LASSE HEJE PEDERSEN

EXERCISES

FOR

EFFICIENTLY INEFFICIENT

HOW SMART MONEY INVESTS & MARKET PRICES ARE DETERMINED

Contents

Preface to the Exercises

This compendium of exercises is meant to be used with the book on *Efficiently Inefficient: How Smart Money Invests and Market Prices Are Determined,* by Lasse Heje Pedersen, Princeton University Press, 2015. The compendium contains exercises for each chapter in the book, except the introductory chapters (i.e., chapters 6, 10, 13). I am grateful for feedback from students and colleagues at New York University Stern School of Business and Copenhagen Business School and especially to Niklas Kohl for taking the lead on developing several of the exercises (7.1-7.6, 9.8-9.12, 16.1-16.8).

Several of the exercises require additional material, which is distributed separately. For example, several problems rely on data to be processed in a spreadsheet such as Excel, while other problems rely on financial statements such as merger offers. Professors who use the book can contact me for this material.

1. Exercises for *Understanding Hedge Funds and Other Smart Money*

1.1. **Selection vs. Timing.** Explain the meanings of market timing and security selection, highlighting their similarities and differences.

1.2. **Biases.** You work as an analyst at a discretionary equity hedge fund. You have the investment thesis that it pays to buy the "best in breed", that is, stocks that are the industry leaders. You find the companies that are currently the largest in each industry and track their performance the last 5 years. This portfolio significantly outperforms the market over the time period.

Are there any issues with this analysis? Should the hedge fund buy this portfolio and, if so, what are the risks?

1.3. **Hedge funds vs. mutual funds.** Consider a passive mutual fund, an active mutual fund, and a hedge fund. The mutual funds claim to deliver the following gross returns:

$$r_t^{\text{passive fund before fees}} = r_t^{\text{stock index}}$$

$$r_t^{\text{active fund before fees}} = 2.20\% + r_t^{\text{stock index}} + \varepsilon_t$$

The passive fund charges an annual fee of 0.10%. The active mutual fund charges a fee of 1.20% and seeks to beat the same stock market index by about 1% per year after fees. The active mutual fund has a beta of 1 and has a tracking error volatility of $\sqrt{\text{var}(\varepsilon_t\ )} = 3.5\%$.

The hedge fund uses the same strategy as the active mutual fund to identify "good" and "bad" stocks, but implements the strategy as a long-short hedge fund, applying 4 times leverage. The risk-free interest rate is $r^f = 1\%$ and the financing spread is zero (meaning that borrowing and lending rates are equal). Therefore, the hedge fund's return before fees is

$$r_t^{\text{hedge fund before fees}} = 1\% + 4 \times \left(r_t^{\text{active fund before fees}} - r_t^{\text{stock index}}\right)$$

a. What is the hedge fund's volatility?

b. What is the hedge fund's beta?

c. What is the hedge fund's alpha before fees (based on the mutual fund's alpha estimate)?

d. Suppose that an investor has \$40 invested in the active fund and \$60 in cash (measured in thousands, say). What investments in the passive fund, the hedge fund, and cash (i.e., the risk-free asset) would yield the same market exposure, same alpha, same volatility, and same exposure to ε_t ? As a result, what is the fair management fee for the hedge fund in the sense that it would make the investor indifferent between the two allocations (assume that the hedge fund charges a zero performance fee)?

e. If the hedge fund charges a management fee of 2%, what performance fee makes the expected fee the same as above? Ignore high water marks and ignore the fact that returns can be negative, but recall that performance fees are charged as a percentage of the (excess) return after management fees. Specifically, assume the performance fee is a fraction of the hedge fund's outperformance above the risk-free interest rate.

f. Comment on whether it is clear that hedge funds that charge 2-and-20 fees are "expensive" relative to typical mutual funds. More broadly, what should determine fees for active management?

1.4. **Styles and Strategies**

a. Fill out the answers for each HF style in the table below. (While most problem set questions will test that you can apply what you learned in class, some of the information in the table was not covered in class. The idea is that you should start thinking carefully about each style, discussing it with your classmates, friends in the industry, and answer to the best of your knowledge.)

Long-short equity	**Short biased**	**Quant equity**	**Global macro**	**Man. futures**	**Fixed income arb**	**Convert bond arb**	**Event driven arb**
Name the securities most commonly used							
Invests in liquid securities (1=highly illiquid, 5=highly liquid)							
Has a large turnover (1=very low turnover, 5=high turnover)							
Uses a lot of leverage (1=unlevered, 5=super high leverage)							
Discretionary/heuristic or quantitative/systematic (1=gut driven, 5=model driven)							
Left tail (1=often positive return, but sometimes blows up, 5=positive skewness)							
Name one or more hedge funds in this style							

b. Explain the main idea behind the three equity strategies and how they are different. Also, discuss why these strategies might profit over the long term and why they might not.

c. Discuss how global macro investors and managed futures traders trade and the potential drivers of their returns. Explain the distinction between top-down vs. bottom-up investing.

d. Discuss the common idea behind arbitrage strategies. What are the potential risks of trading on an apparent arbitrage opportunity? What are the differences across the three types of arbitrage strategies?

2. Exercises for *Evaluating Trading Strategies: Performance Measures*

For each of the following exercises, consider the hedge fund index data provided and evaluate the performance (abstracting here from the potential biases in the data).

2.1. **Performance measures.** For each hedge fund style, calculate and interpret the following performance measures

a. Annualized arithmetic average return
b. Annualized geometric average return
c. Annualized volatility
d. Annualized Sharpe ratio
e. Market beta
f. Annualized alpha to the market
g. Annualized Information ratio
h. Maximum drawdown
i. Skewness
j. Excess kurtosis

2.2. **Cumulative return and drawdown.** Make the following plots for Global Macro Hedge Fund index

a. The cumulative return
b. The drawdown

2.3. **Factor models.** For Equity Long/Short, run two regressions: (i) a univariate regression of the hedge fund index's excess return on market excess return; and (ii) a multivariate regression on the market, size, value, and momentum factors.

a. Interpret the loadings on the different factors. What do we learn of the investment style?
b. Compare the multivariate alpha with the alpha from the univariate market regression. Discuss the difference in interpretation between the univariate vs. multivariate alphas.

2.4. **Illiquidity and stale prices.** For Convertible Bond Arbitrage, compare:

a. The beta in a monthly univariate regression on the market
b. The beta in a univariate regression on the market using 3-month returns. (The regression coefficients can still be estimated by running the regression monthly, i.e., with overlapping data, but, in this case, t-statistics need to be adjusted if you were to consider these)
c. The sum of betas in a monthly regression on the market, the 1-month lagged market, and the 2-month lagged market

3. Exercises for *Finding and Backtesting Strategies: Profiting in Efficiently Inefficient Markets*

Examples of backtests of trading strategies are contained in many of the exercises in the chapters to come (e.g., 9.1-9.12, 11.1-11.7, 12.1-12.4, 16.11-16.13). Hence, exercises with techniques for backtests are not included here, but instead we consider some conceptual exercises.

3.1. **Information collection.** Discuss how active investors can be compensated for their information collection. Give examples of how you could try to collect information about specific firms and how you could trade on this.

3.2. **Adverse selection and IPOs.** Some initial public offerings (IPOs) are oversubscribed, meaning that more investors want to be allocated shares than what is for sale. Other IPOs are undersubscribed, meaning that the firm and its underwriter struggle to sell the shares.

- In which case do you expect that the return after the IPO is the highest?
- Suppose that you bid for an allocation for IPO shares without knowing whether the offering is oversubscribed or undersubscribed. In which case are you more likely to be allocated the number of shares that you ask for and how does this affect your expected return?
- Historically first-day IPO returns have been positive on average, i.e., an investor who put an equal amount in all IPOs and sold at close on the first trading day made abnormal profits. Does this imply abnormal profits from participating in IPOs?

3.3. **Market and funding liquidity.** Suppose that you are considering buying a home, which you expect to live in for about 5 years, and, given the mobile workforce in the region, you also expect future buyers of the property to move relatively frequently. You find a house and an apartment which are equally attractive and consider which one to buy. (The house and apartment are equally attractive in the sense, for instance, that something similar could be rented at the same rates.)

a. **Market liquidity.** Suppose that the house is much more expensive to trade in terms of fees to the real estate agent, a longer expected waiting time when the property is on the market (and you may already have moved), and other costs. What would you pay more for, the house or the apartment? Explain your answer.

b. **Funding liquidity.** Suppose that the house and apartment are equally easy and costly to trade (have equal market liquidity), but the bank will give you (and future potential buyers) a larger loan for the apartment. Would that lead you to be willing to pay more for the apartment than the house? What would Modigliani-Miller say and why? Why might your answer be different?

c. Liquidity spirals and liquidity risk.

- If the house can be expected to be more difficult to trade than the apartment, which property do you think the bank will be more willing to provide a large loan for?

- If the apartment is more easy to borrow against, which property do you think will be more easy to sell?
- If suddenly there are many more properties for sale in this area than available buyers, how could the market and funding liquidity evolve? Might the market for houses evolve differently than the market for apartments?
- How does this liquidity risk affect the price you want to pay for the house vs. the apartment?
- How does the answer change if you expect to live in the property for 40 years?

3.4. **Demand pressure.** Suppose that a significant fraction of the population of investors needs to buy a security, say a stock *ABC*, for reasons unrelated to the stock's fundamentals (its expected future earnings and dividends). For instance, suppose that an important stock market index suddenly gives a large weight to stock *ABC*.

a. What will happen to the stock price in a perfectly efficient market?

b. What is likely to happen to the stock price in a market with limited arbitrage?

c. In an efficiently inefficient market, where the stock price moves (as discussed in 3.4), what is likely to happen to the price of another stock that is highly correlated to stock *ABC* (but not directly affected by the demand pressure)?

4. Exercises for *Portfolio Construction and Risk Management*

The following exercises are based on the hedge fund index data provided. The underlying data is the same as that used in the exercises for Chapter 2 and these exercises complement each other.

4.1. **Portfolio optimization.** Suppose that you were running a fund of hedge funds in 2003 and needed to allocate your capital between the various hedge fund styles. (Alternatively, you could be running a multi-strategy hedge fund and allocating capital across the various trading groups or running a pension fund allocating capital to various hedge funds.) Compute the excess return of each of the hedge fund indices.

a. Define portfolio weights above each column for each of the first 9 hedge fund styles (not including the overall index called "DJCS Hedge Fund USD") and choose these portfolio weights to be equal (i.e., 1/9). Compute the excess return of the corresponding portfolio (as the SUMPRODUCT of portfolio weights and excess returns of hedge funds). Finally, compute the Sharpe ratio over the early sample 1994-2003 (that you would have been aware of in 2003), the late sample 2004-2012 (the period over which your returns would be realized), and the full sample.

b. Compute another weighted average of these 9 hedge fund styles, where the weights are chosen to maximize the Sharpe ratio over the early sample (e.g., use the "solver" in Excel). What is the SR of this portfolio over the late sample? How does the answer compare to a.? Discuss the issues with portfolio optimization and what you might do about it.

4.2. **Risk management and drawdown control.**

a. For each hedge fund style and each month, compute the annualized volatility as the realized standard of excess returns over the past 12 months. For the first year 1993, use the value from January 1994 (which is cheating, but it does not matter here). Plot the volatility over time for fixed income arbitrage.

b. For each hedge fund style, compute the return of the risk-managed strategy. Specifically, choose an investment *x* such that

$$x\, 3\, \sigma_t \le MADD - DD_t$$

where σ_t is the current annualized volatility, $MADD$=30% is the maximum acceptable drawdown, and DD_t is the current drawdown of the risk-managed strategy. Specifically, if $3\, \sigma_t \le MADD - DD_t$ then you are not in "drawdown control mode" and you continue with a full investment of x=1. Otherwise, you enter drawdown control model is set $x = (MADD - DD_t) / (3\, \sigma_t)$.

In one plot, show the drawdowns of emerging markets hedge funds with and without drawdown control. In another plot, show the cumulative return of these two strategies.

c. Compute the SR, average return, and maximum drawdown for the strategy without drawdown control (as in the exercises for Chapter 2, where x is always 1) and the corresponding numbers for the risk-managed strategies. Comment on the differences.

5. Exercises for *Trading and Financing a Strategy: Market and Funding Liquidity*

The following sections contain exercises related to how trading is funded (e.g., 8.1, 15.4, 16.13) and how transaction costs affect the performance of trading strategies (e.g., 11.4). The following questions regarding trade execution should be answered independently of each other and relate to the following limit order book:

Top of the limit order book

	Shares	Price
Asks	1900	34.56
	1700	34.54
	1200	34.53
	400	34.52
	300	34.51
Bids	1000	34.49
	1100	34.48
	1400	34.47
	1500	34.46
	2200	34.45

5.1. **Bid-ask spread.** What is the posted bid-ask spread in cents and basis points of the mid price? If you buy 100 shares with a market order and immediately (i.e., before any new orders arrive or any existing orders are cancelled) sell them with a market order, then what is your P&L?

5.2. **Limit order.** A limit order to buy 150 shares at $34.50 arrives in the market. What happens? I.e., which transactions occur and what is the resulting bid-ask spread in cents? (In the rest of the exercise, assume that this order is subsequently cancelled.)

5.3. **Walking the book.** A limit buy order for 2000 shares at $34.53 arrives. Document all transactions, compute the volume-weighted average execution price of the transaction, and determine the bid-ask spread after the transaction(s).

5.4. **Market impact curve.** Compute the average execution price for market orders to buy, respectively, 10, 1000, 2000, 3000, and 4000 shares. Plot the market impact curve, that is, the execution price as a function of the size of the order. Discuss the relative importance of the bid-ask spread vs. the slope of the market impact curve for small and large traders. Also, discuss what market liquidity risk means in terms of what can happen to the limit order book in the future.

7. Exercises for *Discretionary Equity Investing*

Assume that you are portfolio manager of a market neutral discretionary equity hedge fund with EUR 1 billion in NAV. Your mandate is to maximize the return measured in EUR with a volatility of at most 15% annually. You are permitted to take long and short positions in equities, equity indices, and currencies as well as futures and derivatives on these. Find 1-6 companies that you consider taking positions in, or agree in class on a short list of companies to be studied.

You can find a lot of information on companies on the internet, e.g., on the firms' homepages, Wikipedia, and investor sites such as finance.yahoo.com and www.4-traders.com.

7.1 **Valuation ratios.** For each of these companies find or calculate market cap (market value), P/E, B/M, and dividend yield using the most recent data available. Find the dividend yield for each of the past five years.

7.2 **Expected near-term dividends.** For each company give your point estimate and 90% confidence interval for the dividend for the next three years.

7.3 **Valuation methods.** Which methods are particular suitable for calculating the fundamental value of each of the companies? Are there any methods which are particular unsuitable or difficult to apply? Are there any specific issues, e.g. risks or upside potentials, which should be taken into consideration in the valuation of each company. Think about and use the terminology of the course e.g. value trap, sustainable growth, management quality, triggers, activist investment, etc.

7.4 **Expected return.** Which return do you expect from each of the companies over the next 12 months and 36 months? Give point estimates and your 90% confidence intervals. Which return would you require from an investment in each of the companies?

7.5 **Positions.** Which position, in terms of EUR invested, would you take in each of the companies. Why? (Remember that your hedge fund also has long and short positions in other global equities.)

7.6 **Portfolio construction.** Assume you have decided to take a non-zero position in each of the companies. Are there any other positions you would consider to take to hedge unwanted risks or to comply with your mandate?

8. Exercises for *Dedicated Short Bias*

8.1. **Short selling and capital.** Suppose that you are the manager of a dedicated short bias hedge fund with an NAV of $100M. You sell short 10 stocks, with a short position of $20M for each of them. Specifically, you borrow the shares through your broker and sell the shares. You must pass the shortsell proceeds as cash collateral as well as a 20% additional margin requirement. The positions are hedged by buying 8 stocks of $20M each. Your broker also finances the long positions and also requires a 20% margin on those.

a. What is the current minimum margin requirement? Correspondingly, what is the current level of free cash? What is the current balance sheet for the hedge fund?

b. If the margin requirement for long and short positions changed to 30%, would the current positions remain sustainable? If not, how much would they need to be scaled back?

c. Suppose that margin requirements remain at 20% and over the next year. Further, the overall stock market performs strongly, yielding a return of around 25% for major stock indices. The short positions increase in value by 10% and the long positions by 25%. The risk-free return is 4%, including on your brokerage account and your margin loans (no financing spread).

- What is the NAV at the end of the year?

- What is the percentage return of the hedge fund (ignoring transaction costs and other costs)?

- Did the hedge fund perform well? Specifically, how what was the hedge fund's alpha with respect to the market (assuming that all stocks have a beta of 1)?

d. Suppose instead that the stocks that you shortsell are on special such that the short proceeds earn a return of 0% instead of 4%. (The additional 20% margin cash for short positions earn the normal risk free rate.) Under this scenario, what is the return over the year?

8.2. **Short selling and valuation.** Two investors, A and B, trade the stock TWTR. Each investor maximizes his expected future wealth subject to a penalty for risk (as discussed in Chapter 5). Investor A's optimal position measured in amounts of money x^A is given by

$$x^A = (\gamma^A)^{-1}\Omega^{-1}E(R^e)$$

Recall that γ^A is the risk aversion, is Ω is the risk of TWTR (i.e., variance), and $E(R^e)$ is the expected excess return. The absolute risk aversion is decreasing in the investor's wealth W^A such that $\gamma^A = 1/W^A$. Further, the current dividend yield and risk free rate are zero so investor A's expected excess return is given by $E(R^e) = \frac{\mu^A - P}{P}$, where $\mu^A > 0$ is his expectation of the value of a share next year. Finally, $\Omega = \text{var}\left(\frac{\mu^A - P}{P}\right) = \frac{\sigma_\mu^2}{P^2}$. The same expressions hold for investor B with two exceptions. First, his wealth is W^B and, second, his expectation is that the stock will be worthless next year ($\mu^B = 0$) so that his expected return is $E(R^e) = -1$ and his position is $x^B = W^B \frac{P^2}{\sigma_\mu^2}(-1)$. The supply of shares is given by s.

a. Explain why equilibrium is characterized by the condition that

$$\frac{x^A}{P} + \frac{x^B}{P} = s$$

and show that the equilibrium price without short-sale constraints is (where we assume throughout that the numerator is positive).

$$P = \frac{W^A\mu^A - s\sigma_\mu^2}{W^A + W^B}$$

b. Is investor A long or short? What about investor B?

c. What is the equilibrium price if no investor is allowed to sell short? How does the answer compare to the equilibrium without short-sale constraints in question a.?

d. Suppose that the investor B face is allowed to sell short, but the size of any short position $x^B < 0$ is limited by the following margin requirement:

$$M\,(-x^B) \leq W^B$$

where the margin requirement $M = m\,\sigma\left(\frac{\mu^A - P}{P}\right) = m\,\frac{\sigma_\mu}{P}$ depends on the volatility σ_μ and a parameter $m > 0$. Assume that this margin requirement is binding and solve for the equilibrium price. How does the price depend on the margin parameter m?

e. How does the equilibrium price with margin requirements in d. depend on the investors' wealth W^A and W^B? Specifically, what happens to the price if optimists get wealthier and pessimists get poorer (W^A increases and W^B decreases)?

f. **Short** squeeze **and liquidity spiral.** Suppose that agents take positions as in d. Immediately after their trades (but before any time passes), the margin requirement unexpectedly increases.

- Holding agents' wealth fixed, how does the increased margin requirement affect the price?
- How does the price change affect the agents' wealth given their initial positions?
- How does the change in wealth affect the price?
- Discuss the concepts of short squeeze and liquidity spiral

(You need not solve for the new equilibrium price.)

9. Exercises for *Quantitative Equity Investing*

Backtesting Industry Momentum

In problems 9.1-9.7, you backtest an equity strategy called industry momentum. The idea is to buy industries on the rise, and short declining industries. The accompanying Excel spreadsheet has returns on 30 industry portfolios, the risk free return, and the market return.[1] You can do the problem set using Excel or any other program of your choice.

9.1 Starting in 1927/07, for each industry and each month, compute the (arithmetic) average return over the previous 12 month for that industry (not including the month itself). Then for each month, **rank** the industries based on their past average return (hint: Excel has a function called "RANK(cell,range,1)"). Compute each industry's average rank (1=lowest past average return, etc.).

- Which industry has the lowest average rank and which has the highest?
- What is the average rank of these lowest and highest industries?
- Plot of the rank of Autos industry over time.
- Are the top industries stable or moving around a lot? I.e., is industry momentum a long-term bet on a few industries or a very dynamic strategy? Do you expect high or low turnover from this strategy?

9.2 **Winner portfolio.** Let the "winner industries" be the 15 industries with the highest past 12-month returns. For each month after 1927/07, compute the average return of the winner industries. I.e., compute the return on a portfolio of winner industries. (Hint: There are many ways of doing it. In Excel, an easy way is to use the function IF inside the function AVERAGE: ` =AVERAGE(IF(rank-range >= 16, return-range, ""))', but then you must hit control-shift-enter to execute (this is called an *array formula*). Another way is to do this in two steps: (1) For each industry, report the return if it is a top industry and a blank otherwise, IF(rank>= 16, return, ""). (2) Take the average of these numbers.)

- What is the average monthly return on this winner portfolio in excess of the risk free return
- What is the standard deviation of its monthly excess returns?
- What is its monthly Sharpe ratio?
- What is its annualized Sharpe ratio?

9.3 **Loser portfolio.** Compute the return of a portfolio of "loser industries," the 15 industries with the worst past returns.

- What is the average monthly return on this loser portfolio in excess of the risk free return
- What is the standard deviation of its monthly excess returns?
- What is its monthly Sharpe ratio?
- What is its annualized Sharpe ratio?
- What is the annualized Sharpe ratio of the overall market index?

9.4 **Long-short ind-mom.** Compute the return of a portfolio of that goes long $1 of winner industries and short $1 of loser industries each month. This is already an excess return. (To understand this, note

[1] All data is from http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

that if you first compute the winner's and loser's excess returns over R^f and then subtract one from the other, then the risk-free rates will cancel.) Regress this monthly ind-mom excess return on the excess return of the market. (In Excel, you can use the function LINEST.)

- What is its annualized Sharpe ratio?
- What is the market beta and the t-statistic of the market beta?
- What is the monthly alpha and the t-statistic of the alpha?
- What is the annualized alpha (12 times monthly alpha)?
- Comment on these numbers

9.5 **Cumulative return.** Compute the cumulative return of (a) the winner portfolio, (b) the loser portfolio, (c) the long/short ind-mom portfolio, and (d) the market. (Remember to use total returns, not excess returns, i.e., add the risk free return to the returns that are excess returns.) Plot these cumulative returns on a log-scale.

9.6 **Ind-mom loss.** Industry momentum had a big loss in 3 consecutive months in 2009. Which months? How did the market do those months? What do you think happened?

9.7 **Extra question (not required)**. Suppose you buy the top *N* winner industries and shortsell the worst *N* loser industries, where *N* is some number. Above we consider the top/bottom half, so we had *N*=15, but the strategy might work better for a smaller *N*. A smaller *N* concentrates the portfolio is more extreme winners/losers, which might perform better, at the expense of less diversification. What has been the best *N* historically?

Pairs Trading and Statistical Arbitrage

In problems 9.8-9.12, you have to explore the potential profits on trading twin stocks. The accompanying Excel sheet contain the stock price and the return index at close of 16 stocks, corresponding to two share classes for the following eight companies: A.P. Møller Mærsk (Denmark), Industrivärden, Investor, Svenska Handelsbanken and Volvo (Sweden), Volkswagen (Germany), Hyundai Motors (Korea) and Store Enso (Finland). All these shares pay dividends and you can assume that two stocks in the same pair pay the same dividend[2] on the same day.

Stock prices have been adjusted for splits, but not for dividends and other corporate actions, whereas you can think of the return index as a stock price adjusted for dividends and other corporate actions (i.e. with reinvested dividends etc.).

9.8 **Pair correlation.** First calculate the daily returns for each stock. Then calculate the correlation between daily returns for the stocks in the each pair. Make a bar plot of the correlations.

9.9 **Pair co-movement.** Adjust all the return indices to 100 on the September 8, 2004. Plot the return indices for stocks in the same pair together and assess whether you think there may be an arbitrage strategy. Do you see any unusual or surprising patterns?

9.10 **Spreads.** Calculate and plot the relative spread between the stock prices in the same pair (i.e., one price divided by the other minus 1) and assess whether you think there may be an arbitrage strategy. Do you see any unusual or surprising patterns?

9.11 **Pairs trading based on absolute prices.** Implement the following strategy: At close on the last day of each year, take a self-financing position in each pair where you go long the stock with the lowest price and short the one with the highest price. The initial value of each long position should be $1 and, similarly, the initial value of each short position should be $1. Hold the position for a year and rebalance again at close on the last day of the year.

a. Why might this strategy be profitable? Hint: What happens if the share price is unchanged from rebalancing to rebalancing?
b. Calculate the yearly excess return per pair, the SR, and test whether the yearly excess returns are statistically significant from zero (under the assumption that returns are independent and normally distributed).
c. Same as question b for a portfolio consisting of all eight pairs, equally weighted.
d. Which costs would you incur if you were to implement this strategy in practice?

9.12 **Pairs trading based on "unusual" price spreads: mean-reversion.** Consider the following alternative strategy: Put on a trade whenever the spread (relative price difference) between the stocks in a pair is "unusual" relative to the recent historical value of this spread. Specifically, at such times, go long $1 of the stock that is currently cheap (relative to what it "usually" is) and shortsell $1 of the stock which is currently expensive. Each day, either rebalance back to $1 long and $1 short or, when the

[2] For Volkswagen and Hyundai Motors there is a small difference in dividends but we can safely ignore this in this problem set.

spread again is "usual," close the position. The strategy can be implemented in many ways, for instance, you can do the following for each pair on each day:

- Calculate the relative price spread $S_t = \frac{P_t^A - P_t^B}{P_t^B}$, where P_t^A and P_t^B are the prices of each of the share classes on day *t*.
- Calculate the rolling 20-day average spread, $\bar{S}_t = \sum_{i=t-19}^{i=t} S_i /20$, and the 20-day spread volatility, $\sigma_t^S = \sqrt{\sum_{i=t-19}^{i=t} (S_i - \bar{S}_t)^2/19}$.
- Calculate the *z*-score of the spread, $z_t = \frac{S_t - \bar{S}_t}{\sigma_t^S}$.
- Open a position when the absolute value of the *z*-score exceeds 2, going long the stock that is usually cheap and short the other one (i.e., sign the positions based on the sign of the *z*-score).
- Close the position when the sign of the *z*-score reverses.
- Calculate the daily return (zero on days where no position is open).
- Calculate the daily return of a strategy that equal weights all the pairs (including pairs that have no position on).

a. Why might this strategy be profitable?
b. Assume you can observe closing prices and trade on these prices same day, i.e. if z_t exceeds 2 on day *t*, a position is opened at close on day *t* and profits are recorded from day *t+1*. Plot the cumulated profits from the strategy for each pair and for the equal-weighted portfolio. What is the annualized SR of the portfolio?
c. Alternatively, assuming that you have to wait one day from you observe close prices until you trade. Now plot the cumulated profits from the strategy for each pair and the portfolio. What is the annualized SR of the portfolio? Which is more realistic and implementable, b or c?

11. Exercises for *Global Macro Investing*

FX carry trading

In problems 11.1-11.7, you backtest the currency carry trade using the data provided in the accompanying Excel spreadsheet. You can do the problem set using Excel or any other program of your choice.

11.1 **Investment currencies and funding currencies.** For each month of the sample, **rank** the countries based on their interest rate (hint: Excel has a function called "RANK(cell,range,1)"). Compute each country's average rank (1=lowest interest rate, etc.).

- Which country has the lowest average rank, i.e., most often "funding currency" with the lowest interest-rate?
- Which country is the second to most often funding currency (second lowest average rank)?
- Which country is most often "investment currency," i.e. highest average rank?
- Which country is second to most often investment currency?
- Plot here the rank of the US over time.

11.2 **Carry positions.** Create positions for each currency, either $1 (long), $-1 (short), or 0 (flat). Do this by going short the three currencies with the lowest interest rate, and long the three with the highest interest rate. (Hint: you can use the Excel function "IF" twice, one inside the other: " = IF(cell <= 3 , -1 , *IF(cell >= 7 , 1 , 0)*) ".

- What is the average position in New Zealand?

11.3 **Carry trade return.** Compute the excess return on each position, and add these up to get the excess return of the entire portfolio in any month. Make sure to get the timing right. (Hint: use SKEW and KURT, and annualize as in notes.)

- What is the annualized average excess return of the portfolio?
- What is the annualized standard deviation?
- What is the annualized SR?
- What is the skewness of monthly returns?
- What is the (excess) kurtosis of monthly return?
- Comment on these numbers

11.4 **Transaction costs.** For each currency, compute the trade each month, that is, the change in position. (Position this month, minus last month.) Assuming that the transaction costs are proportional as given in the sheet, compute the transaction costs for each currency. Add up the transaction costs to get the total transaction costs. Subtract total transaction costs from the portfolio's excess return to get the return net of trading costs.

- What is the annualized average net return of the portfolio?
- What is the annualized net SR?

- Why is the effect of transaction costs so modest in this case? Do you think that this is typical of all trading strategies? Under which circumstances might a global macro trader incur larger transaction costs in connection with the currency carry trade?

11.5 **High water mark.** Compute the portfolio's total return including the US risk free rate, but net of transaction costs (i.e. add the annual US interest rate divided by 12 to the portfolio's return). Next, compute the cumulative return, assuming you start with $1, and then keep reinvesting all profits/losses. Further, compute the high water mark as the maximum cumulative return from the first date to the current date. (Hint: Excel has a function called "MAX"). Make a plot with both the cumulative return and the high water mark.

11.6 **Drawdown.** Compute and plot the drawdown, $DD_t = (HWM_t - P_t) / HWM_t$, where P is the cumulative return and HWM is the high water mark.

11.7 **Timing the carry trade.** Suggest a way of dynamically timing the carry trade (that is, increasing and decreasing the position sizes over time) that might improve the performance of the strategy and/or reduce the drawdowns.

12. Exercises for *Managed Futures: Trend-Following Investing*

In problems 12.1-12.4, you backtest the time series momentum strategies using the data provided in the accompanying Excel spreadsheet.

12.1 **Direction of the estimated trend.** For each instrument, estimate the direction of the trend as the sign of the past 12-month returns (+1 if the past return is positive, -1 otherwise). What is the average over time of these trend direction indicators for each instrument? Interpret these numbers and discuss whether the strategy is market neutral at any point in time and on average.

12.2 **Time series momentum: constant notional.** For each instrument, consider the strategy of going long $1 whenever the trend is estimated to be positive and otherwise go short $1.

a. What is the average SR of each of these strategies?

b. Consider the equal-weighted portfolio of these strategies. What is the SR of this portfolio?

c. What is the correlation between each individual strategy and the equal-weighted average? What are the maximum and minimum correlations?

d. Are there any problems of realisms with using the end-of-month return to compute the trading signal and the next month's return (from end-of-month to end-of-month) to compute the strategy return (as is common in academic research papers)? What would be a more realistic approach? (The effect is not large in this case, and we continue with the same approach in the rest of the exercise.)

12.3 **Time series momentum: risk balanced.** For each instrument, first estimate the ex ante volatility as the standard deviation over the past 2 years. Then consider the strategy of going long $x whenever the trend is estimated to be positive and otherwise go short $x, where x is chosen such that the position's volatility is 40% based on the ex ante asset volatilities.

a. What is the average SR of each of these strategies? How does the answer compare to that in 12.2.a.?

b. Consider the equal-weighted portfolio of these strategies. What is the SR of this portfolio? How does the answer compare to that in 12.2.b.?

c. What is the correlation between each individual strategy and the equal-weighted average? What are the maximum and minimum correlations?

d. Comment on the ideas of being risk balanced a) over time and b) across securities.

12.4 **Return during 60/40 drawdowns.** Compute the return on the 60/40 stock/bond portfolio that some view as a benchmark for pension funds (although the only benchmark that can be used for all investors in the market-capitalization weighted average of all securities).

a. Compute the drawdowns of the 60/40 portfolio and identify the time periods of the 3 largest drawdowns from the beginning of the drawdown to the peak of the drawdown. What are the returns of the 60/40 portfolio and the risk-balanced time series momentum portfolio over each of these time periods?

b. Identify the "recovery time periods" corresponding to these drawdowns, namely the time periods from the peak of the drawdown to the end of the drawdown. What are the returns of the 60/40 portfolio and the risk-balanced time series momentum portfolio over each of these time periods?

c. What is the return over the full cycle, from the beginning of the drawdown to the end of each drawdown?

14. Exercises for *Fixed-Income Arbitrage*

To answer problems 14.1-14.7, consider the following bonds, each with a face value of $100:

Type of bond	Maturity	Coupon	Price	YTM
Zero coupon	1	0	96.32	3.82%
Zero coupon	2	0	*P_zero*	4.60%
Zero coupon	3	0	89.11	*Y*
Annual-pay coupon	2	5%	*P_coupon*	

14.1 **Price and yield.** What is the price of the 2-year zero-coupon bond, P_zero? What is the yield to maturity of the 3-year zero coupon bond?

14.2 **No arbitrage pricing.** Which price would be consistent with no arbitrage for the annual-pay coupon bond (i.e., a bond that pays $5 after one year and $105 after two years)?

14.3 **Fixed income arbitrage.** Suppose that the coupon bond trades at a price of $101.00.

a. What arbitrage trade would you do?

b. Suppose that you hold this arbitrage position until maturity in two years. What will be your profit in dollars? What is the annual return as a percentage of the value of the long side of the position? If the margin requirement is 10% for all long and short positions, what is the initial margin requirement in dollars? What is the annual return as a percentage of this initial margin requirement?

c. Suppose that, after one year, the yield to maturity on all bonds is 5%. What is the profit or loss in dollars at this time? What is the annual return as a percentage of the initial margin requirement?

d. Suppose that the yield to maturity on all bonds becomes 5% already 1 month after you put on the trade. What is the profit or loss in dollars at this time? What is the annual return as a percentage of the initial margin requirement?

14.4 **Forward rates and directional fixed income trading.**

a. What is the forward rate from time 1 to time 2 implied by the above zero-coupon bond prices?

b. Suppose that you believe that the 1-year interest rate will be 4% in one year from now (based on your views on central bank policy). What trade would you consider as a result of the difference between your view and the forward rate?

14.5 **Yield curve.** Plot the zero-coupon yield curve, that is, the yields on zero-coupon bonds as a function of their time to maturity. Include the overnight interest rate of 3.7%.

14.6 **Duration.** Compute the duration and modified duration of each of the four bonds. If each bond's yield to maturity immediately increases by 1 percentage point, approximately how many dollars will each price decline?

14.7 **Yield curve trading.** What is average of the yields of the 1-year and 3-year zero-coupon bonds? Suppose that you view the 2-year interest rate as abnormally high relative to this average. Your view that the 2-year rate is too high is supported by information that several pension funds and banks have been forced to sell large positions of 2-year bonds, pushing down the price, hopefully only temporarily.

a. Structure a long-short trade between 1, 2, and 3-year zero coupon bonds which reflects this view while being relatively immune to changes in the level of yield curve (i.e., the modified duration of long side is equal to that of the short side) and relatively immune to changes in the slope of yield curve. Specifically, go long one 2-year bond and decide on you positions in 1-year and 3-year bonds. Hint: as discussed in the book, you can try having a dollar duration in each "wing" bond that is equal to half the dollar duration of the "body" bond. I.e., with positions (the number of bonds) denoted by x, prices by *P*, modified duration by $\overline{D}$, and bonds indicated by their maturity (1, 2, or 3), we have $x^2 = 1$ and x^1 and x^3 given by

$$x^1\,\overline{D}^1\,P^1 = x^3\,\overline{D}^3\,P^3 = -0.5\,x^2\,\overline{D}^2\,P^2.$$

b. **Level change up**. What is your profit or loss if the yields of the three zero-coupon bonds immediately change to 4.82%, 4.87%, and 4.92%?

c. **Level change down**. What is your profit or loss if the yields of the three zero-coupon bonds immediately change to 2.82%, 2.87%, and 2.92%?

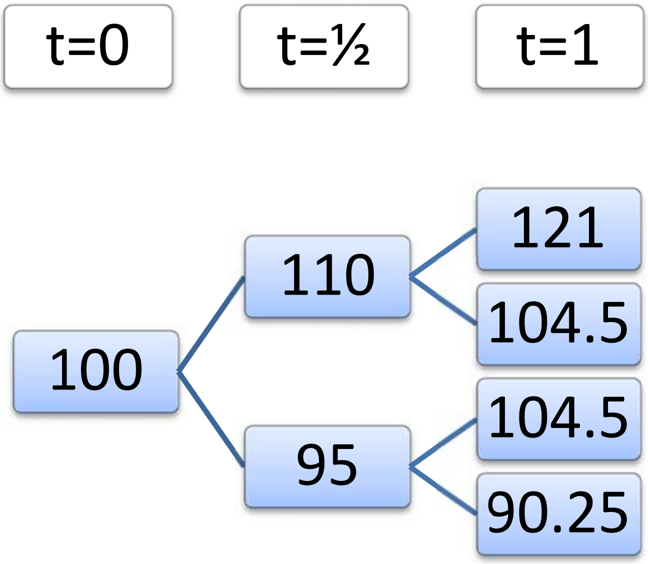
d. **Slope change up**. What is your profit or loss if the yields of the three zero-coupon bonds immediately change to 2%, 3%, and 4%?

e. **Slope change down**. What is your profit or loss if the yields of the three zero-coupon bonds immediately change to 4%, 3%, and 2%?

f. **Bigger kink**. What is your profit or loss if the yields of the three zero-coupon bonds immediately change to 3.82%, 5%, and 3.92%?

15. Exercises for *Convertible Bond Arbitrage*

Consider a convertible bond with 1 year to maturity. The bond has a face value of $100 and pays an annual coupon of $5. The convertible bond has no call and put features and faces no risk of default. The conversion price is 100, corresponding to a conversion ratio of 1 (i.e., you can convert 1 convertible bond to 1 stock). The risk free return is 2% per period (i.e., per half year). The current stock price is $100 per share and evolves in a binomial tree with two periods per year with 10% up moves and -5% down moves:



15.1 **Theoretical value of the convertible bond:**

a. When should the convertible bond be converted?

b. What is the theoretical value of the convertible bond at each state in the tree?

15.2 **Convexity.** At time 0, a hedge fund buys a convertible for the price computed in 1 and optimally hedges the position.

a. Suppose that the stock prices unexpectedly jumps to a new value *S* immediately at time 0. From then on, the stock price again evolves in a binomial tree with two periods per year with 10% up moves and 5% down moves. What is the hedge fund's P&L at time 0 for *S* = 90, 95, 100, 105, 110?

b. Suppose that the stock price jumped down to *S*=90 and that the hedge fund re-adjusts its hedge at this price level. Then the stock price jumps back up 100. All this happens completely unexpectedly at time 0, and, from then on, the stock moves in the binomial tree. What is the P&L from the jump up in price?

c. Suppose instead that the stock price remains 100, but that the volatility changes immediately at time 0. Specifically, suppose that the jump sizes change to up=20% and down=-10%. What is the P&L of the hedge fund? What is the P&L if the jump sizes change to up=5% and down=-3% ?

15.3 **Cheapness.** Suppose that stock market evolves as in the initial tree above, but the market price of the convertible bond differs from its theoretical value. At time 0, the convert has a price of 101. A hedge fund buys a convertible bond and hedges it (in the same way as if the convert was priced at the theoretical value). At time t=½, the stock price falls to 95 and the convert price falls to 96.

a. How cheap is the bond relative to its theoretical value?

b. What is the P&L in dollars of the hedged convert position? In percentage of the converts initial price? How is the answer related to the convert's cheapness?

c. If the hedge fund can hold its position until time 1, what will be its P&L from time ½ to time 1?

15.4 **Margin requirements.** After the hedge fund has marked-to-market its time-½ loss when the convert drops to 96, it has a net asset value of $100M. The hedge fund owns 4M convertible bonds. The hedge fund's prime broker states that the margin requirement for each convertible bond and its hedge is 30% of the convert value.

a. Does the hedge fund have sufficient capital to meet the margin requirement for its current position?

b. What is the maximum position that the hedge fund can take?

16. Exercises for *Event-Driven Investments*

Volkswagen's Takeover of Scania

In this problem set, we study Volkswagen's takeover of the Swedish heavy truck and bus manufacturer Scania, a transaction valued at almost SEK 60 billion SEK (EUR 6.5 billion). The transaction was completed, but this was not a certain outcome during most of the process. You can find a lot of information on the process on the internet, but you are encouraged to solve the questions with the information provided before you seek further information. You are provided with five press releases, please read them as instructed below.

16.1 Merger premium. Read the press release "*Volkswagen-announces-a-cash-offer*." What was the price before the announcement for A and B shares and what is the offered price. Discuss the difference, the "merger premium," and compare this concept to the "deal spread."

16.2 **Merger event risk.** Volkswagen's offer to purchase all outstanding Scania shares comes with six conditions.

a. For each of these conditions give your subjective estimate of the probability of the condition being met or waived. What is the probability of the transaction being completed?

b. If you worked for an event-driven investment manager and had more time and resources, what kind of information or research do you think is most valuable in this type of merger?

16.3 **Market-implied market risk.** Scania closed at a price of SEK 194.5 per share on February 24, 2014 (the first trading day after the offer was announced). What does this price say about the implied risk neutral probability of the transaction going through? You will need to make some assumptions. State these explicitly.

16.4 **Mergers and share classes.** Scania has two share classes, A and B. Immediately before the offer, the A share traded at a discount of 3 SEK, perhaps because it was less liquid than the B share. What do you think the discount was at close on February 24? Argue why your answer is consistent with the answers given to the questions above.

16.5 **Mergers and options.** Consider options written on Scania B shares with expiry on September 19, 2014 and strike price SEK 150. Assume that, on February 21, call options traded for SEK 12 and put options traded for SEK 13. Approximately at which prices do you think these options traded at the close on February 24? Do you think the Black-Scholes formula would have been appropriate to calculate the price of these options at close on February 24? Why?

16.6 **Merger news.**

a. **Internal recommendation.** Read the press releases “Independent-committee” and “Recommendation-independent-committee.” How do you think the recommendation of the independent committee affected the price of Scania stock? What do you think the value of the Scania stock should have been after the recommendation was announced?

b. Assume, in this question only, that the announcement of the independent committees’ recommendation was greeted with no reaction in the stock market. What would this say about the type of information that was priced into the value of Scania stock before the announcement?

c. **Initial outcome of tender offer.** Read the press release “Volkswagen-announces-outcome.” How do you think this announcement affected the Scania stock price? What do you think the value of the Scandia stock should have been at close on April 30?

16.7 **Merger outcome.** Read the press release “Volkswagen-declares-unconditional.” What do you think the value of the Scandia stock should have been at close on May 13?

16.8 **Negative deal spread.** In some cases, the price of the takeover target exceeds the offer price after the offer is announced. What are some possible reasons for such a negative deal spread?

Trading on Carve-Outs

Read Harvard Business School Case 9-202-024 on Strategic Capital Management, LLC (A) and answer the following questions.

16.9 **Understanding carve-out trading.**

a. Suppose that Elena wanted to buy either Creative Computers or Ubid. What are the arguments for/against buying Creative Computers? Arguments for/against buying Ubid?

b. How many Ubid shares were held by Creative Computers in total?

c. If you owned 1 share of Creative Computers, how many shares of Ubid did you effectively own?

d. Is there a long-short strategy that she should consider?

e. Choose a single trade that you would recommend Elena to pursue and specify how she should size the position. I.e., how many dollars should be invested in this opportunity? Answer this question before you read the following questions.

16.10 **Balance sheet.** Create a market-value balance sheet for Creative Computers.

16.11 **Long-short stub trade.** Suppose Elena goes long 1 share of Creative Computers and short 0.7159 Ubid shares and that the risk-free interest rate is zero.

a. **Return on convergence.** After the market closed on June 7, 1999 Creative Computers distributed all its Ubid shares to its shareholders on a pro-rata basis. This was 6 months after the partial IPO, as planned. At this time, Creative Computers' stock price was $32.625 per share and Ubid was trading at $34 per share. What is the return on her strategy in dollars? What is the return as a percentage of the initial long position? What is the annualized return?

b. **Initial equity.** Assume that Strategic Capital Management initially posts 50% margin for both long and short positions. What is the initial margin equity on Dec. 9, 1998 for each share that SCM is long? I.e. 0.50 times (the dollar value of long 1 CC share plus dollar value of short 0.7159 Ubid shares).

c. **Margin equity.** Assuming that Strategic Capital Management does not add or withdraw from the margin account, what was the margin equity on Dec. 18, 21, 22, 23 given the following evolution of the stock prices?

	9-Dec-98	18-Dec-98	21-Dec-98	22-Dec-98	23-Dec-98
CC share price	$22.750	$28.875	$35.375	$46.922	$59.688
Ubid share price	$35.688	$53.125	$84.125	$134.500	$188.000

d. **Margin requirements.** Assuming that the minimum maintenance margin requirements were 25% for long positions and 30% for short positions, what was the minimum required margin equity on Dec. 18, 21, 22, 23? Is the margin equity sufficient to cover these margin requirements or is there a margin shortfall on these dates? (Continue to do this analysis for 1 share of CC.)

e. **Margin calls.** Given the size of the position that you chose in question 16.9.e., how many shares would you have bought? (I.e. if you invested $5M, it would be 5M/22.75.) Could you sustain the margin call on Dec.23?