

Optimization: Continuous Portfolio Allocation

Short Examples Series
using
Risk Simulator



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Optimization – Continuous Portfolio Allocation

File Name: *Optimization – Continuous Portfolio Allocation*

Location: *Modeling Toolkit | Optimization | Continuous Portfolio Allocation*

Brief Description: *This model illustrates how to run an optimization on continuous decision variables, viewing and interpreting optimization results*

Requirements: *Modeling Toolkit, Risk Simulator*

This model shows 10 asset classes with different risk and return characteristics. The idea here is to find the best portfolio allocation such that the portfolio's bang-for-the-buck or returns to risk ratio is maximized. That is, to allocate 100% of an individual's investment portfolio among several different asset classes (e.g., different types of mutual funds or investment styles: growth, value, aggressive growth, income, global, index, contrarian, momentum, and so forth). In order to run an optimization, several key specifications on the model have to be identified first:

Objective:

Maximize Return to Risk Ratio (C18)

Decision Variables:

Allocation Weights (E6:E15)

Restrictions on Decision Variables:

Minimum and Maximum Required (F6:G15)

Constraints:

Portfolio Total Allocation Weights 100% (E17 is set to 100%)

The model shows the 10 asset classes. Each asset class has its own set of annualized returns and risks, measured by annualized volatilities (Figure 1). These return and risk measures are annualized values such that they can be consistently compared across different asset classes. Returns are computed using the geometric average of the relative returns, while the risks are computed using the annualized standard deviation of the logarithmic relative historical stock returns approach.

The allocation weights in column E hold the decision variables, which are the variables that need to be tweaked and tested such that the total weight is constrained at 100% (cell E17). Typically, to start the optimization, we will set these cells to a uniform value; in this case, cells E6 to E15 are set at 10% each. In addition, each decision variable may have specific restrictions in its allowed range. In this example, the lower and upper allocations allowed are 5% and 35%, as seen in columns F and G. This setting means that each asset class may have its own allocation boundaries (Figure 1).

Next, column H shows the return to risk ratio, which is simply the return percentage divided by the risk percentage, where the higher this value, the higher the bang-for-the-buck. The remaining sections of the

model show the individual asset class rankings by returns, risk, return to risk ratio, and allocation. In other words, these rankings show at a glance which asset class has the lowest risk or the highest return, and so forth.

	A	B	C	D	E	F	G	H
1								
2								
3		ASSET ALLOCATION OPTIMIZATION MODEL						
4								
5		Asset Class Description	Annualized Returns	Volatility Risk	Allocation Weights	Required Minimum Allocation	Required Maximum Allocation	Return to Risk Ratio
6		Asset Class 1	10.54%	12.36%	10.00%	5.00%	35.00%	0.8524
7		Asset Class 2	11.25%	16.23%	10.00%	5.00%	35.00%	0.6929
8		Asset Class 3	11.84%	15.64%	10.00%	5.00%	35.00%	0.7570
9		Asset Class 4	10.64%	12.35%	10.00%	5.00%	35.00%	0.8615
10		Asset Class 5	13.25%	13.28%	10.00%	5.00%	35.00%	0.9977
11		Asset Class 6	14.21%	14.39%	10.00%	5.00%	35.00%	0.9875
12		Asset Class 7	15.53%	14.25%	10.00%	5.00%	35.00%	1.0898
13		Asset Class 8	14.95%	16.44%	10.00%	5.00%	35.00%	0.9094
14		Asset Class 9	14.16%	16.50%	10.00%	5.00%	35.00%	0.8584
15		Asset Class 10	10.06%	12.50%	10.00%	5.00%	35.00%	0.8045
16								
17		Portfolio Total	12.6419%	4.58%	100.00%			
18		Return to Risk Ratio	2.7596					

Figure 1: Asset allocation optimization model

Running an Optimization

To run this model, simply click on **Risk Simulator | Optimization | Run Optimization**. Alternatively, for practice, you can try to set up the model again by doing (the steps are illustrated in Figure 2):

1. Start a new profile (**Risk Simulator | New Profile**) and give it a name.
2. Select cell **E6**, and define the decision variable (**Risk Simulator | Optimization | Decision Variables**, or click on the *Define Decision D* icon) and make it a *Continuous Variable* and then link the decision variable's name and minimum/maximum required to the relevant cells (**B6, F6, G6**).
3. Then use the **Risk Simulator Copy** on cell **E6**, select cells **E7 to E15**, and use **Risk Simulator's Paste** (**Risk Simulator | Copy Parameter** and **Risk Simulator | Paste Parameter** or use the *copy and paste icons*). To re-run the optimization, type in **10%** for all decision variables.
4. Next, set up the optimization's constraints by selecting **Risk Simulator | Optimization | Constraints**, selecting **ADD**, and selecting the cell **E17**, and making it (**==**) equal **100%** (for total allocation, and remember to insert the % sign).

5. Select cell **C18** as the objective to be maximized (**Risk Simulator | Optimization | Objective**).
6. Select **Risk Simulator | Optimization | Run Optimization**. Review the different tabs to make sure that all the required inputs in steps 2-4 are correct.
7. You may now select the optimization method of choice and click **OK** to run the optimization:

***Discrete Optimization** is an optimization that is run on a discrete or static model, where no simulations are run. This optimization type is applicable when the model is assumed to be known and no uncertainties exist. Also, a discrete optimization can be run first to determine the optimal portfolio and its corresponding optimal allocation of decision variables before applying more advanced optimization procedures. For instance, before running a stochastic optimization problem, first run a discrete optimization to determine if there exist solutions to the optimization problem before performing a more protracted analysis.*

***Dynamic Optimization** is applied when Monte Carlo simulation is used together with optimization. Another name for such a procedure is Simulation-Optimization. In other words, a simulation is run for N trials, and then an optimization process is run for M iterations until the optimal results are obtained or an infeasible set is found. That is, using Risk Simulator's optimization module, you can choose which forecast and assumption statistics to use and replace in the model after the simulation is run. Then, you can apply these forecast statistics in the optimization process. This approach is useful when you have a large model with many interacting assumptions and forecasts, and when some of the forecast statistics are required in the optimization.*

***Stochastic Optimization** is similar to the dynamic optimization procedure except that the entire dynamic optimization process is repeated T times. The results will be a forecast chart of each decision variable with T values. In other words, a simulation is run and the forecast or assumption statistics are used in the optimization model to find the optimal allocation of decision variables. Then another simulation is run, generating different forecast statistics, and these new updated values are optimized, and so forth. Hence, each of the final decision variables will have its own forecast chart, indicating the range of the optimal decision variables. For instance, instead of obtaining single-point estimates in the dynamic optimization procedure, you can now obtain a distribution of the decision variables, and, hence, a range of optimal values for each decision variable, also known as a stochastic optimization.*

Note: If you are to run either a dynamic or stochastic optimization routine, make sure that you define the assumptions first in the model. That is, make sure that some of the cells in C6:D15 are assumptions. The model setup is illustrated in Figure 2.

Decision Variable Properties

Decision Name:

Decision Type:

- Continuous (e.g., 1.15, 2.35, 10.55)
 - Lower Bound: Upper Bound:
- Integer (e.g., 1, 2, 3)
 - Lower Bound: Upper Bound:
- Discrete (e.g., 3, 4-6, 7.5-9.5, 11, 14.3)
 -
- Binary (0 or 1)

OK Cancel

Constraint

Cell: Constraint:

OK Cancel

Constraints

Current Constraints:

- \$E\$17 == 1.0

Add Change Delete OK Cancel

Optimization Summary

Optimization is used to allocate resources where the results provide the max returns or the min cost/risks. Uses include managing inventories, financial portfolio allocation, product mix, project selection, etc.

Method Objective Constraints Statistics Decision Variables

- Static Optimization**
Run on static model without simulations. Usually run to determine the initial optimal portfolio before more advanced optimizations are applied.
- Dynamic Optimization**
A simulation is first run, the results of the simulation are applied in the model, and then an optimization is applied to the simulated values.
Number of Simulation Trials:
- Stochastic Optimization**
Similar to dynamic optimization but the process is repeated several times. The final decision variables will each have its own forecast chart indicating its optimal range.
Number of Simulation Trials:
Number of Optimization Runs:

OK Cancel

Figure 2: Optimization model setup

Results Interpretation

Refer to Chapter 11 of Modeling Risk: Applying Monte Carlo Simulation, Real Options Analysis, Forecasting, and Optimization, by Dr. Johnathan Mun (Wiley 2006) for more detailed explanations about this model, the different optimization techniques, and an interpretation of the results. Chapter 11's appendix also details how the risk and return values are computed.

Briefly, the optimization results show the percentage allocation for each asset class (or projects or business lines, et cetera) that would maximize the portfolio's bang-for-buck, that is, the allocation that would provide the highest returns subject to the least amount of risk. In other words, for the same amount of risk, what is the highest amount of returns that can be generated, or for the same amount of returns, what is the least amount of risk that can be obtained? See Figure 3. This is the concept of the Markowitz efficient portfolio analysis. For a comparable example, see the Efficient Frontier model where we also generate the entire efficient frontier model.

ASSET ALLOCATION OPTIMIZATION MODEL										
Asset Class Description	Annualized Returns	Volatility Risk	Allocation Weights	Required Minimum Allocation	Required Maximum Allocation	Return to Risk Ratio	Returns Ranking (Hi-Lo)	Risk Ranking (Lo-Hi)	Return to Risk Ranking (Hi-Lo)	Allocation Ranking (Hi-Lo)
Asset Class 1	10.54%	12.36%	11.09%	5.00%	35.00%	0.8524	9	2	7	4
Asset Class 2	11.25%	16.23%	6.87%	5.00%	35.00%	0.6929	7	8	10	10
Asset Class 3	11.84%	15.64%	7.78%	5.00%	35.00%	0.7570	6	7	9	9
Asset Class 4	10.64%	12.35%	11.22%	5.00%	35.00%	0.8615	8	1	5	3
Asset Class 5	13.25%	13.28%	12.08%	5.00%	35.00%	0.9977	5	4	2	2
Asset Class 6	14.21%	14.39%	11.04%	5.00%	35.00%	0.9875	3	6	3	5
Asset Class 7	15.53%	14.25%	12.30%	5.00%	35.00%	1.0898	1	5	1	1
Asset Class 8	14.95%	16.44%	8.90%	5.00%	35.00%	0.9094	2	9	4	7
Asset Class 9	14.16%	16.50%	8.37%	5.00%	35.00%	0.8584	4	10	6	8
Asset Class 10	10.06%	12.50%	10.35%	5.00%	35.00%	0.8045	10	3	8	6
Portfolio Total	12.6920%	4.52%	100.00%							
Return to Risk Ratio	2.8091									

Figure 3: Optimization results