"Fixed Income plus" Portfolio using Bond Hedging Strategy

------MF728 Final Project Report

Course:	MF728 Fixed Income
School:	Questrom School of Business
Group members:	Zhonglin Gu (BU ID: U32213289; Email: zlgu@bu.edu)
	Yifan Dong (BU ID: U71363037 Email: dyifan@bu.edu)
	Jianghao Han (BU ID: U34066740; Email: jianghao@bu.edu)
	Ruoshan Wang (BU ID: U89370436; Email: rswang@bu.edu)
	Liangqi An (BU ID: U53508009, Email: alq@bu.edu)
	Tian Qiu (BU ID: U02721288, Email: tianqiu@bu.edu)

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Introduction

The goal of the project is to construct a bond portfolio consisting of corporate bonds and rate securities. Our target is to enhance bond portfolio return as much as possible while controlling possible risk such as credit risk and interest risk. Our target annualized return is 8%, which is significantly higher than most bonds in the market.

To build this “fixed income plus” fund, we will firstly select high-yield corporate bonds from both yield and default probability perspectives. We will consider hedging the interest risk for debenture bonds by achieving duration neutrality or matching CDS. Therefore, we can get high coupon revenue without market risk. Next step we will trade rate securities and convertible bonds with high liquidity to catch more revenue from fluctuation of market price. In this section, we will model the interest rate curve and find trading opportunities based on it.

Data Collection and Cleaning

There are four major portions and sources for this project.

The first is interest rate related data, such as LIBOR, Treasury market yield, IRS, etc. The data for interest rate is mainly obtained from the Federal Reserve Economic Database, the frequency of data is daily. Interest rate data barely have any missing data, so forward filling is used for filling the missing portion. Then, the Bond Pool data, which is all corporate and municipal bonds starting from 2008/01/01 to present with credit rating higher than B- and coupon rate higher than 5% fixed, is filtered and downloaded directly from Bloomberg. The Bond Pool mainly served as a package of bonds which we selected for construction of the corporate bond portfolio portion of the project.

As the quality of CDS data is not as good as bond pool data, all available CDS data is downloaded from Bloomberg, and corresponding firms between CDS and Bond Pool’s issuer firms are selected from all available CDS data. The CDS data is then first bootstrapped for each single day in order to construct a mostly filled 1Y CDS market spread. If 1Y CDS market spread is missing, then the next available spread is used to calculate 1Y CDS spread assuming constant hazard rate during the data missing period. After bootstrapping, the rest of the gaps are filled by forward filling, as for this project, CDS data is preferred to be full rather than with high accuracy. Finally, daily bond trade data is obtained from Wharton School Database Finra Daily Bond Trade summary, all bonds’ daily market yield for available intersection of firms between CDS and Bond Pool are downloaded, and bond code and issuer’s name can be used to obtain the required data.

Corporate bond Selection

For the corporate bond part, the first step is to identify bonds that meet certain criteria and prioritize the bonds based on their scores. Firstly, we matched bonds' issuer name with the CDS data, because we need CDS to hedge credit risk, but we only have a small amount of quotation CDS data, so after matching issuer name, we get 178 bonds that meet this constraint.

Then we choose several features to score the 178 corporate bonds, including their credit rating, duration, coupon rate and total debt. We weigh these features and sort the scores of these bonds from highest to lowest. Here are the standardizations of each feature:

1. Credit rating: we drop the bonds whose credit ratings are below B-, and transform the ratings into points. (like this credit rating points: 'AAA': 15, 'AA+': 14, 'AA': 13, ……, 'B-': 0)
2. Duration: we use bond's maturity minus bond's issue date to calculate the duration and drop the bonds whose durations are bigger than 20 years.
3. Coupon rate: at first, we want to drop the bonds whose coupon rates are lower than 6, however we find this is a little bit high to select corporate bonds, because we can just get 7 bonds, which means the number of bonds is so small. After tuning parameters, we drop the bonds whose coupon rate is lower than 5%.
4. Total debt: we drop the bonds whose total debt is higher than 60.

After selecting the features and defining them, we need to weigh them. After back testing, we find a weight set is the best one to select good-performance corporate bonds: credit rating weight: 0.1; Duration weight: 0.4; coupon rate weight: 0.4; debt weight: 0.1. And calculate the 178 corporate bonds' score by using: score = credit rating points * credit rating weight + coupon rate * coupon rate weight - duration * duration weight - total debt * debt weight

Finally, we sort all the 178 corporate bonds, and then choose top 10 bonds to build our high-quality corporate bond pool further.

Here are the Top 10 corporate bonds that we choose:

```
['443201AA6', '844741BK3', '032511BN6', '25179MAV5', '832248BB3', 'AX9051191', '053807AV5', '29250RAW6', '65339KCJ7',
'745867AX9']
```

Corporate Bond Portfolio Optimization

We aim to optimize the corporate bond portfolio by assigning weights to individual bonds we've selected before, with criteria mainly focused on the portfolio duration with a given target volatility to achieve high expected returns.

The first approach takes only the efficient frontier into consideration to maximize the expected return of the portfolio. However, maximizing portfolio return based solely on efficient frontier lacks consideration of the market risk and relies on accurate estimates of expected returns and risks.

To solve the limitation of such a method, the second approach is developed by adding duration as a constraint to hedge market risk. Given a specific date, the durations of individual bonds are computed and then the portfolio is constructed by assigning weights to each of them to achieve neutral duration. By maintaining a neutral duration, the portfolio's sensitivity to changes in interest rates is reduced. This can help to stabilize the portfolio's returns and reduce volatility. Also, it can help to create a consistent income stream. Bonds with longer durations generally offer higher yields than bonds with shorter durations, but they also have greater interest rate risk. By holding a mix of bonds with different durations, investors can create a balanced income stream that provides a reasonable yield while also mitigating interest rate risk.

The implementation of such optimization includes using historical data of corporate bonds we selected from the previous 3 months and constructing the efficient frontier with the Python package PyPortfolioOpt. Given the date and volatility, we can output the weights of bonds with optimal returns. Given a holding period from Oct 2022 to Mar 2023, the performance of a portfolio without neutral duration is not as desired, with an annualized return of -4.42%, an annualized volatility of 11.65%, and a maximum drawdown of 6.73%. After adding the constraint for the neutral duration, we are able to achieve better results with a higher annualized return of 3.42%, a lower volatility of 7.37%, and a smaller maximum drawdown of 4.76%.

Out of sample test

The holding period was from October 2022 to March 2023.

(1) Test the effect of neutral duration strategy

In the part of bond portfolio optimization, we tried two methods to allocate weights for individual bonds. The first is to assign weights to the bond portfolio based on Markowitz efficient frontier in order to maximize the expected return of the portfolio given a target volatility. As mentioned before, this strategy cannot hedge market risk.

The second method is the weight allocation strategy to realize neutral duration on the starting date of the holding period. Because our trading strategy is to buy and hold, we can only achieve neutral duration on the first day of holding period, October 3, 2022. With the change of time, the duration of our bond portfolio will change. However, due to the neutral duration strategy, we will reduce the market risk to a large extent for the remaining holding period. If the market interest rate does not fluctuate sharply, our portfolio will maintain a relatively small duration and thus will not be very sensitive to market interest rate fluctuation.

The out of sample performance also proves our theory. You can see the performance of the neutral duration strategy is much better than that of maximizing expected return given the target risk. Our strategy of neutral duration to hedge market risk in the holding period is very effective.

(2) Further analysis of the bond portfolio

If we only consider the corporate bond portfolio, our annualized return can reach 3.42 %, the annualized volatility is 7.37 %, and the maximum withdrawal during the holding period is 4.76 %.

```
In [25]:  corp_portfolio_performance(corp_bond_price, test_start, test_end, optimal_weights_neutral, weights_CDS)

Portfolio Annualized Return:  3.42 %
Portfolio Annualized Volatility:  7.37 %
Portfolio Maximal Drawdown :  4.760000000000001%
```

(3) Consider adding CDS portfolio

Since corporate bonds are a kind of debenture bonds, they may have credit risk if the issuer of a bond within our bond portfolio defaults.

We have to add CDS to our corporate bond portfolio to hedge the credit risk. And for the bonds we selected, whether we have long or short positions for the bonds, we still long corresponding CDS which are linked to our bonds. We constructed another portfolio of CDS in which the weight distribution of CDS is consistent with the weight distribution of our bond portfolio. For example, a company, CVS Health, has issued two bonds. The weights of these two bonds in our portfolio are 20% and 30% respectively. Then we need to buy the linked CDS for these two bonds and the weight for this kind of CDS is 20% plus 30%, i.e., 50%.

When calculating the cost of adding CDS to our bond portfolio, we use the following idea. Since the CDS market quotation we obtained from Bloomberg is spread over Treasury rate of the same maturity, that is, 1Y Treasury bill interest rate. So to calculate the fixed lag premium of CDS, which could be regarded as the annualized cost of credit insurance, we need to add 1Y Treasury rate to the quoted spread for CDS. After we get the CDS premium, we can calculate the cost of holding the whole portfolio of CDS based on the weight distribution of CDS we just calculated. The annualized premium rate for the entire CDS portfolio is about 5.5%.

The added cost of CDS made annualized return on our bond portfolio fell to -2 %. And it looks like our portfolio has lost money.

```
In [29]:
# bond & CDS portfolio
# now just consider the cost of CDS, not the revunue from CDS
corp_portfolio_performance(corp_bond_price, "2022-10-03", test_end, optimal_weights_neutral, weights_CDS, with_CDS = True)
```

```
Portfolio Annualized Return:  -2.04 %
Portfolio Annualized Volatility:  7.37 %
Portfolio Maximal Drawdown :  4.760000000000001%
```

CDS can provide credit protection for our bond portfolio. At the same time, CDS is also a derivative and a kind of securities. Its price may fluctuate, so the CDS portfolio may also bring us gains or losses. Let us look at the performance of our CDS portfolio during the holding period.

The annualized return of the CDS portfolio is 70.53 %, the annualized volatility is 62.09 %, and the maximum drawdown during the holding period is 25.67 %. We make big money from CDS!

```
In [30]:

    '''
        step4-2: calculate the performance of 1Y CDS during holding period

    '''
    # now consider CDS revenue, assume recovery rate is zero for all the bonds we selected
    # Under this assumption, CDS protects the full value of the bond
    # When we buy a CDS, if the premium is 0.1, then the cost of holding this pair of bonds & CDS is the premium of the CDS,
    # This assumption greatly simplifies our calculation process

    # We don't sell CDS in the end of holding period, we just calculate the book gain of CDS
    cds_portfolio_performance(premium_CDS, weights_CDS, "2022-10-03", "2023-03-31")
```

```
Portfolio Annualized Return:  70.53 %
Portfolio Annualized Volatility:  62.09 %
Portfolio Maximal Drawdown :  25.679999999999996%
```

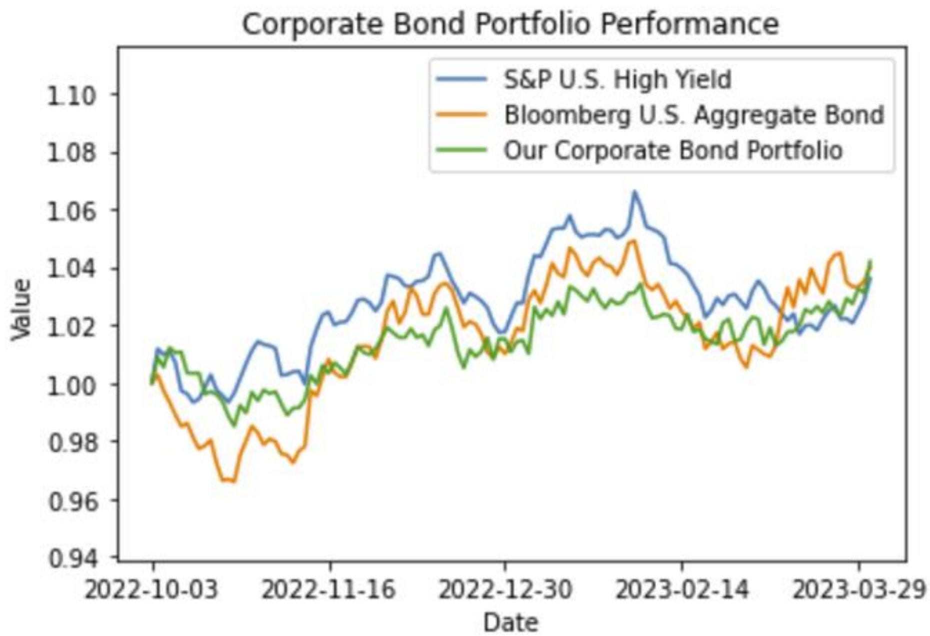
This is a surprising performance. In fact, this phenomenon is really easy to understand. Since 2023, the collapse of Silicon Valley Bank in the United States, as well as the liquidity crisis and credit crisis of a series of large banks in the US, these crises exactly pushed up the price of CDS, while the bond market has not performed well. Our out-of-sample test result is highly consistent with reality!

(4) Focus on bond portfolio and evaluate performance

We want to be fairer in evaluating the performance of our corporate bond portfolio, so we selected two bond indices to compare them with our portfolio's performance during the holding period. One index is the S&P U.S. High Yield Bond Index whose constituents are exclusively high yield bonds. Another index is the Bloomberg U.S. Aggregate Bond who consists of some investment grade bonds and some high yield bonds.

In this case we can ignore CDS and just focus on comparing the performance of bond portfolios.

As we can see in the picture, because of realizing duration neutrality to hedge market risk, our bond portfolio is more stable in its NAV during the holding period, with less volatility, and achieved higher return for the holding period.



(5) Conclusion of out-of-sample test

Overall, out-of-sample test outcomes of our performance are very good, whether for our corporate bond portfolio, or the CDS portfolio, or the mixed portfolio of bond and CDS packages.

Interest Rate Curve Construction

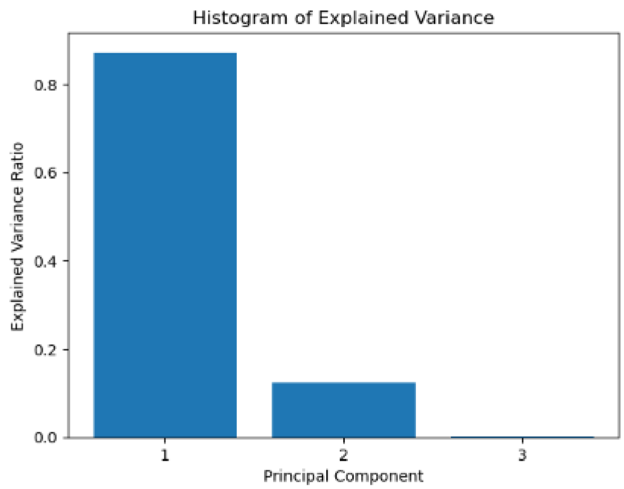
We utilized market data of swaps to estimate the current interest rate curve using the formula.

Treasury yield with similar maturity = Fixed interest rate + SOFR swap spread

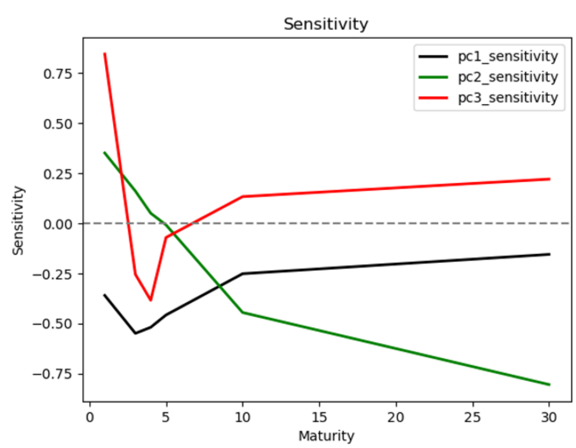
After we have an interest rate curve, we can construct scenarios of interest rate movements to perform risk analysis on our portfolio. We constructed four scenarios: parallel shifting (up and down), steepening, and flattening. Among these scenarios, steepening appears more likely in a context where the economy grows steadily and thus the difference between the yield of short-term interest and the long-term yield widens. During the time of recession or crisis, where investors seek shelters or expect low for the future, the demand for short-term treasury rises thus flattens the yield curve. We would like to see what our portfolio performs in these likely scenarios.

Principal Component Factor Hedging in Treasury Bonds

After interest rate curve estimation, our focus transforms to figure out how we can make treasury bond portfolios facing the existing market risk. For this problem, the project decides to refer to principal component analysis to hedge the risk. Principal component analysis is a popular technique for analyzing datasets containing a high number of features per observation, increasing the interpretability of data while preserving the maximum amount of information, and enabling the visualization of multidimensional data. In this problem, as we have treasury bond yield rate for different maturities on a given date, using PCA can help us find out main components explaining all the variances in different treasury bond yield rates. As a result, the project decides to focus on a 10-year data sample from 2010 to 2019 to find out the new factors, and the reason why 10 years is a suitable time range is that normally the economic span is about ten years, which can better explain the volatility in treasury bond yield rates. Based on the graph below, we can find that three principal components can explain 99.89% of the possible variance in treasury bond yields rates.



To better illustrate the relationship between principal components and treasury bond yield rate curve, the project aims at finding out the sensitivity of each component's exposure to different maturities' yield rate, which means the change in yield rates when factor changes one. To did this, we create a new dependent variable, which equals the matrix multiplication between the eigenvectors of the covariance matrix and the raw dataset. Then we regress three main components on the new dependent variable, the answer is just as followed:



Here we can find that the sensitivity of factor 1 is nearly constant for long-term maturity bonds across different times to maturity, which changes the yield curve equally over long-term bonds. The sensitivity of factor 2 is decreasing across maturities, and it will cause the short-term bond yield to increase and long-term bond yield to decrease. The sensitivity of factor 3 is U-shaped, which first decreases and then increases across maturities. It will lead a smaller change to medium-term bond yields than short- and long-term bond yields and change the yield curve less hump-shaped.

After that, everything has been prepared for creating a portfolio. Here we decide to use hedge factors to deal with market risk. There are four main steps in hedging risk. Firstly, the project uses principal component analysis on treasury bond yields to get three PCs based on data from 2013.10.01-2022.10.01 to get three main components and sensitivity of each component. Secondly, we decide to use 1-year,2-year,5-year,10-year,30-year treasury bonds to hedge the three principal components. For this step, we assume all treasury bonds we are going to invest are issued at par at 2022.10.01. Then we started to hedge the factors, by making the portfolio multiplication of sensitivity and modified duration equals 0. As we know, modified duration means how much the price of a bond will change when the yield to maturity of this bond changes 1 bp. If we let the multiplication equals zero, we can at least ensure the present value of bonds remains unchanged because three principal components can explain nearly 100% of volatility in yield curve. The mathematical expression is just as followed, we first short one 1-year bond and one 30-year bond:

$$\begin{matrix} sens(pc1,2_{year}) * MD\_2 & sens(pc2,2_{year}) * MD\_2 & sens(pc2,2_{year}) * MD\_2 \\ sens(pc1,5_{year}) * MD\_5 & sens(pc2,5_{year}) * MD\_5 & sens(pc3,5_{year}) * MD\_5 \\ sens(pc1,10_{year}) * MD\_10 & sens(pc2,10_{year}) * MD\_10 & sens(pc3,10_{year}) * MD\_10 \end{matrix} \qquad (1)$$

$$\begin{matrix} Q2 \\ Q5 \\ Q10 \end{matrix} \qquad (2)$$

$$\begin{matrix} sens(pc1,1_{year}) * MD_1 + sens(pc1,30_{year}) * MD_{30} \\ sens(pc2,1_{year}) * MD_1 + sens(pc2,30_{year}) * MD_{30} \\ sens(pc3,1_{year}) * MD_1 + sens(pc3,30_{year}) * MD_{30} \end{matrix} \qquad (3)$$

Our target is to let (1) * (2) + (3) = 0, then we can get the target quantity for each bond.

Thirdly, we calculate the present value of the portfolio on 2023.03.31, assuming the first coupon is paid on that day. Then annualized return can be calculated by holding period return regarding value of portfolio. Finally, we will create a new factor hedging portfolio on 2023.03.31, using the predicted interest rates and test different scenarios' return by making shifts to the interest rate. The result is as followed:

	1-YEAR	2-YEAR	5-YEAR	10-YEAR	30-YEAR	Annualized Return for 6-month
2022/10/1	-1	-3.63527	-0.47991	10.26784	-1	7.10%
2023/3/31	-1	-6.14761	1.246081	11.84394	-1	3.85%(predicted)

Quantity and Return table for two portfolios.

	6 month annualized return
predicted return (parallel up)	-18.03%
predicted return (parallel down)	19.93%
predicted return(steepening)	13.63%
predicted return(flattening)	7.52%

Scenario Tests

Conclusion and Limitation

In fact, during our test period between 2022.10.01 - 2023.03.31, The Federal Reserve increased the Federal Funds Rate twice, which really did harm to the bond market. What's more, accompanied with the collapse of SVB, the cost of CDS also increased a lot. However, we still got positive returns in such situations, which was beyond expectations.

Nevertheless, the project has some limitations. Firstly, we did not take transaction fees and liquidity risk into consideration which is a commonly faced question. Secondly, the availability of shorting both the corporate bonds and rate securities is also challenged.