - R_f) + \epsilon_t,$$

with the standard deviation of ϵ_t equal to 1%. Russell 2000 has an expected return of $\mathrm{E}(R_{B,t}) = 1\%$ per month and standard deviation of 5% per month. The risk-free rate is constant at $R_f = 0.25\%$ per month. The returns are simple returns.

(a) **(9 points)**. What is the maximum Sharpe ratio obtainable by combining your portfolio with Russell 2000?

First, compute your portfolio's (monthly) information ratio:

$$IR = \frac{\alpha_P}{\sigma_\epsilon} = \frac{0.0025}{0.01} = 0.25.$$

Second, compute the (monthly) Sharpe ratio of the Russell 2000 index:

$$S_B = \frac{E_B - R_f}{\sigma_B} = \frac{0.01 - 0.0025}{0.05} = 0.15.$$

Finally, combine these two quantities to obtain the maximum Sharpe ratio:

$$\begin{aligned} S_{P+B}^2 &= S_B^2 + (IR)^2 \\ &= 0.15^2 + 0.25^2 = 0.0850 \\ S_{P+B} &= 0.2915. \end{aligned}$$

(Note: An alternative (but longer) solution first computes the optimal weights in P and B, and then the Sharpe ratio S_{P+B} for that portfolio.)

(b) **(9 points)**. What is the one-month 5% value-at-risk of your portfolio P, under the assumption that your portfolio's returns are normally distributed?

$$\begin{aligned} E_P &= R_f + 0.0025 + 0.8(\mathrm{E}(R_{B,t}) - R_f) = 0.0025 + 0.0025 + 0.8(0.01 - 0.0025) \\ &= 0.011 \\ \mathrm{Var}(R_{P,t}) &= 0.8^2 \mathrm{Var}(R_{B,t}) + \mathrm{Var}(\epsilon_{P,t}) = 0.8^2(0.05)^2 + (0.01)^2 \\ &= 0.0017 \\ \sigma_P &= \sqrt{\mathrm{Var}(R_{P,t})} = \sqrt{0.0017} = 0.0412. \end{aligned}$$

The 5% VAR is then

$$VAR = -\$50\mathrm{m}(E_P - 1.65\sigma_P) = -\$50\mathrm{m}(0.011 - 1.65(0.0412)) = \$2.8516\mathrm{m}.$$

(c) **(3 points)**. Would the VAR obtained in part (b) increase or decrease if we replaced the normality assumption by a more realistic assumption? Circle one answer and briefly explain (in one line).

i. Increase, because ... in reality, stock returns have fat tails (kurtosis > 3).

(d) **(5 points)**. What is the probability that your portfolio will outperform the T-bill over the following month?

$$\begin{aligned}
\text{Prob}(R_P > R_f) &= 1 - \text{Prob}(R_P < R_f) = 1 - \text{Prob}(R_P < 0.0025) \\
&= 1 - \text{Prob}(z < \frac{0.0025 - E_P}{\sigma_P}) \\
&= 1 - \text{Prob}(z < \frac{0.0025 - 0.011}{0.0412}) \\
&= 1 - \text{Prob}(z < -0.2063) \\
&= 1 - 0.4183 \\
&= 0.5817 = 58.17\%
\end{aligned}$$

(e) **(6 points)**. What is the probability that your portfolio will outperform its benchmark over the following month?

First, compute the covariance σ_{PB}:

$$\sigma_{PB} = \beta_P \sigma_B^2 = 0.8(0.05)^2 = 0.0020.$$

Now we can compute the desired probability:

$$\begin{aligned}
\text{Prob}(R_B < R_P) &= \text{Prob}(z < \frac{E_P - E_B}{\sqrt{\sigma_P^2 + \sigma_B^2 - 2\sigma_{PB}}}) \\
&= \text{Prob}(z < \frac{0.011 - 0.010}{\sqrt{0.0017 + 0.0025 - 2 \times 0.0020}}) \\
&= \text{Prob}(z < \frac{0.001}{0.0141}) \\
&= \text{Prob}(z < 0.0709) \\
&= 0.5283 = 52.83\%
\end{aligned}$$

From now on, assume that continuously compounded returns are normally distributed, and that all of the above quantities (such as the means, variances, risk-free rate, etc.) apply to continuously compounded returns rather than to simple returns. Also assume that all returns are i.i.d. over time.

(f) **(5 points)**. What is the probability that your portfolio will outperform the T-bill over the following 10 years?

$$\begin{aligned}
\text{Prob}(V_T > e^{Tr}) &= 1 - \text{Prob}(V_T < e^{Tr}) \\
&= 1 - \text{Prob}(\ln(V_T) < Tr) \\
&= 1 - \text{Prob}(z < \frac{Tr - T\mu}{\sqrt{T}\sigma}) \\
&= 1 - \text{Prob}(z < \sqrt{T}\frac{r - \mu}{\sigma}) \\
&= 1 - \text{Prob}(z < \sqrt{120}\frac{0.0025 - 0.011}{0.0412}) \\
&= 1 - \text{Prob}(z < -2.2600) \\
&= 1 - 0.0119 \\
&= 0.9881 = 98.81\%
\end{aligned}$$

(g) **(5 points)**. What is the fair cost of insurance guaranteeing that your portfolio will not underperform the T-bill over the following 10 years?

The value of the protective put option is

$$P = 2N\left(\frac{\sigma_P\sqrt{T}}{2}\right) - 1 = 2N\left(\frac{0.0412\sqrt{120}}{2}\right) - 1 = 2(0.5893) - 1 = 0.1786$$

per dollar invested, so you'd pay $\$50m \times 0.1786 = \$8.93m$.

13. Consider two investment strategies, S_1 and S_2, whose expected simple total returns and the covariance matrix of returns are given by the following annual quantities:

$$ER = \begin{pmatrix} 0.14 \\ 0.10 \end{pmatrix}, \quad V = \begin{pmatrix} 0.03 & 0.02 \\ 0.02 & 0.03 \end{pmatrix}.$$

You can borrow and lend at the T-bill rate of 1%. Your investment horizon is one year.

(a) **(9 points)**. You have mean-variance utility $U = \mathrm{E}(R) - 2\mathrm{Var}(R)$ and \$1 million to invest. What is your optimal dollar allocation between S_1, S_2, and the T-bill?

First, note that $\gamma = 4$. Form the vector of expected excess returns:

$$E = ER - R_f = \begin{pmatrix} 0.14 - 0.01 \\ 0.10 - 0.01 \end{pmatrix} = \begin{pmatrix} 0.13 \\ 0.09 \end{pmatrix}.$$

The optimal weights are then given by

$$w = \frac{1}{\gamma} V^{-1} E = \frac{1}{4} \begin{pmatrix} 60 & -40 \\ -40 & 60 \end{pmatrix} \begin{pmatrix} 0.13 \\ 0.09 \end{pmatrix} = \begin{pmatrix} 1.05 \\ 0.05 \end{pmatrix}.$$

The T-bill weight is $1 - (1.05 + 0.05) = -0.1$. That is, borrow \$100,000 (-10% in the T-bill), invest \$1.05 million (105%) in strategy S_1, and invest \$0.05 million ($= \$50,000 = 5\%$) in strategy S_2.

(b) **(9 points)**. What is the Sharpe ratio of your optimal portfolio from part (a)?

$$\begin{aligned} E^* &= w'E = \begin{pmatrix} 1.05 & 0.05 \end{pmatrix} \begin{pmatrix} 0.13 \\ 0.09 \end{pmatrix} = 0.1410 \\ V^* &= w'Vw = \begin{pmatrix} 1.05 & 0.05 \end{pmatrix} \begin{pmatrix} 0.03 & 0.02 \\ 0.02 & 0.03 \end{pmatrix} \begin{pmatrix} 1.05 \\ 0.05 \end{pmatrix} \\ &= 0.0353 \\ S^* &= \frac{E^*}{\sqrt{V^*}} = \frac{0.1410}{\sqrt{0.0353}} = 0.7505. \end{aligned}$$

14. True/False questions. **Circle** the correct answer and briefly **explain**.

(a) **(3 points)**.
TRUE or FALSE

Target-date retirement funds are a more suitable investment choice for people working in the government sector than for people working in the finance industry.

True. The human capital of people working in the government sector is more bond-like than that of people working in the finance industry.

(b) **(3 points)**.
TRUE or FALSE

TIPS represent a combination of an inflation-protected bond and an implicit call option, issued by the U.S. Treasury, which pays off when there is deflation.

False. Everything is true except the option is a put, not a call. At maturity, you have the right to sell TIPS back to the Treasury at their par value, so you effectively own a put option, as we discussed in class.

(c) **(3 points)**.
TRUE or FALSE

Suppose the sample estimate of α for an industry portfolio is 6%, with a standard error of 3%. Also suppose that a rational (Bayesian) investor's prior distribution on α has zero mean and 2% standard deviation. The investor's best estimate (i.e., posterior mean) of α is then a little larger than 3%.

False. The best estimate of α is a precision-weighted weighted average of the prior mean (zero) and the sample estimate (6%). Since the precision of the prior is higher ($2\% < 3\%$), the estimate of α is closer to the prior mean $\Rightarrow$ it is $< 3\%$.

(d) **(3 points)**.
TRUE or FALSE

Implementation shortfall tends to be larger for small-cap stock strategies than for large-cap stock strategies.

True. Implementation shortfall is the difference between the pre-transaction-cost hypothetical returns on a strategy and the after-transaction-cost actual returns. Transaction costs are larger for small stocks.

(e) **(3 points)**.
TRUE or FALSE

The returns on the value and momentum strategies were negatively correlated before year 2000, and the correlation has been even more negative since 2000.

True. Recall the GMO case and our class discussion.

(f) **(3 points)**.
TRUE or FALSE

Index reconstitutions present opportunities for active investors to front-run index funds whose sole aim is to minimize their tracking error.

True. For example, when Standard & Poor's announces that a given stock will be added to their S&P 500 index two weeks later, the stock's price usually rises immediately, and often a bit more over the following two weeks, in anticipation of purchases by index funds. An index fund whose sole aim is to minimize tracking error will wait for two weeks before buying the stock at the higher price.

(g) **(3 points)**.
TRUE or FALSE

The constituent stocks of the S&P 500 index are chosen by committee at irregular intervals, whereas the constituents of most other major indices, such as Russell, MSCI, and CRSP, are chosen by mechanical rules at regular intervals.

True. S&P 500 is the only major index that is reconstituted by committee.

(h) **(3 points)**.
TRUE or FALSE

Most "smart beta" strategies overweight both large-cap stocks and value stocks and underweight both small-cap stocks and growth stocks, compared to the market-capitalization-weighted stock market index.

False. Smart beta strategies weight stocks by quantities other than market cap, such as sales, dividends, earnings, etc., typically resulting in small-cap (not large-cap) and value tilts relative to the market portfolio.

(i) **(3 points)**.
TRUE or FALSE

Leveraged ETFs are particularly well suited for long-term investors looking for a levered investment in the underlying index.

False. Leveraged ETFs are designed for short-term investors. They provide the desired levered return only on a daily basis.

(j) **(3 points)**.
TRUE or FALSE

If the stock market rises sharply between 3pm and 4pm, abusive market timers shift capital out of large-cap mutual funds and into small-cap mutual funds just before 4pm.

True. Since many small stocks (but not large stocks) do not trade between 3 and 4pm, their most recent transaction prices are stale—too low—just before 4pm.

(k) **(3 points)**.
TRUE or FALSE

Research shows that the performance of a typical active mutual fund is inversely related not only to the size of the fund but also to the size of the aggregate active mutual fund industry.

True. Research finds empirical evidence of both fund-level and industry-level decreasing returns to scale. A larger fund's trades have a bigger price impact, hurting the fund's performance. A larger industry implies more competition to find mispricing, hurting every active fund's performance.

(l) **(3 points)**.
TRUE or FALSE

Research shows that the investment strategy of buying stocks of firms with overfunded pension plans and selling stocks of firms with underfunded pension plans has produced significant positive risk-adjusted returns.

True. See Franzoni and Marin (Journal of Finance, 2006). The authors argue that the stock market does not fully recognize pension fund assets and liabilities.

(m) **(3 points)**.
TRUE or FALSE

Significant tax advantages are achieved if a company issues new stock to repurchase its bonds and if the company's pension fund simultaneously engages in a transaction of the opposite nature.

False. The tax arbitrage involves the company issuing bonds to repurchase stock and the pension fund doing the opposite (selling stocks, buying bonds).

(n) **(3 points)**.
TRUE or FALSE

If a portfolio's sample average return is 10% per year and the sample standard deviation is 20% per year, then we need at least 24 years of data to conclude with 95% confidence that the portfolio's average return is different from zero.

False. The t-test is $t = \sqrt{T}\frac{\bar{R}-\mu}{s}$, and the solution to $2 = \sqrt{T}\frac{10}{20}$ is $T = 16$, not 24.

(o) **(3 points)**.
TRUE or FALSE

Suppose you invest \$1,000 in a portfolio whose continuously compounded returns are normally distributed with mean 4% and standard deviation 15%. With 50% probability, your investment will grow to at least \$1,669 over the next 10 years.

False. \$1,669 is the expected future value of the investment. The median future value is $1000 \times \exp(T\mu) = 1000 \times \exp(10 \times 0.04) = \$1,492$.