10/19/2018

IE 523

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Midterm Prog: Fixed Income Portfolio Optimizer

Please note: the majority of my comments and explanations for the code can be found in the bondportfolio.cpp file. Users should quickly be able to understand what is happening, as the explanations and naming conventions are logical and efficient. The purpose of this write-up is to highlight a few things that I want to explain about my code, as well as show sample outputs.

Due to my background in finance, the major change that I wanted to point out is the naming convention of the variables and function. Since we're building *Portfolio Optimization Software,* I changed the perspective of the variables/functions from a debt obligation perspective to a fixed income portfolio perspective. So the time that the debt obligation is due is known as the "investment horizon" and the debt obligation amount is "investment amount" and so on.

For investment strategy, we're trying to find the optimal portfolio of bonds to meet our investment requirements. These requirements are that the solution value must equal the PV of the debt, and that the solution duration = our investment horizon. Rather than using the -minimize for the LP, I called the setmaxim(lp) function, which maximizes the function of the LP and with set_obj_fn(lp, row), the LP's objective is to find the optimal portfolio allocation with largest convexity and meets our other constraints defined above.

I used two of the given input files, inputs 3 and 2 (shown below) to verify that I was getting the same output. Note that the input2 file could not find an optimal portfolio to meet the investment requirements (constraints), and so it correctly outputs that no optimal portfolio could be found.

Lastly, I created my own file, called *bonds1* to test my portfolio optimizer. I really wanted to push it to the limits, so I used bonds that do occur in real life, but they are unconventional in nature (such as bonds that do not pay coupon payments for the first 5 years, with the first coupon beginning at the 6^{th} year). I also tried bonds that have varying coupon payments (32.5 65 32.5 65, etc…) and finally, the extremely rare (but very interesting) bonds that begin with a par value different from the standard "$1,000." Take a look at the input file *bonds1* to see these unique bond types.

```
C:\Users\jloss\source\repos\ConsoleApplication3\Debug>bondportfolio.exe input3
Input File: input3

We want to invest 1790.85 over 10 years
Number of Bonds: 3
-----------------------------------------------------
Bond #1
Current Price = 1051.52
Maturity = 10
Percentage of Face Value that would meet investment requirements = 0.951007
Yield to Maturity = 0.0600001
Duration = 7.6655
Duration (to be used in LP-formulation below) = 8.0604
(Note) 7.6655 = 8.0604 x 0.951007
Convexity = 67.9958
Convexity (to be used in LP-formulation below) = 71.4987
(Note) 67.9958 = 71.4987 x 0.951007
-----------------------------------------------------
Bond #2
Current Price = 1095.96
Maturity = 15
Percentage of Face Value that would meet investment requirements = 0.912445
Yield to Maturity = 0.0599997
Duration = 10
Duration (to be used in LP-formulation below) = 10.9596
(Note) 10 = 10.9596 x 0.912445
Convexity = 121.484
Convexity (to be used in LP-formulation below) = 133.142
(Note) 121.484 = 133.142 x 0.912445
-----------------------------------------------------
Bond #3
Current Price = 986.24
Maturity = 30
Percentage of Face Value that would meet investment requirements = 1.01396
Yield to Maturity = 0.0599996
Duration = 14.6361
Duration (to be used in LP-formulation below) = 14.4347
(Note) 14.6361 = 14.4347 x 1.01396
Convexity = 296.143
Convexity (to be used in LP-formulation below) = 292.067
(Note) 296.143 = 292.067 x 1.01396
-----------------------------------------------------
Average YTM (to compute PV of debt) = 0.0599998
Present value of debt = 1000
-----------------------------------------------------
Model name:
                C1       C2       C3
Maximize   71.4987  133.142  292.067
R1         1051.52  1095.96   986.24  =     1000
R2          8.0604  10.9596  14.4347  =       10
Type          Real     Real     Real
upbo           Inf      Inf      Inf
lowbo            0        0        0
Largest convexity we can get is: 144.404

Optimal portfolio (%):
Bond 1: 0.632508
Bond 2: 0
Bond 3: 0.339581

To create optimal portfolio: BUY
$665.095 of Bond 1
$334.908 of Bond 3


Press any key to continue . . .
```

```
C:\Users\jloss\source\repos\ConsoleApplication3\Debug>bondportfolio.exe input2
Input File: input2

We want to invest 1790.85 over 10 years
Number of Bonds: 3
-----------------------------------------------------
Bond #1
Current Price = 1131.27
Maturity = 10
Percentage of Face Value that would meet investment requirements = 0.934116
Yield to Maturity = 0.0499999
Duration = 7.7587
Duration (to be used in LP-formulation below) = 8.30593
(Note) 7.7587 = 8.30593 x 0.934116
Convexity = 70.4264
Convexity (to be used in LP-formulation below) = 75.3936
(Note) 70.4264 = 75.3936 x 0.934116
-----------------------------------------------------
Bond #2
Current Price = 1121.39
Maturity = 11
Percentage of Face Value that would meet investment requirements = 0.942346
Yield to Maturity = 0.0549998
Duration = 8.20531
Duration (to be used in LP-formulation below) = 8.70733
(Note) 8.20531 = 8.70733 x 0.942346
Convexity = 79.1966
Convexity (to be used in LP-formulation below) = 84.042
(Note) 79.1966 = 84.042 x 0.942346
-----------------------------------------------------
Bond #3
Current Price = 1148.75
Maturity = 12
Percentage of Face Value that would meet investment requirements = 0.919902
Yield to Maturity = 0.0574999
Duration = 8.58082
Duration (to be used in LP-formulation below) = 9.32798
(Note) 8.58082 = 9.32798 x 0.919902
Convexity = 87.6798
Convexity (to be used in LP-formulation below) = 95.3144
(Note) 87.6798 = 95.3144 x 0.919902
-----------------------------------------------------
Average YTM (to compute PV of debt) = 0.0541665
Present value of debt = 1056.74
-----------------------------------------------------
Model name:
                C1       C2       C3
Maximize   75.3936   84.042  95.3144
R1         1131.27  1121.39  1148.75  =  1056.74
R2         8.30593  8.70733  9.32798  =       10
Type          Real     Real     Real
upbo           Inf      Inf      Inf
lowbo            0        0        0
There is no portfolio that meets the duration constraint of 10 years


Press any key to continue . . .
```

```
C:\Users\jloss\source\repos\ConsoleApplication3\Debug>bondportfolio.exe bonds1
Input File: bonds1

We want to invest 2320.85 over 11 years
Number of Bonds: 5
-----------------------------------------------------
Bond #1
Current Price = 998.27
Maturity = 11
Percentage of Face Value that would meet investment requirements = 1.23646
Yield to Maturity = 0.0482353
Duration = 8.82242
Duration (to be used in LP-formulation below) = 7.13523
(Note) 8.82242 = 7.13523 x 1.23646
Convexity = 88.8129
Convexity (to be used in LP-formulation below) = 71.8284
(Note) 88.8129 = 71.8284 x 1.23646
-----------------------------------------------------
Bond #2
Current Price = 815.8
Maturity = 15
Percentage of Face Value that would meet investment requirements = 1.51302
Yield to Maturity = 0.0500994
Duration = 13.5238
Duration (to be used in LP-formulation below) = 8.93827
(Note) 13.5238 = 8.93827 x 1.51302
Convexity = 183.03
Convexity (to be used in LP-formulation below) = 120.97
(Note) 183.03 = 120.97 x 1.51302
-----------------------------------------------------
Bond #3
Current Price = 863.5
Maturity = 30
Percentage of Face Value that would meet investment requirements = 1.42944
Yield to Maturity = 0.0700015
Duration = 13.6776
Duration (to be used in LP-formulation below) = 9.56852
(Note) 13.6776 = 9.56852 x 1.42944
Convexity = 262.775
Convexity (to be used in LP-formulation below) = 183.831
(Note) 262.775 = 183.831 x 1.42944
-----------------------------------------------------
Bond #4
Current Price = 1120.75
Maturity = 12
Percentage of Face Value that would meet investment requirements = 1.10133
Yield to Maturity = 0.0605809
Duration = 8.53532
Duration (to be used in LP-formulation below) = 7.74999
(Note) 8.53532 = 7.74999 x 1.10133
Convexity = 86.5443
Convexity (to be used in LP-formulation below) = 78.5813
(Note) 86.5443 = 78.5813 x 1.10133
-----------------------------------------------------
Bond #5
Current Price = 1031.39
Maturity = 14
Percentage of Face Value that would meet investment requirements = 1.19675
Yield to Maturity = 0.066486
Duration = 9.4336
Duration (to be used in LP-formulation below) = 7.88265
(Note) 9.4336 = 7.88265 x 1.19675
Convexity = 106.763
Convexity (to be used in LP-formulation below) = 89.2101
(Note) 106.763 = 89.2101 x 1.19675
-----------------------------------------------------
Average YTM (to compute PV of debt) = 0.0590806
Present value of debt = 1234.32
-----------------------------------------------------
Model name:
                C1       C2       C3       C4       C5
Maximize   71.8284   120.97  183.831  78.5813  89.2101
R1          998.27    815.8    863.5  1120.75  1031.39  =  1234.32
R2         7.13523  8.93827  9.56852  7.74999  7.88265  =       11
Type          Real     Real     Real     Real     Real
upbo           Inf      Inf      Inf      Inf      Inf
lowbo            0        0        0        0        0
Largest convexity we can get is: 171.011

Optimal portfolio (%):
Bond 1: 0
Bond 2: 0
Bond 3: 0.685124
Bond 4: 0.573469
Bond 5: 0

To create optimal portfolio: BUY
$591.605 of Bond 3
$642.716 of Bond 4


Press any key to continue . . .
```