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ORF 535 – Fall 2017

Financial Risk Management

Project Part 2 Report

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<u>Abstract</u>

In this report, we combine the two parts of the final project for Financial Risk Management.

For Part 1 of the term project for Financial Risk Management, I will discuss each given question (research topic) by suggesting recommendations about their experimentation (wherever appropriate and applicable), followed by a quick summary of their goals and briefly explain the methodologies applied to analyze them. I will then report and summarily describe the empirical results obtained from each experiment. Lastly in the appendix, I will provide detailed analysis and supporting discussion for each of the research experiments. Finally, wherever applicable, I will compare across the different variants of experiments conducted and how their analyses could be improved from a robust risk management standpoint.

The research questions for Part 2 of the project will all be answered within the appendix of this report, while empirical observations and results will be attached following the results of Part 1.

For Part 2 of the term project for Financial Risk Management, we look at the returns of the more volatile and higher returning government bonds (compared with AGG) and see if our bank strategy's risk adjusted performance could be improved by adding them. We follow that by looking at a famous property casualty re-insurance company's (Renaissance Re-Insurance) returns and having looked at its internal enterprise risk management system that dictates its asset allocation strategies, see how it has performed relative to our bank. We try to answer questions of combining its cash flow streams into our bank's strategy. Finally, in an independent research question, we take a deeper dive into the topic of **goal-based investing** and **robo-advisors**, and try to answer some critical questions about how to use them effectively and what their use means to the macro-economy.

<u>Arbitrage</u>

Goal of the research experiment: Calculation of spot and 1-year forward prices for 10 securities (4 currencies, 1 commodity (gold), 4 government bills and 1 equity).

Methodologies Applied:
    (a) <u>Spot Price Calculation</u> – Interconvert using given conversion rates across different securities, and using transitive nature of relationship to convert across those securities whose relationships weren't explicitly given. Furthermore, used the fact that there is a unit spot conversion factor between the same securities. Represented the spots as a 10x10 matrix with each index corresponding to one security (e.g. index 0 corresponded to USD, index 9 corresponded to S&P 500, etc.).
    E.g. of transitive relation: SecurityA_to_SecurityC = SecurityA_to_SecurityB * SecurityB_to_SecurityC.

    (b) <u>Forward Price Calculation</u> – Spot Currency rates were used along with interest rates to calculate currency foreign exchange forward rates. S&P 500 spot price was used along with present liability (via dividends) and combined with USD's interest rate to provide a forward value. Gold spot price was discounted with holding cost for the year to calculate the 1-year forward. Government bills were discounted with their corresponding currencies' risk-free interest rate. Similar to Spot Price calculations, there was a unit forward conversion factor between the same securities. Finally, transitive relationships were used to calculate forwards between the other inexplicitly related securities. Represented the forwards as a 10x10 matrix with each index corresponding to one security (same as Spot Price).

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Research Goals:
- Calculate spot price across 10 different securities belonging to different asset classes
- Calculate 1-year forward price across 10 securities belonging to different asset classes
- Apply No Arbitrage Theorem to determine spot and forward values

Empirical Results: The following is the calculated Spot Prices and Forward Prices represented as individual 10x10 matrices.
(*Notation* – Index0: USD, Index1: GBP, Index2: EU, Index3: RMB, Index4: Gold, Index5: U.S. Government Bill, Index6: German Government Bill, Index7: U.K. Government Bill, Index8: Chinese Government Bill, Index9: S&P 500)

Spot Price Matrix -

[[1.00000000e+00 7.46937556e-01 8.44309355e-01 6.58000000e+00
   7.91765637e-04 1.00000000e+00 8.44309355e-01 7.46937556e-01
   6.58000000e+00 3.74293521e-03]
 [1.33880000e+00 1.00000000e+00 1.13036136e+00 8.80930400e+00
   1.06001584e-03 1.33880000e+00 1.13036136e+00 1.00000000e+00
   8.80930400e+00 5.01104166e-03]
 [1.18440000e+00 8.84672841e-01 1.00000000e+00 7.79335200e+00
   9.37767221e-04 1.18440000e+00 1.00000000e+00 8.84672841e-01
   7.79335200e+00 4.43313246e-03]
 [1.51975684e-01 1.13516346e-01 1.28314492e-01 1.00000000e+00
   1.20329124e-04 1.51975684e-01 1.28314492e-01 1.13516346e-01
   1.00000000e+00 5.68835138e-04]
 [1.26300000e+03 9.43382133e+02 1.06636272e+03 8.31054000e+03
   1.00000000e+00 1.26300000e+03 1.06636272e+03 9.43382133e+02
   8.31054000e+03 4.72732717e+00]
 [1.00000000e+00 7.46937556e-01 8.44309355e-01 6.58000000e+00
   7.91765637e-04 1.00000000e+00 8.44309355e-01 7.46937556e-01
   6.58000000e+00 3.74293521e-03]
 [1.18440000e+00 8.84672841e-01 1.00000000e+00 7.79335200e+00
   9.37767221e-04 1.18440000e+00 1.00000000e+00 8.84672841e-01
   7.79335200e+00 4.43313246e-03]
 [1.33880000e+00 1.00000000e+00 1.13036136e+00 8.80930400e+00
   1.06001584e-03 1.33880000e+00 1.13036136e+00 1.00000000e+00
   8.80930400e+00 5.01104166e-03]
 [1.51975684e-01 1.13516346e-01 1.28314492e-01 1.00000000e+00
   1.20329124e-04 1.51975684e-01 1.28314492e-01 1.13516346e-01

4

```
  1.00000000e+00  5.68835138e-04]
[ 2.67170000e+02  1.99559307e+02  2.25574130e+02  1.75797860e+03
  2.11536025e-01  2.67170000e+02  2.25574130e+02  1.99559307e+02
  1.75797860e+03  1.00000000e+00]]
```

Forward Price Matrix -

```
[[ 1.00000000e+00  7.39788770e-01  8.26315194e-01  6.51702417e+00
   7.54062512e-04  9.86679822e-01  8.33063004e-01  7.36988215e-01
   6.49235323e+00  3.76043292e-03]
 [ 1.35173720e+00  1.00000000e+00  1.11696099e+00  8.80930400e+00
   1.01929435e-03  1.33373182e+00  1.12608225e+00  9.96214385e-01
   8.77595537e+00  5.08311706e-03]
 [ 1.21019195e+00  8.95286418e-01  1.00000000e+00  7.88685022e+00
   9.12560385e-04  1.19407198e+00  1.00816615e+00  8.91897209e-01
   7.85699365e+00  4.55084567e-03]
 [ 1.53444267e-01  1.13516346e-01  1.26793330e-01  1.00000000e+00
   1.15706570e-04  1.51400363e-01  1.27828742e-01  1.13086617e-01
   9.96214385e-01  5.77016875e-04]
 [ 1.32615000e+03  9.81070878e+02  1.09581789e+03  8.64255161e+03
   1.00000000e+00  1.30848545e+03  1.10476650e+03  9.77356921e+02
   8.60983424e+03  4.98689812e+00]
 [ 1.01350000e+00  7.49775919e-01  8.37470449e-01  6.60500400e+00
   7.64242356e-04  1.00000000e+00  8.44309355e-01  7.46937556e-01
   6.58000000e+00  3.81119877e-03]
 [ 1.20038940e+00  8.88034598e-01  9.91900000e-01  7.82296674e+00
   9.05168646e-04  1.18440000e+00  1.00000000e+00  8.84672841e-01
   7.79335200e+00  4.51398382e-03]
 [ 1.35687380e+00  1.00380000e+00  1.12120544e+00  8.84277936e+00
   1.02316767e-03  1.33880000e+00  1.13036136e+00  1.00000000e+00
   8.80930400e+00  5.10243291e-03]
 [ 1.54027356e-01  1.13947708e-01  1.27275144e-01  1.00380000e+00
   1.16146255e-04  1.51975684e-01  1.28314492e-01  1.13516346e-01
   1.00000000e+00  5.79209539e-04]
 [ 2.65926828e+02  1.96729681e+02  2.19739379e+02  1.73305157e+03
   2.00525452e-01  2.62384636e+02  2.21533803e+02  1.95984939e+02
   1.72649090e+03  1.00000000e+00]]
```

Static Strategy Simulation of A Synthetic Bank

Recommendations:
- Decision variable must be able to be varied based on spread
- Include more volatile asset classes for investments

Goals of the research experiment:
- Simulate various long/short and investment portfolio of a synthetic bank in different scenarios to calculate risk/rewards for each
- Optimize over decision variable (leverage factor) and/or weighted investments over different securities

Methodologies Applied:
(a) <u>Decision variable y = 2</u> – For each month long 2 * capital (borrow) and short (2 * capital) in AGG bonds and T-Bills, respectively and invest the rest in T-Bills to calculate capital returns each month, and then calculate risk/reward metrics.
(b) <u>Optimization over only Decision variable 'y'</u> – Similar to above except perform a grid search over different values of y over a range (0 to 5 spaced at regular intervals) and brute-forcedly check for CVaR <= $200 Million and no red flags. Finally pick the 'y' that yields the best return.
(c) <u>Optimization over only Decision variable 'y' and weights over 3 securities</u> – Similar to (b) except introduce 3 weight variables all adding upto 1 spaced at regular intervals, and in conjunction with possible 'y' values perform a grid search over red flag constraints and pick the best returning portfolio.

Empirical Results and Observations:
(a) <u>Decision variable y = 2</u> –

        Number of red cards = 0
        Number of yellow cards = 152
        Number of inverted yields = 134
        Annual geometric return (R) = 0.489173
        Annualized volatility = 0.069215
        Risk Free rate of return = 1.749596
        Sharpe Ratio = -4.790879
        Annualized downside variance = 0.068448

Sortino Ratio = -4.817674
Maximum DrawDown = 1309164328.331643
VaR = 70511.956637
CVaR = 65382.811719

Adding U.S. government bond fund TLT in the following two stages:
- (i)   Replacing AGG index
- (ii)   Adding with AGG index

(i)   Replacing AGG index with TLT –

Number of red cards = 0
Number of yellow cards = 151
Number of inverted yields = 124
Annual geometric return (R) = 0.496933
Annualized volatility = 0.125894
Risk Free rate of return = 1.749596
Sharpe Ratio = -3.530468
Annualized downside variance = 0.086849
Sortino Ratio = -4.250614
Maximum DrawDown = 1320845006.565898
VaR = 84789.254071
CVaR = 81393.424035

(ii)   Adding TLT with AGG index –

Number of red cards = 0
Number of yellow cards = 151
Number of inverted yields = 0
Annual geometric return (R) = 0.495467
Annualized volatility = 0.087905
Risk Free rate of return = 1.749596
Sharpe Ratio = -4.229949
Annualized downside variance = 0.076062
Sortino Ratio = -4.547346
Maximum DrawDown = 1314999939.561593
VaR = 82784.721117

CVaR = 78116.005055

Finally, adding RNR as a long asset to the bank strategy –

Number of red cards = 0
Number of yellow cards = 152
Number of inverted yields = 0
Annual geometric return (R) = 0.498660
Annualized volatility = 0.085384
Risk Free rate of return = 1.749596
Sharpe Ratio = -4.281011
Annualized downside variance = 0.083602
Sortino Ratio = -4.326404
Maximum DrawDown = 1317088719.087593
VaR = 100895.147233
CVaR = 85420.818573

(b) Optimization over only Decision variable 'y' –

Value of optimized decision variable (y) = 1.151151
Number of red cards = 0
Number of yellow cards = 119
Number of inverted yields = 134
Annual geometric return (R) = 0.877546
Annualized volatility = 0.005517
Risk Free rate of return = 1.749596
Sharpe Ratio = -11.740267
Annualized downside variance = 0.005466
Sortino Ratio = -11.795077
Maximum DrawDown = 1173949859.579548
VaR = 199172765.912113
CVaR = 194300775.372668

Adding U.S. government bond fund TLT in the following two stages:
- (i) Replacing AGG index
- (ii) Adding with AGG index

(i)   Replacing AGG index with TLT –

Value of optimized decision variable (y) = 1.156156
Number of red cards = 0
Number of yellow cards = 63
Number of inverted yields = 124
Annual geometric return (R) = 0.888421
Annualized volatility = 0.024155
Risk Free rate of return = 1.749596
Sharpe Ratio = -5.541046
Annualized downside variance = 0.016006
Sortino Ratio = -6.806980
Maximum DrawDown = 1179278621.266002
VaR = 195433413.898147
CVaR = 195385612.364512

(ii)   Adding TLT with AGG index –

Value of optimized decision variable (y) = 0.580581
Number of red cards = 0
Number of yellow cards = 110
Number of inverted yields = 0
Annual geometric return (R) = 0.880120
Annualized volatility = 0.011905
Risk Free rate of return = 1.749596
Sharpe Ratio = -7.968857
Annualized downside variance = 0.010112
Sortino Ratio = -8.646333
Maximum DrawDown = 1182811398.389470
VaR = 192625939.894718
CVaR = 188138670.303443

Finally, adding RNR as a long asset to the bank strategy –

Value of optimized decision variable (y) = 0.570571
Number of red cards = 0
Number of yellow cards = 59
Number of inverted yields = 0
Annual geometric return (R) = 0.894994
Annualized volatility = 0.009576
Risk Free rate of return = 1.749596
Sharpe Ratio = -8.733301
Annualized downside variance = 0.009434
Sortino Ratio = -8.798631
Maximum DrawDown = 1178310061.926081
VaR = 198010379.215973
CVaR = 195169431.738196

(iii)   Optimization over only Decision variable 'y' and weights over 3 securities
        –

Value of optimized decision variable (y) = 0.050505
Value of optimized weight variable for SP500 = 0.100000
Value of optimized weight variable for AGG = 0.100000
Value of optimized weight variable for TBill = 0.800000
Number of red cards = 0
Number of yellow cards = 0
Number of inverted yields = 134
Annual geometric return (R) = 1.555360
Annualized volatility = 0.021274
Risk Free rate of return = 1.749596
Sharpe Ratio = -1.331700
Annualized downside variance = 0.004787
Sortino Ratio = -2.807358
Maximum DrawDown = 4048618922.568420
VaR = 1431918291.274914
CVaR = 1371246808.793591

Adding U.S. government bond fund TLT in the following two stages:
  (i)   Replacing AGG index
  (ii)   Adding with AGG index

(i)   Replacing AGG index with TLT –

Value of optimized decision variable (y) = 0.050505
Value of optimized weight variable for SP500 = 0.100000
Value of optimized weight variable for AGG = 0.100000
Value of optimized weight variable for TBill = 0.800000
Number of red cards = 0
Number of yellow cards = 0
Number of inverted yields = 124
Annual geometric return (R) = 1.556953
Annualized volatility = 0.021234
Risk Free rate of return = 1.749596
Sharpe Ratio = -1.322029
Annualized downside variance = 0.004756
Sortino Ratio = -2.793479
Maximum DrawDown = 3968324381.254517
VaR = 1432197949.507238
CVaR = 1371246808.793591

(ii)   Adding TLT with AGG index –

Value of optimized decision variable (y) = 0.050505
Value of optimized weight variable for SP500 = 0.100000
Value of optimized weight variable for AGG = 0.100000
Value of optimized weight variable for TBill = 0.800000
Number of red cards = 0
Number of yellow cards = 0
Number of inverted yields = 0
Annual geometric return (R) = 1.517104
Annualized volatility = 0.018487
Risk Free rate of return = 1.749596
Sharpe Ratio = -1.709925
Annualized downside variance = 0.004725

Sortino Ratio = -3.382358
Maximum DrawDown = 2887653446.490692
VaR = 1428873112.914362
CVaR = 1371246808.793591

Finally, adding RNR as a long asset to the bank strategy –

Value of optimized decision variable (y) = 0.050505
Value of optimized weight variable for SP500 = 0.100000
Value of optimized weight variable for AGG = 0.100000
Value of optimized weight variable for TBill = 0.800000
Number of red cards = 0
Number of yellow cards = 0
Number of inverted yields = 0
Annual geometric return (R) = 1.517602
Annualized volatility = 0.018482
Risk Free rate of return = 1.749596
Sharpe Ratio = -1.706480
Annualized downside variance = 0.004742
Sortino Ratio = -3.368848
Maximum DrawDown = 3138075755.616119
VaR = 1428973344.227493
CVaR = 1371246808.793591

Observations:
- For highest annualized returns, optimization over weighed securities (S&P 500, AGG, T-Bills) combined with levered long-short portfolio is the best option
- Sharpe Ratio and Sortino Ratio was the highest for the above portfolio (also lowest volatility and downside variance)
- Last portfolio is the best capitalized (no yellow cards) but also very high VaR/CVaR

- Lowest Maximum Draw Down (MDD) for optimization of leverage factor achieved along with moderate annualized returns and Sharpe and Sortino Ratios
- For minimizing VaR/CVar, static leverage factor = 2 is the best portfolio
- Last portfolio produces the best overall returns, lowest volatility but highest MDD
- First portfolio is the worst capitalized, also leading to low VaR/CVaR – meaning it's not necessarily that helpful from a bank investment point of view
- Diversifying investments and reducing leverage is clearly preferable
- Adding TLT by replacing it with AGG increases the volatility by at least one order or magnitude while barely increasing returns and having no useful effect on risk-adjusted performance
- Adding TLT with AGG has the desired effect of bringing the volatility down to the levels of AGG with modest increase in returns
- Optimized over the decision variable 'γ' yields higher risk-adjusted performance by adding TLT, while volatility is increased by an order of magnitude or two
- Optimized over decision variable 'γ' and weighted securities SP500, AGG and T-Bills, we see that adding TLT to the bank strategy actually diminishes performance in terms of both risk-adjusted performance and returns when AGG and TLT are long assets, while replacing TLT with AGG leads to very little in risk-adjusted performance and returns
- Adding TLT increases the bank's VaR/CVaR numbers
- Adding RNR's cash flow to the bank strategy is generally rewarded with better risk-adjusted performance with volatility within the same range as without it
- With 3 optimized weighted asset classes and decision variable 'γ', combining RNR returns with our banking strategy yields worse performance, risk-adjusted or otherwise
- Adding RNR's cash flow to the bank increases the bank's VaR/CVaR numbers

Dynamic Strategy Simulation of A Synthetic Bank

Recommendations:
- Dynamic decision variable for leverage should be combined with investments over different asset classes instead of stable T-Bill to introduce diversity to investments

Goals of the research experiment:
- Dynamically change the decision variable for leverage based on spread (long returns – short liabilities) and see if a dynamic leverage outperforms the best static portfolio

Methodologies Applied:
- Similar to Static Simulation except that 'y' changes each month based on if the spread is positive or negative.
- If spread is positive, then y = 4 (expectation is that it is expected to continue so lever more)
- If spread is negative, change 'y' based on the ratio between asset returns and shorted liabilities, and leverage should be < 1.

Empirical Results and Observations:

       Number of red cards = 0
       Number of yellow cards = 0
       Number of inverted yields = 134
       Annual geometric return (R) = 1.588064
       Annualized volatility = 0.036052
       Risk Free rate of return = 1.749596
       Sharpe Ratio = -0.850736
       Annualized downside variance = 0.010104
       Sortino Ratio = -1.606981
       Maximum DrawDown = 79653527554.717957
       VaR = 1371246808.793591
       CVaR = 1309229711.143363

Adding U.S. government bond fund TLT in the following two stages:

(i)   Replacing AGG index
(ii)   Adding with AGG index

(i)   Replacing AGG index with TLT –

       Number of red cards = 0
       Number of yellow cards = 0
       Number of inverted yields = 124
       Annual geometric return (R) = 1.528455
       Annualized volatility = 0.155330
       Risk Free rate of return = 1.749596
       Sharpe Ratio = -0.561102
       Annualized downside variance = 0.064721
       Sortino Ratio = -0.869253
       Maximum DrawDown = 352744770872.994507
       VaR = 1371246808.793591
       CVaR = 1320926399.989934

(ii)   Adding TLT with AGG index –

       Number of red cards = 16

Number of yellow cards = 148
Number of inverted yields = 0
Annual geometric return (R) = 0.001252
Annualized volatility = 2.958254
Risk Free rate of return = 1.749596
Sharpe Ratio = -1.016504
Annualized downside variance = 2.525512
Sortino Ratio = -1.100151
Maximum DrawDown = 1315078055.580083
VaR = -0.000884
CVaR = -0.013435

Finally, adding RNR as a long asset to the bank strategy –

Number of red cards = 0
Number of yellow cards = 158
Number of inverted yields = 0
Annual geometric return (R) = 0.223541
Annualized volatility = 0.279096
Risk Free rate of return = 1.749596
Sharpe Ratio = -2.888640
Annualized downside variance = 0.268301
Sortino Ratio = -2.946177
Maximum DrawDown = 1317174138.697401
VaR = 1.647456
CVaR = 1.208766

Observations:
- Clearly preferable over static strategy (High Sharpe/Sortino Ratios, high returns but higher volatility)
- Well capitalized to simulate banking liabilities (no yellow cards)
- CVaR decreased compared to best performing static strategy
- Extremely high MDD
- With dynamic strategy, adding TLT yields increased volatility by one or more orders of magnitude

- Substituting AGG with TLT yields better capitalization (zero red cards and zero yellow cards) than going long on both TLT and AGG, which dramatically lowers the bank's capital as evidenced by negative VaR/CVaR numbers
- Substituting AGG with TLT still underperforms the bank's original dynamic strategy (only going long on AGG) in terms of annualized returns while performing relatively better in risk-adjusted performance
- Adding RNR's cash flows to the bank's dynamic strategy leads to lower risk-adjusted performance, diminishes returns and leads to increased volatility
- RNR also leads to lower capitalization of the bank (evidenced by the number of yellow cards) and lower VaR/CVaR numbers

Comparison with Commercial Banks

Recommendations:
- A significant portion of the period was during the recession, and commercial banks (especially Citi) had very high exposure to toxic assets, so the time frame could be properly weighed for normal vs crash vs growth scenarios

Goals of the research experiment:
- Compare returns of two commercial banks (Citi and BOA) over a 14-year span with the best strategy of our simulated bank

Methodologies Applied:
- Calculate monthly returns based on the monthly price information given for each bank – BOA and Citi
- Starting with capital of $1.3 Billion, and with the calculated monthly returns, simulate how much that capital would have yielded each month for both banks
- Calculate usual risk/reward measures and compare with our best static and dynamic strategies

Empirical Results and Observations:
(a) <u>BOA</u> –

> Number of red cards = 0
> Number of yellow cards = 0
> Annual geometric return (R) = 0.997562
> Annualized volatility = 0.004707
> Risk Free rate of return = 1.749596
> Sharpe Ratio = -10.961316
> Annualized downside variance = 0.004354
> Sortino Ratio = -11.396615
> Maximum DrawDown = 515683891.247933
> VaR = 990406457.020483
> CVaR = 979467126.455483

(b) <u>Citi</u> –

Number of red cards = 0
Number of yellow cards = 122
Annual geometric return (R) = 0.647956
Annualized volatility = 0.288612
Risk Free rate of return = 1.749596
Sharpe Ratio = -2.050609
Annualized downside variance = 0.210363
Sortino Ratio = -2.401901
Maximum DrawDown = 2256595550.869646
VaR = 1961767.656650
CVaR = 1848801.540885

Observations:
- Citi was not very well-capitalized during this period (122 yellow cards) and had higher volatility than BOA
- Citi also suffered a high MDD compared to BOA
- BOA performed better on average than Citi, but still lagged behind both best performing static and dynamic strategies of our simulated bank
- BOA was relatively stable with very low volatility during this period

Appendix

Salient Points from Observations:
- Dynamic strategy was clearly the best performing strategy for our bank model
- Both dynamic strategy and best static strategy (diversified investments with static leverage factor) beat out both commercial banks in terms of annualized returns
- Sharpe and Sortino Ratios were negative since none of the strategies (or commercial banks) were able to beat risk-free rate of return
- Dynamicity and diversification led to better capitalization and no yellow cards. On the contrary, static strategies without diversification led to extremely high chances of getting a yellow card
- AGG bonds being stable and less volatile (to cancel out shorted T-Bills which are also stable and less volatile) led to capital growth under the risk-free rate
- With more volatile security to long we would potentially see more capital growth (to beat risk-free rate), therefore to simulate a real bank, we should hold more assets that are more risk-rewarding in nature
- The most volatile security (S&P 500) was only weighed for 10% of the portfolio along with relatively stable T-Bills and AGG bonds, which implied that our annualized returns weren't boosted with high performing stocks as much as we would've liked
- Our simulated bank strategies (dynamic and best static) clearly outperformed both commercial banks – BOA and Citi. This could've been due to the period in time in which those banks' returns were considered, having been during a recession
- Therefore, the we should go short on Citi and go long on our dynamic strategy

Limitations of the Previous Analysis (and steps to provide robust recommendations):

- _Tail Risk Measures Not Considered_ – The objective was to maximize returns but we didn't minimize (from portfolio theory) risk measures such as VaR/CVaR/variance. Thus, our CVaRs were high for higher returning strategies. We should take tail risk into consideration while testing out robust strategies.
- _Behavior under different scenarios of different regimes not considered (Modeling Uncertainty)_ – We didn't simulate probabilistically determined behavior under multiple regimes, which should be essential to stress test a bank's capital returns and retention.
- _Asset Liability Management not considered_ – We did not consider the dynamic cash outflows that occur in each period and the liabilities that accumulate due to them to manage our bank's strategy.

Improving Bank Synthetic Model with Addition of Government Bond (TLT):

(a) Does TLT improve performance (plus recommendations)?
- Marginal improvement of annualized returns with substantial increase in volatility
- Marginally improved risk-adjusted performance (higher Sharpe and Sortino ratios)
- Better capitalization of the bank (lower yellow cards)
- Replacing AGG with TLT as the bank's long only asset provides better performance than combining AGG with TLT, meaning higher returning government bonds are more useful to manage cash inflows of banks than lesser returning, more stable government/corporate bond index AGG
- When combining asset-liability with additional investment in 3 asset categories SP500, T-Bill and AGG, due to the more volatile SP500 and TLT, the risk-adjusted performance begins to wear off. Thus, the best strategy would be to go long TLT optimized over the decision variable 'y' (how much to borrow)
- Dynamic strategy simulation dramatically underperforms when TLT is combined with AGG, whereas it performs relatively well for risk-adjusted returns (albeit lower annualized returns) when TLT replaces AGG for bank's asset. For the former, bank's capitalization is uncharacteristically low and should never be pursued
- Therefore, AGG replaced with TLT without investing excess capital in other volatile assets is the best strategy for our synthetic bank

(b) Possible implementation issues with TLT?
- Increase in volatility by one or more orders of magnitude
- Combining TLT with AGG to increase asset base is not helpful due to their conflicting natures (lower returns with more stability vs higher returns with greater volatility), thus only one class of bond index should be used within a bank's strategy
- Government bonds were relatively stable than corporate bonds during the recession period, which formed a large chunk of time from January 2004 – December 2017. In fact, it was this "flight to quality" nature that was reinforced by better risk-adjusted performance despite the volatility. During periods of growth however, we possibly wouldn't see such a clear-cut recommendation of preferring one bond index over the other and

therefore, hedging between them would be more sensible. In our implementation, we did not consider that situation. Would be great to stochastically simulate under different regimes and dynamically determine which bond to hold and which to not

- Higher values of VaR/CVaR with higher on-average capitalization when combining TLT to our bank implies greater propensity for tail risk

Pranjit K. Kalita

Property Causality Re-Insurance and its effect on our Banking Strategy:

(a) *Renaissance Re-Insurance Geo-Returns and Risk Measures from 1995 – 2017 (code attached at end of report):*

> Monthly geometric return (R) = 1.004073
> Annual geometric return (R) = 1.049986
> Annualized volatility = 0.008953
> Risk Free rate of return = 1.749596
> Sharpe Ratio = -7.393667
> Annualized downside variance = 0.007850
> Sortino Ratio = -7.896027
> Maximum DrawDown = 1043206307.043322
> VaR = 1308405579.084720
> CVaR = 1303085661.234046

(b) *Does RNR help with diversification?*
  - Yes, RNR when combined with AGG bond index yields (depending on whether using leverage of 2 or optimized leverage) leads to better performance (albeit modestly) for both annualized as well as risk-adjusted returns
  - However, RNR does not help when already combined with investing excess monthly capital in 3 asset classes – SP500, T-Bill, AGG
  - For dynamic strategy simulation of bank, RNR yields extremely low annualized returns, and lower Sharpe and Sortino ratios while increasing volatility. The number of yellow cards is a staggering 158 out of 168 months meaning very low capitalization of the bank

(c) *What is the best combination of the synthetic bank and RNR in terms of risk-adjusted performance?*
  - Highest Sharpe Ratio/Sortino Ratio was obtained when optimized over weighted combination of 3 asset classes – SP500, T-Bill, AGG and leverage decision variable. Obtained Sharpe Ratio = -1.7, Sortino Ratio = -3.4.
  - Sortino Ratio for Dynamic Strategy case was the highest (-2.94) but the dismal performance of annualized returns (~-0.78%) along with extremely low capitalization of the bank (158 yellow cards of 168 months) leading to low VaR/CVaR means that this is not a viable strategy to use

Asset and Liability Management for Individuals:

(a) *Pros and Cons of a Fully Integrated ALM system for an individual vs. a sequence of goal based ALM systems for separate goals-*
  (i)   Pros-
        1. Better real-world modeling since cash flows are interconnected among different goals and this increases the robustness and dynamicity of the system
        2. In terms of system design, due to the lower level of granularity, the amount of possible assumptions possibly lower and hence more beneficial from a risk-management standpoint
        3. Higher dynamicity leads to better preparedness in situations when an unexpected event occurs since the system will be calibrated to that unexpected event probabilistically
        4. From the point of view of the individual, easier to use since only one source of input/output and less overhead in managing different ALM systems

  (ii) Cons-
        1. Some of the liabilities to which the system is calibrated to might not be useful for certain individuals (For example: A business person may not necessarily care about "retirement" savings since their business' ERM system could very well dictate how they do financially)
        2. Certain individuals might have more "exotic" goals in which case it might make sense to have an individual goal-based ALM system (For example: Should I invest in a wine business from my personal savings and if yes, how do I manage risk based on the introduction of an unknown variety of grape to a particular region and how do I quantify those risks – the point is that certain liabilities and risks are non-quantifiable at least within the confines of a known ALM system)
        3. When the number of conflicting goals are less, then individual ALM systems might be more sensible

(b) *Macro-economic impacts of Noticeable Increase in Savings per Individual-*
- Entertainment and tourism industries will be noticeably shrunken
- An economy will suffer from lower GDP (and as a consequence, lower GDP growth) since consumption and spending are essential aspects of any vibrant economy
- Real assets (real estate, private equity) will dwindle in value since investments in them will go down along with lesser consumer activity
- The consumer industry (and perhaps the economy itself) will undergo a recession, which is connected to the original premise of lower expected stocks and bond returns
- The central banks will lower interest rates to foster more economic activity and loans will be more easily available, leading to greater investments in safe assets such as gold and T-bills
- The financial markets will be noticeably affected with this relative lack of liquidity within the economy
- I believe that with depression of the consumer market industry within a capitalistic economy like the United States, the propensity of individuals to take risk will decrease, followed by or even fostered by a lack of competition among individuals and corporations, which would lead to a depressed economy in the long run. The point is that a vibrant middle class is very essential for any nation's future growth.

(c)
1. *Should robo-advisors be regulated?*

    Not in their current forms since it is hard to see where to impose fiduciary responsibilities on them as it relates to both individuals and corporations. They do not actively manage wealth, but are rather just tools that optimize over the provided (sometimes possibly wrong) inputs, with probabilistic discounting of asset classes over time. I do not believe that robo-advisors should be held accountable for not being able to spot macro-economic trends which would render calibrating returns of certain asset categories over time meaningless. They should instead be made more technologically sound over time by using some of their forecasting failures to reinforce back into their systems to continually improve with time. Regulating them by penalizing would demoralize their continued development. Furthermore, regulations tend to for the most part (there are always

exceptions) hamper creativity especially in technology, and I view robo-advisors in their current forms as being primarily a technology product, and hence just like I wouldn't want data analytics and Google to be regulated, the same argument would apply for robo-advisors too.

2. *Issues to address w.r.t estimation of expected returns of assets* –
- Risk of Inflation
- Tax Increase/Decrease (individual, corporate, property)
- Income Disparity and Wealth Disparity
- Trajectory of economy (developing vs. developed vs. poor, manufacturing vs. agrarian vs. service-oriented)
- Emerging technologies (fossil fuel vs. renewable/clean)
- Technology (growth in GDP while lowering median income – majority of assets today owned by corporations and wealthy individuals in the U.S.)