Midterm Project Write Up

Motivation of Question:

The question I sought to answer with this research project was "How do individual asset types vary in regards to return and risk, and how does diversification affect this?" In this day and age it seems to have become trendy to invest large amounts of money into securities that are trending upwards. It seems like every week there is news of a new stock or crypto coin that has jumped up 40, 50, 60 percent in a very short timeframe. Whether it be Gamestop, AMC, Dogecoin or some other asset, many people advise to go all in on one security in the hopes that it will explode in growth. Diversification as a strategy while still utilized by more experienced investors seems to be dropping in popularity among new retail investors. Due to this recent trend in investing, I wanted to analyze and research if the benefits of diversification still hold up in this current market climate. Is investing into one security now better overall than diversification, or does diversification still bring more positive returns overall?

Test Design and Sample Choice:

For my test I wanted to compare 3 different types of securities, stocks, crypto, and etfs. To do this I chose 2 from each, 2 stocks, 2 crypto currencies, and 2 etfs. I wanted to choose among the largest and more popular from each category. For stocks I chose Amazon and Tesla. Tesla is more of a wildcard since it behaves much differently than most other major stocks, however I wanted to include Tesla since it is one of the more trendy and popular stocks among inexperienced investors, one that many people who invest in it may not think about the potential benefits of diversification with TSLA. For the crypto currencies I selected Bitcoin and Ethereum. The 2 current largest crypto currencies. For the etfs I selected QQQ and VGT, again these were among the largest etfs. The data source I used for each of my assets was Yahoo finance and the

timeframe I looked at for my sample of securities was about the latest 4-5 years worth of data, this will give a better picture on the current performance of each asset than using data 15+ years old. In order to get a complete representation of the population of each category I would need to compare more assets from each category, however this test and its results should provide at least some insight to the overall population and should be representative of the population of each of the individual securities. The format of my test was as follows: first compare individual securities to one another, 2nd form a portfolio by each category and compare, 3rd diversify across asset types, 4th conduct hypothesis testing on the mean and variance.

Individual securities Results:

My 1st order of business was visualizing adjusted close for each security, just to get a rough feel of how each stock performs. Next I moved on to calculating and visualizing yearly returns. This showed that ETH, BTC and TSLA had the highest annual returns. Of course with high returns investors should expect a high amount of risk, this was shown in the standard deviation. The 3 highest risk levels also corresponded to the highest returns. In order to get a better idea of how the data of these securities are dispersed, Histogram visualization was next. These graphs clearly showed that the higher risk assets had much more variance in the distribution of its returns. Compared to QQQ whose data was mostly within -2.5% to 2.5%, BTC ranged mostly from -15% to 15%. Lastly I calculated and visualized sharpe ratio which showed TSLA, ETH and BTC had the highest.

Forming Portfolios:

The second part of my test was forming 3 portfolios consisting of both stocks, both cryptos and both etfs for 3 different types of investor, risk neutral, risk averse and risk inclined. Risk neutral corresponded to a 50 50 split, risk averse was 80 20 with 80% on the least risky

asset, vice versa for risk inclined. For etfs I neglected the risk averse and risk inclined investors since both etfs had similar risk levels. This gave me a total of 7 portfolios and for each of the 7 portfolios I calculated annual return, annual risk level and the sharpe ratio. From here I visualized avg annual return and risk level to reveal that the crypto portfolios had a higher overall return however this also came with higher risk as expected. The more risky portfolios from risk incline investors followed this trend. However when looking at the graph of sharpe ratios it is shown that the Risk neutral portfolio of stocks actually had the highest sharpe ratio. In fact the portfolio of stocks held the top 3 sharpe ratios, suggesting that while crypto offers higher overall return, due to its high risk level it may not be the best strategy to invest only into crypto.

Effects of diversification:

After comparing these portfolios I switched to forming portfolios with 3 assets, one from each security type. Originally the sharpe ratio where we had 50% ETH and 50% BTC was around 1.01, however when diversifying it with AMZN and QQQ (50% on ETH still) we obtain a sharpe ratio of 1.12. A 0.11 increase with the same amount of weight just diversifying a little bit. This was mostly due to standard deviation being reduced from 0.82 to 0.54, later I will discuss whether this difference is statistically significant. Similarly I tested Tesla using the same method (forming a portfolio 50% Tesla with BTC and VGT) and saw similar results. The shape ratio had increased to 1.45 compared to before where 50% on TSLA produced a 1.28 sharpe ratio. Finally I took it a step further and formed portfolios consisting of all 6 assets. Still keeping 50% on TSLA and another with 50% on ETH for consistency sake. Again sharpe ratio was increased for both portfolios, due to a decrease in risk level.

Hypothesis testing:

For both TSLA and ETH I conducted several hypothesis tests. First I wanted to see if the mean return and variance was statistically different for the individual asset and portfolio with 2 assets and portfolio with 3 assets compared to the portfolio with 6 assets, for this I used a 2 sample t-test. Similarly I wanted to compare the variances, for this I used a 2 sample F-test. My goal was to see how each level of diversification affects variance, as I did not expect much change from mean returns since the goal of diversification is mainly to reduce risk. Starting with TSLA the 2 sample t-test confirmed my thinking, the mean average returns could not be said to be statistically significant due to the large p-value produced. Next I conducted a 2 sample variance test using TSLA the individual stock and the portfolio with 6 assets (50% on TSLA). This produced a large test statistic of 2.30 and a very small p-value. Similarly testing each more diversified portfolio produced smaller and smaller test statistics, implying that each level of diversification was reducing variance and moving towards the risk level of the well diversified portfolio. The 3 asset TSLA portfolio produced a p-value of over 0.20, using a 5% significance level this would lead to the null not being rejected. This meant the portfolio with 3 assets and the 6 assets did not have a statistically different variance. ETH followed the same pattern. The 2 sample t test on the means of ETH and the well diversified portfolio produced a p-value of 0.62 which meant the means were not statistically different from one another, however conducting the 2-sample variance tests produced smaller and smaller F-statistics. From 2.8 to 2.3 to 1.2. However unlike TSLA the p-value for the 3 asset portfolio for ETH was $0.99e^{-11}$, with a critical value of 1.05. Suggesting that more diversification is needed for ETH when compared to TSLA, likely due to the higher overall risk level of ETH.

Economic Significance and Conclusion:

From these results I see that diversification does indeed reduce risk, given by the fact that the F statistic kept lowering when testing each portfolio implying the variance was approaching the variance of the portfolio with 6 assets. While mean average returns could not be said to be statistically different. Economically this implies that for the same mean return diversification reduces risk, which overall will lead to a higher sharpe ratio and therefore a more optimal investing strategy. However as was shown with TSLA there is a limit of diversification, at some point the 2 variances can not be said to be statistically different. Economically this means there is a middle point of diversification that should give you the optimal portfolio and optimal strategy for a given asset. This middle point varies based on the risk level of the asset as was shown by ETH where more diversification is needed in order to reach that threshold. Finding this middle point would be a good next step. Overall diversification was shown to reduce risk for these assets, however more assets would need to be tested to apply such a statement to the overall market.

<center>**Final Project Section**</center>

Recap:

From the previous portion of this project we looked at 6 securities from varying asset types. First analyzing each security separately and then focusing on how diversification across different sectors affects portfolio return, risk and sharpe ratio. From this it was shown diversification can be a powerful tool in reducing risk while keeping returns relatively constant and therefore increasing sharpe ratio. In the next few sections we will continue to expand on this idea

Monte Carlo Simulation:

I began the second half of this project by running a Monte Carlo simulation on each of the 6 assets to get a better picture on the probabilities of observing a certain return. By iterating 10000 times this gave me a clear picture on the spread of return for each asset. The assets with the most volatility had the greatest spreads which was expected. I wanted to see how likely it is for each asset to return a yearly return of over 50%. Of course the 2 etfs had relatively low probabilities of this happening while Tesla and ETH had an almost 70 percent chance to provide a return greater than 50% over these iterations. So while Tesla and ETH have a very high risk level this is compensated by their very large return. Seeing this result led me to hypothesize that in an optimal portfolio with these 6 assets we should expect to see a large portion of Tesla and ETH in the portfolio regardless of the fact that they both carry a large amount of risk.

Finding the Optimal Portfolio:

In order to find the optimal portfolio I first generated 100 thousand random sets of weights that sum up to 1. While of course this does not consider every last possible combination as those would be infinite, this should give us a rough idea of what an optimal portfolio may look like. Using the 100 thousand sets of weights I calculated return, risk level and the sharpe ratio for each of the 100 thousand portfolios. From these portfolios I picked out the portfolio that gave the highest sharpe ratio (Note: The portfolio will slightly change each time the program is run as the weights are random). This confirmed my hypothesis. The optimal portfolio had a heavy weight on Tesla, over 44%, and over 25% combined on the 2 crypto assets. Amounting to over nearly 70% on the 3 most risky assets. Amazon also saw a significant weight given to it, at over 24%, making it the second largest asset in the optimal portfolio. As I expected the 2 etf's only made up a small portion of the portfolio, less than 4% of the portfolio combined. Conversely the portfolio with the lowest sharpe ratio was over 50% etfs and over 43% Amazon. Just over 2% was

allocated to Tesla, Bitcoin, and Ethereum combined in this portfolio. From these results I hypothesized that the optimal portfolio should put more weight on those assets that outperform the market relative to those that do not.

Linear Regression:

I ran a CAPM regression on each of the 6 assets to see which asset outperformed the market over the time period examined. From the regression output it was shown that Tesla had a positive constant and was significant at the 5% level, which means Tesla outperformed the market. This was reflected in its heavy weight in the optimal portfolio. Both Bitcoin and ETH had positive constants however were not significant at the 5% level. Both of these assets were close however and if I switched to a 10 percent significance level ETH (p-value of about 7%) would be significant and would have outperformed the market. Surprisingly VGT would have also outperformed the market if a 10 percent significance level was used, most likely due to the very low level of risk combined with a return of over 23% over this time period. When testing the amount that an asset outperformed the market was not taken into account so it is possibile VGT may have slightly outperformed, while an asset like Tesla outperformed by a larger margin. Finally I wanted to go back and check the effects of diversification here, so I conducted CAPM regression on multiple of the portfolios I tested in the past. Initially Amazon had a huge p-value, however with the portfolio with Tesla and Amazon it produced a p-value of under 0.02, which means this portfolio outperformed the market. Same for ETH, initially the p-value was over 7% however when testing the portfolio with 50% ETH and 10% on the other 5 assets the p-value is reduced to 0.035, making this result significant and showing that this portfolio outperformed the market.

Economic Significance of Final report portion/ Conclusion:

From this second half of the project I was able to see how valuable risk can be in a portfolio. While many people may tend to shy away from risky assets like Tesla or crypto through the Monte Carlo simulations and optimal portfolio calculation it was shown that these assets are important to include. These assets although have a large amount of risk, the investor is compensated for this risk by the very large amount of average return. However, too much risk can be bad so there needs to be a balance. In the case of these assets Amazon was used to balance the risk out in the optima portfolio. Too much risk is not good but as was shown with the lowest sharpe ratio portfolio, too little risk may be even worse. Diversification was also shown to increase the likelihood of outperforming the market compared to each asset by itself, again reiterating the importance of diversification. For investors finding this balance in diversification between risky and non risky assets should be the goal.