

**Department of Operations Research and Financial Engineering
Bendheim Center for Finance
Princeton University
Princeton, New Jersey 08540**



**ORF 435/535 Final Project
Professor John M. Mulvey
December 22, 2017
Part 1: Due January 8, 2018, 5 pm**

This is the first part of the term project. Students must work alone and cannot discuss with others. Indicated percentages are referenced to the first part of the project.

It is essential that you spend time writing your report in a professional manner; the grade will be lowered for poorly constructed reports. Accordingly, you should put the recommendations at the beginning, along with a quick summary of the research goals and methods. The reader's time is important. Subsequent sections can discuss summary empirical results and observations therein. Detail analyses and supporting discussion should be included in the appendix.

1. Arbitrage (25%)

This section takes up the calculation of no-arbitrage prices for securities that are readily available in both long and short positions. For simplicity, assume no transaction costs and no cash flows until the one-year expiration (forward markets).

Compute all of the cross-spot rates and the one-year forward rates for the following securities:

Currencies: USD, GBP, EU, and CNY;

Commodity: gold;

Government bills (1y): U.S., Germany (use EU for determining arb-free prices), U.K, and China;

Equities: S&P 500.

You should write a program to calculate the two 10 by 10 matrices -- spot and forward cross prices.

The following relationships are known:

1 EU = \$1.1844, \$1 = 6.58 RMB, 1 GBP = \$1.3388

Gold spot = \$1263/oz., SPY spot = \$267.17 with dividends = 1.8%

One-year interest rates: U.S. = 1.35%, U.K. = .38%, Germany = -.81% (for EU), China = 3.8%

Assume that the holding costs for gold is .5% per year.

2. Basic Synthetic Bank Model (35%)

In this exercise, we attempt to “replicate” some of the primary characteristics of a domestic commercial bank. In this context, a domestic bank will make long duration loans while employing short duration demand deposits and other sources of capital to fund the loans. The bank generates a profit via the spread between the long assets and the short liabilities. Of course, there are many missing features that will complicate our analysis. Never the less, we start with this basic premise. Your job is to attempt to discover an investment strategy that is superior to one or more of the domestic banks in the U.S. (and conduct a brief analysis for the hedge fund that you are working for).

Let's begin at time $t = 0$ with capital $C_0 = \$1.3$ Billion. To address the spread, we consider the following investment: Go long a bond index (ETF AGG) and go short 13 week T-bills, and rebalance the portfolio to the target [y times net capital] each month. The level of the overlay strategy will be a decision variable $y \geq 0$. For example, suppose that we set $y = 2$. Then we invest $2 * \$1.3 \text{ B} = \2.6 B in the overlay at the beginning of the first period. The remaining capital will be invested in T-bills at each period in this basic set up.

Next, we employ the historical period January 1, 2004 to November 30, 2017, monthly for our empirical tests. We will first simulate the performance of the combined investment: overlay + T-bills. Starting with $y = 2$, simulate this strategy and calculate the usual reward and risk measures, including annual geometric return, annualized volatility, Sharpe ratio, Sortino ratio, maximum drawdown, VaR and CVaR at 1%. If the capital drops below zero, the bank must be recapitalized (indicated as a red card). Another threshold takes place when capital approaches a low number such as 20% of the original capital. We call this a yellow card.

Note that if a gradual deterioration of capital occurs, the bank is reasonably protected since the overlay strategy will be reduced along with risks. At some point, however, a yellow card or red card may occur.

Conduct an optimization to determine the best value of the leverage y , assuming that excess capital is invested in T-bills. The objective is to maximize the geometric return of the bank's capital, while setting a constraint on the CVaR ($h=.01$) at \$200 Million and avoiding red cards.

Next, you are allowed to invest capital in any of three assets: S&P 500 (SPY), Bonds (AGG), and T-Bills. Assume fixed mix at each period for the first step. Find the optimal combination of leverage (y) and asset allocation for x_1 , x_2 , and x_3 . For instance, you may wish to engage a modest leverage, while adding stocks to the asset mix to generate higher long-term returns.

3. Dynamic Strategies (25%)

Here, you are allowed to change the degree of leverage, depending upon your expectations and current market conditions. For instance, suppose the spread between long bonds and short bill is wide. You could apply higher leverage. Also, note that every recession in the U.S. over the past 60 years has been preceded by an inverted yield curve (interest rates on short bills higher than long bonds); see the chart below. In this situation, you might lower leverage dramatically when an inversion occurs. Calculate the same risk measures for your best dynamic strategy and compare with the previous static strategy.

While real banks have the advantage of ultra-low borrowing costs and higher returns from their loans as compared with long bonds, they suffer from several headwinds. First, there is the cost of running a bank --- all of the employees and executives and the physical branches. Second, banks have the risk of a bank run and their duration mismatch can be a big problem in crash periods. Third, the synthetic bank has much flexibility to adapt quickly to changing conditions. It can readily modify the leverage for example as we mentioned in this section. So, there might be a horse race, indeed, between a real bank and our “synthetic” bank. Let’s see.

Propose and test out a dynamic strategy of your choice, again calculating the reward and risk measures and compare with the static strategy above.

4. Comparing with Commercial Banks (15%)

Evaluate the best of your results with the performance of two domestic commercial banks: Citigroup and Bank of America over the 2004-2017 time-period. Employ the same reward and risk measures as above. Make a decision about the one that you will recommend to the hedge fund committee. For example, you might go long the designated strategy and go short one of the selected banks.

As always in the course, the major concern is **financial risk management**, and it is your job to be aware of the risks, both explicit and implicit. Briefly discuss the limitations of the previous analysis and steps that you might take to provide robust recommendations.

Exhibit 1
Recessions in the U.S. have been anticipated by the bond market
via inverted yield curves

