

# Portfolio Allocation Optimization Using Crystal Ball

Research Performed by:

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Help Received: LTC Cobb (helped

In my understanding of the model and corrected

Paper and simulation problems)

Yahoo.com (sourced all stock prices from Yahoo.com)

## **Introduction**

Research is the cornerstone for new ideas, products, and processes. In my undergraduate research project, I decided that I was going to develop something that people could truly use. With the stock market being in turmoil over the past year, I have decided to develop a project that deals with stocks and the market, placing a particular emphasis on minimizing risk. I have created a stock portfolio model that will help minimize risk and variance within a selected group of stocks to help maximize gains. In this synopsis I will give a detailed explanation of my initial problem I was presented with, the methods for developing the portfolio, my results, and finally recommendations and conclusions.

## **Problems and Goals**

### *Initial Assessment*

Being an officer in the VMI Cadet Investment Group and having taken a financial models class, I decided that it would be worthwhile to develop a stock portfolio that will minimize risk and variance within a selected group of stocks, while still yielding the highest return possible within the constraints. Utilizing the technology of Crystal Ball Software, an ad-on of Microsoft Excel, gave me the opportunity to develop this model. I picked 10 stocks that were mostly in different industries and I performed an optimization on each that selected the optimal allocation in each stock for each of the ten years. This model gave me the appropriate allocation in each of the ten stocks

### *Basic Definitions and Goals*

To minimize errors, I also decided to use two methods of developing the portfolio. I performed a mean-variance optimization as well as a mean-value at risk (VAR) optimization. The portfolio variance is the average squared distance of the observations from the mean. Value at risk is a risk measure that associates a loss with a probability level. For example, at the 5% VAR there is a 5% chance that the portfolio will lose X amount over X days. Using these two methods, I was able to minimize errors within each portfolio and give myself (or an investor using this model) more of a selection of the allocation of stocks and returns. The portfolio return is simply the dollar amount that the portfolio yields at the end of each simulation (or year).

## **Methods**

### *Data Collection and Template Creation*

To start this model off, I first had to collect my data to use. Using the Yahoo! Finance tool, I gathered the monthly stock prices for 10 different stocks. I collected 10 years worth of data in which to simulate and I placed no specification on industry. The stocks tickers that I picked are as follows (Names on appendix A): GE, JNJ, JPM, GIS, PFE, NSC, CSX, BUD, F, DE. In order to collect this data, there is a historical stock price link on the website in which you can type in a specific date in which to find the data. I started at Jan, 1 1994 and ended with Dec. 31, 2008; I only simulated data from 1994-2004, but ran the simulation forward to 2008. From here I calculated the additive returned by doing the natural log of the most recent year (t) over the previous time period (t-1). I repeated this process for a 5 year time period. The returns are the figures that I will base my simulation off of, because I am able to do a normal distribution on the data. The next step in this process was to create a template which I can base all other years (1-10) on as to keep the model uniform throughout. You can find the basic template, which is year

one in Appendix B. The final step in the template creation process was to create a correlation matrix for each of the stocks. This was later loaded into the crystal ball assumption for the returns, which we will visit in my next section.

### *Crystal Ball Setup and Definition*

Crystal Ball is a ad-on for Excel that takes into account certain assumptions, decision variables, and results and allows you to optimize for certain results or simulate data for a given amount of trials. The specific functions that were important to my simulation were assumption (green boxes), decision variables (yellow boxes), forecasts (blue boxes), and Opt Quest. For my assumptions I set up the data to follow a normal distribution that took into account the mean and standard deviation for each stock, for that given year. This was followed through for each of the 12 months in a simulation. In addition, the assumptions had to be correlated through the correlation matrix as explained above. After successfully completing the assumptions, it will give you a list of randomly generated numbers that change once the simulation is actually run. For the decision variables, which gave my optimal allocations, I set up variables that range from 0 to 1 signifying allocation percentages (1=100%). I then entered in a base value of .10 for each stock which is a baseline to check and see if the simulation actually ran correctly. After this was done I set up the 12 month ending portfolio balance, which is simply the forecasted results from the simulation. The most important part of the simulation was the Opt Quest. Opt Quest finds the portfolio allocations with either the minimum variance or minimum VAR that meet my required return of 6%. I set the criteria and allowed it to run for 5 minutes or 2000 simulations.

### *Simulation One*

For the first simulation I minimized the variance on the model using Opt Quest. As for every year and every simulation I set a required return of 6%. I will use the first year simulation to give an example of the processes involved, which is duplicated for each of nine years after.

After the data collection process I was given a raw template in which to mold into each simulation. As seen in Appendix B, I placed the mean and standard deviation at the top, under each of the 10 stocks that I picked respectively. I then set up my decision variables which as mentioned before ranged from 0 to 1, and plugged in a value of .10 for each stock allocation.

From here, I moved down to the “Beginning Balance” column and entered a value of \$100,000, which is my starting value for this simulation. I then broke the row into 12 months, because as you remember the returns are given in monthly data. The assumptions were then put into place by setting them to a normal distribution with the mean and standard deviation for the given stock, as explained above. The data was correlated using the correlation tool and I was then able to calculate the “random” returns based off of my assumptions and allocation amount. I took the beginning balance and multiplied each stock allocation times its return to get a dollar amount on the simulated returns. This was then added up in the next column for each month. After this process I added the total returns to the beginning balance of \$100,000. Once this process was complete, I needed to make sure that I added the ending balance from the previous month ( $t-1$ ) to the beginning balance of the next or current month ( $t$ ). Finally I added up each of the values and set a forecast to it and was now able to run the simulation successfully.

The next step was setting up the Opt Quest. For the first simulation I opened up Opt Quest and selected the objective to “minimize the variance of the 12 month ending balance.” I set a requirement of 6% return and made sure that the constraints for allocation were additively equal to 1. I then set the simulation to run for 5 minutes or 2000 simulations (just dependent on what I

felt like because they are both about the same 5minutes=around 2000 simulations). Later on, once I realized that the simulation was optimized way under 5 minutes I changed it to run for 3 minutes. When this was done, I made sure all simulations were optimized before, and the maximum that it got to was about 2:30, so this saved me some significant time (especially when I went through and re-ran all the simulations). I was then given the optimal allocation for the stocks for that given year. The best part about this simulation was that I could redo this process again for each subsequent year, as long as I updated the data and accounted for all stock splits and variables that I will discuss in the conclusion. Once this was completed I set up a “Beginning” and “Ending” total for each portfolio allocation. The beginning balance was calculated by multiplying the allocation times the beginning balance for each year. For the ending balance, the process was a little more complicated. I got a list of all the prices for the end of the year for every stock. After this the calculation was simple. I divided the beginning balance by the stock price for the previous year’s ending balance (which gave the amount of shares allocated), then multiplied it by the current years closing price which gave me an actual value for the end of the year.

### *Simulation Two*

The same process was used for simulation two, which was to minimize the value at risk. The one difference in the simulation was to set a forecast to VAR, which is calculated from the beginning balance minus the 12 month forecasted ending balance. I then set this as an individual forecast in which I could run Opt Quest. When it was time to use Opt Quest, I set the constraint to “minimize the value at risk.” I then set the requirement to 6% return and the constraints on the decision variables to equal one, as in simulation one. I repeated the same time and simulation amount in order to keep the testing criteria the same, in order to accurately compare year to year.

## **Results\***

### *Simulation One Results-Minimized Variance*

After the first simulation was run (which can be found in Appendix B), I noticed that both simulations ended up losing value. After the first year, December 31, 1999, the ending balance was \$71,229.14. This led me to believe that this was a bad year for the stock market and/or economy as a whole. It continued to decline in the second year of the simulation, but increased dramatically in 2001. By the end of 2001, the estimated value based on optimal allocation was \$156,765.8, with most of the funds allocated into JNJ (Johnson & Johnson). This was a good year for the second simulation as well, which lagged behind quite a bit. The returns increased into 2002, and dropped slightly in 2003. After 2003, the yearly returns increased significantly, peaking in 2007 at \$203,469.5 which was 103.5% increase from the initial investment of \$100,000. Finally in 2008, the amount dropped significantly to \$163,982.7. I believe that this is attributed to such rough economic times, and the portfolio allocated 25% of funds to JPM, which was hit severely by the mortgage backed security crisis.

### *Simulation Two Results-Minimized Value at Risk*

For the value at risk simulation, the results were similar to the minimized variance simulation but with several key differences. Like in the first simulation, the value decreased in the first two years, hitting a low point of \$60,757.69 in 2000. In 2001, the value of the portfolio increased dramatically to \$104,997, earning roughly 5% since the simulation started. The portfolio continued to increase in value, hitting a peak in 2005 of \$216,387. This was the highest achieved value between the two portfolios and it would have earned a 116% return from 1999 if sold. Most of the allocation for this year appeared to be in GIS, and split equally between NSC and

CSX. The portfolio in simulation two varied up and down until 2008, when it closed at \$165,233.2. The results between the two simulations were similar in this respect, and again it was mainly because of the drop in economic activity.

### **Conclusions and Recommendations**

In conclusion, it appears that the most stable and best way to do this portfolio optimization is to stick with minimizing the variance. The reason for this is because it consistently outperforms the minimized value at risk portfolio, except in 2005. The actual ending balance for each of the portfolios is very comparable, but it appears that this method consistently gives you a higher return for any given year. Having said that, the value at risk minimization method did result in the highest return, which you will recall was roughly 116% in 1999. Since both were compared against each other and had a required return of 6%, the models were very comparable and neither one had an advantage over the other. I would recommend several things to increase the accuracy and validity of this portfolio simulation. First I would increase the required return. Although it is dependant on each investor what they are looking for in return, I believe a higher required return, perhaps 10%, would yield in much larger amounts for an investor. Anything over this amount however may be unrealistic, due to market conditions and the Opt Quest itself not being able to meet the requirements. In addition, it was very important for me to account for stock splits. For the first few simulations I was getting very low results. After some analysis I noticed that the prices were either cut in half or in third for a given year. I corrected for this by multiplying the ending balance (for the stock that was split) by the amount it was split by. For example if there was a 2:1 stock split for GE, I multiplied the ending balance for GE by 2. This corrected the problem, but I wish that there had been a way to automatically account for this. My final recommendation is to increase the amount of stocks in the portfolio. Sometimes, even

though the industry was spread out, all stocks in the portfolio were down which lead to a decreased final value. By increasing the amount of stocks available to invest in, Opt Quest would have a wider range to choose from when optimizing the allocations.

Appendix A

BUD – Anheuser-Busch

CSX – CSX Corp.

DE—Deere & Co.

F – Ford Motor Co.

GE – General Electric

GIS – General Mills

JNJ – Johnson & Johnson

JPM – J.P. Morgan Chase

NSC – Norfolk Southern Corp.

PFE -- Pfizer

# Crystal Ball/Portfolio

Portfolio-1 year-real2 [Compatibility Mode] - Microsoft Excel non-commercial use

Home Insert Page Layout Formulas Data Review View

Clipboard Font Alignment Number Styles Cells Editing

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1		GE	JNJ	JPM	GIS	PFE	NSC	CSX	BUD	F	DE										
2	Mean	-0.000929507	0.01156935	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327										
3	Stdev	0.131988562	0.1091041	0.12024	0.056295	0.141504	0.161255	0.107603	0.105886	0.117088	0.152643										
4																					
5	Allocation	0.07	0	0.11	0.53	0.1	0	0	0.11	0.04	0										
6	Min Variance	0.07	0	0.11	0.53	0.1	0	0.06	0.1	0	0.03										
7	Min VAR	0	0.13	0.11	0.52	0.11	0	0	0.11	0.02	0										
8																					
9																					
10	*Assuming a \$100,000 Beg Bal																				
11																					
12																					
13																					
14																					
15		(Jan 1, 1999)	Beg Balance	GE	JNJ	JPM	GIS	PFE	NSC	CSX	BUD	F	DE	GE Ret	JNJ Ret	JPM Ret	GIS Ret	PFE Ret	NSC ret	CSX Ret	BUD I
16		1	100000	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.50655	0	109.3249	381.7446	111.8288	0	0	40.3
17		2	100627.805	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.5474	0	110.0113	384.1412	112.5308	0	0	40.6
18		3	101259.551	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.5885	0	110.7019	386.5529	113.2373	0	0	40.8
19		4	101895.263	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.62987	0	111.3969	388.9797	113.9482	0	0	41.1
20		5	102534.966	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.67149	0	112.0963	391.4217	114.6636	0	0	41.4
21		6	103178.686	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.71337	0	112.8	393.8791	115.3835	0	0	41.6
22		7	103826.446	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.75552	0	113.5082	396.3519	116.1078	0	0	41.9
23		8	104478.274	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.79793	0	114.2208	398.8402	116.8368	0	0	42.1
24		9	105134.193	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.84061	0	114.9379	401.3441	117.5703	0	0	42.4
25		10	105794.23	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.88355	0	115.6595	403.8638	118.3084	0	0	42.7
26		11	106458.412	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.92677	0	116.3856	406.3993	119.0511	0	0	42.9
27		12	107126.763	-0.00093	0.011569	0.009939	0.007203	0.011183	-0.01208	-0.01345	0.003672	-0.00224	-0.01327	-6.97026	0	117.1163	408.9506	119.7985	0	0	43.2
28																					
29																					
30			VAR																		
31			-7799.30937																		
32																					
																					Total

12 Month Ending Portfolio Balance 107799.3

Required Return 6%

\$ 6000

Stock Prices Portfolio-1 yr Correlation Report Optquest Report Optquest 2 Sheet2 Sheet3

Enter

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