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Utilizing Monte Carlo Simulations to Compare the Effectiveness of Stock vs. ETF Portfolios

Abstract:

In the finance sphere, there are countless investment strategies, but one strategy has remained the pillar for decades: buying and holding a portfolio of securities. The only issue with this strategy is deciding what are the best equities to hold, as the market is filled with thousands of companies, ETFs, and Mutual Funds. The purpose of this project is to mathematically examine the benefits and risks associated with two of the most common styles of portfolios: Stock Portfolios and ETF portfolios. Ultimately, through the use of Monte Carlo Simulations this paper is able to compare and contrast the two strategies and their respective effectiveness.

1. Introduction

Since the inception of stock trading investors have been buying and holding stocks, making money by "buying low, and selling high". For the better part of the two hundred years, investors only traded shares of individual companies, meaning investors had to manually diversify their portfolios. However, in 1990 investing changed dramatically, as ETFs were first introduced. An ETF, exchange traded fund, is a type of pooled investment security that operates much like a mutual fund and tracks a selection of securities, but which can be bought and sold on a stock exchange. This new idea fundamentally changed investing in the stock market, as it allowed everyday investors access to diversified managed funds at low costs. Today over 9.9 trillion dollars are invested in ETFs. All in all, the purpose of this paper is to examine the differences between a traditional stock portfolio and an ETF portfolio, which will help investors make informed decisions when investing their capital.

2. Data and Assumptions

The data used in this examination comes from Yahoo Finance Historical Data, which I pulled using the tidyquant package in R. Secondly, in order to run the simulation I made a few key assumptions in order to maintain consistency for both simulations. These assumptions are as follows:

1. Each portfolio starts with $100,000.

2. The Stock portfolio holds 10 large cap equities, all within top 15 of Market Capitalization.
3. The ETF portfolio holds 5 of the largest ETFs by Assets Under Management.
4. Each portfolio holds each security at equal weight, rounding to the nearest whole number to eliminate fractional shares.
5. Each portfolio assumes 5 years of investing.
6. Each Simulation is 1000 iterations.

3. Monte Carlo Simulations

This project utilizes Monte Carlo simulation, which is a model used to predict the probability of a variety of outcomes when a random variable is present. In this case the performance of the underlying security is our random variable, which will be determined by selecting randomly from a normal distribution. Our model then runs the simulation 1000 different times, leaving us with a distribution of outcomes, which can determine the likelihood of specific outcomes after five years.

a. Stock Portfolio

This portfolio holds equal parts of the following ten companies: Apple, Amazon, Microsoft, Google, JP Morgan Chase, Tesla, Nvidia, Visa, Meta, Exxon-Mobil. To determine the portfolio's performance the Monte Carlo Simulation runs 1000 iterations, pulling random returns from a normal distribution, using the historical means and standard deviations of returns. In other words, our model is determining future returns by sampling how the securities performed in the past.

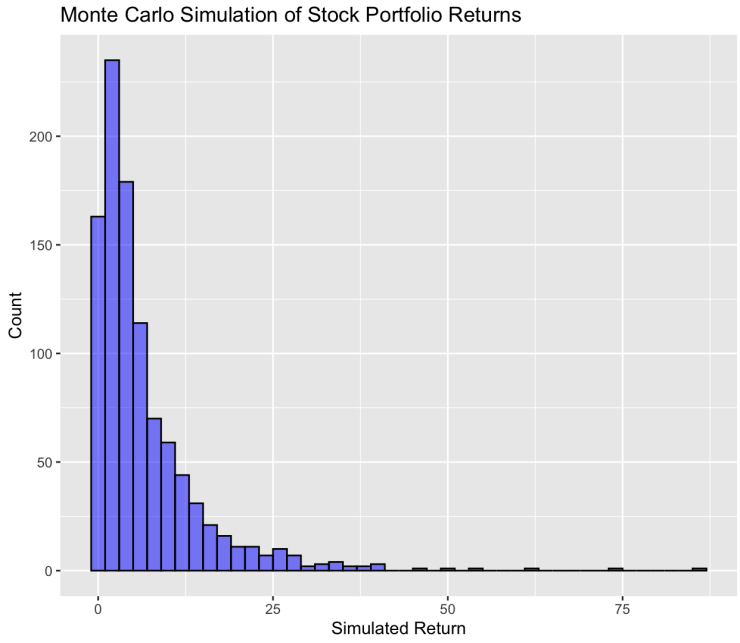

Figure 1. Histogram of Stock Simulation Outcomes.

Our initial results can be seen in the above figure, with this distribution illustrating the number of outcomes with specific return levels. Further statistical investigation shows this particular portfolio performance summary:

Max	Mean	Median	Min
8674%	662%	404%	-66%

Figure 2. Summary Statistics of Stock Portfolio

These summary statistics don't necessarily provide an accurate representation of the probability any of these outcomes will happen, in order to determine that a 95% confidence interval was calculated, which illustrates the performance range where the true value has a 95% chance of lying in. Our confidence interval has the bounds [661.3196%, 663.9202%], meaning this portfolio has a 95% chance of grossing between about 661 and 663 percent over 5 years. These extremely large returns can likely be attributed to the tech stocks, such as Apple and Amazon, that have seen growth of over 200% over the period of historical data. The inherent riskiness of this portfolio can be explained by the standard deviation of the simulation result. This portfolio's standard deviation is 6.626, meaning the data is spread far from the mean. This standard deviation is extremely high meaning this portfolio is exceptionally volatile and can be affected by downward market pressure. This riskiness can be seen by the spread between the best, median, and worst outcomes.

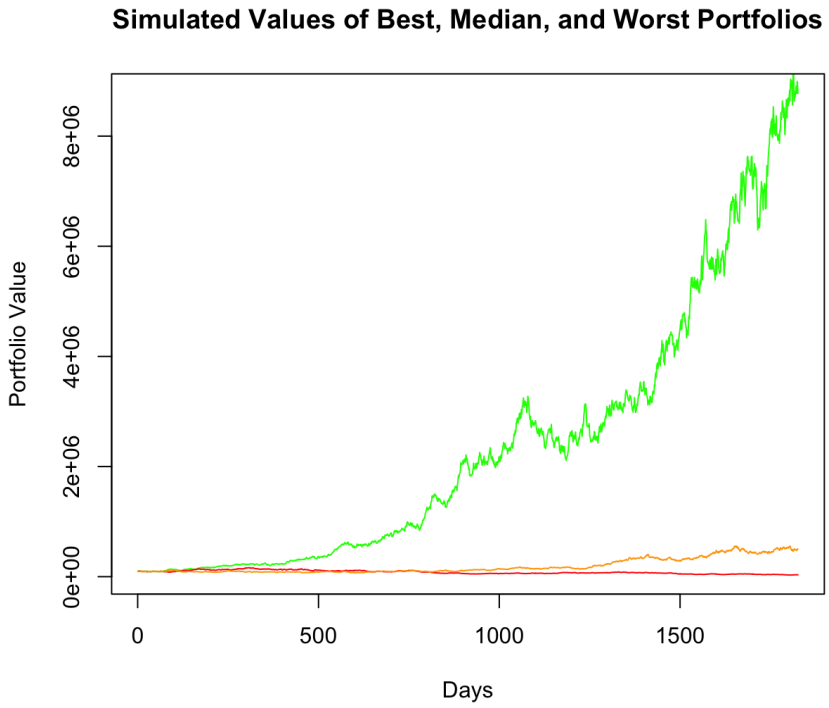

Figure 3. Graph of Best, Median, and Worst Stock Portfolios

As seen in the above graph, the spread between the different outcomes is massive, as the best portfolio has an ending balance of over 8 million dollars, but the median balance being a meager $504,260.30. All in all, this experiment shows the extreme volatility associated with picking individual stocks, where you have a small chance of the portfolio making you a millionaire, but realistically will likely be affected by market volatility and gross much smaller returns.

b. ETF Portfolio

This portfolio holds equal parts of the following five ETFs: Vanguard Total Stock Market Index, Invesco QQQ Trust, SPDR S&P 500 ETF, Vanguard Developed Markets Index, Vanguard 500 Index. This model is run utilizing the exact same procedure as the previous model.

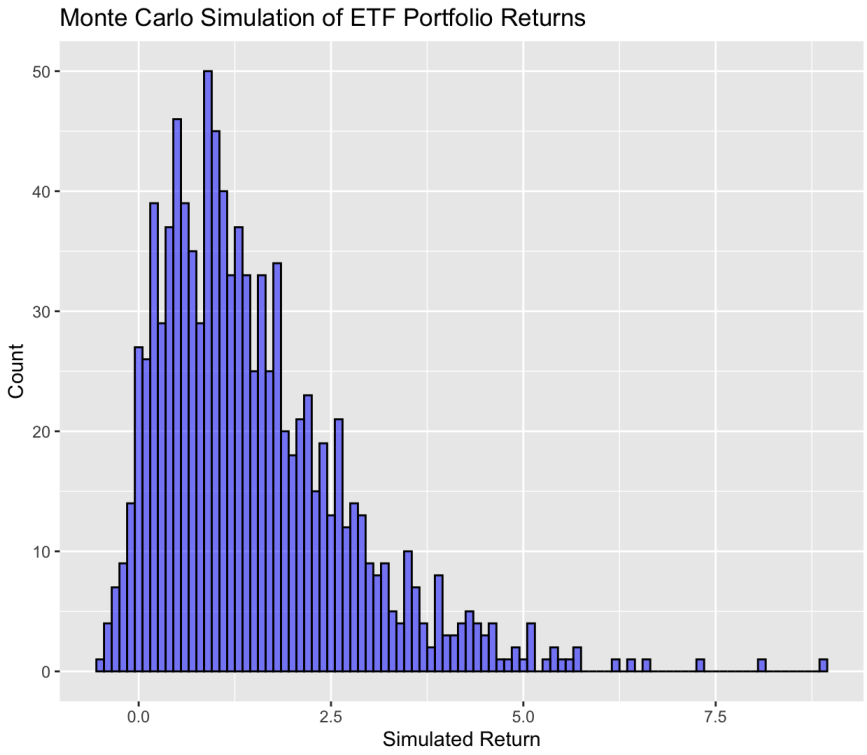

Figure 4. Histogram of ETF Simulation Outcomes.

Upon first glance, the return values are already much lower than the previous simulation, and with a more spread out distribution. The summary statistics for the above distribution are as follows:

Max	Mean	Median	Min
894.65%	149.17%	122.65%	-45.65%

Figure 5. Summary Statistics of ETF Portfolio

These summary statistics, already allude to a smaller variance in results, as the difference between the maximum and mean performances are already much smaller. The 95% confidence interval for the ETF portfolio is as follows: [148.8789%, 149.4644%]. The smaller returns are due to the construction of an ETF, as each ETF is a collection of 100s of securities giving the investor unmatched diversification. This diversification allows the investor to expect reasonably consistent performance over time, this can be illustrated by the standard deviation of this model. The ETF portfolio's standard deviation is 1.249715 which is just about 5 standard deviations less

than the stock portfolio. This decreased volatility can be seen in the graph of the spread between the best, median, and worst performing portfolios, where all returns are under a million dollars.

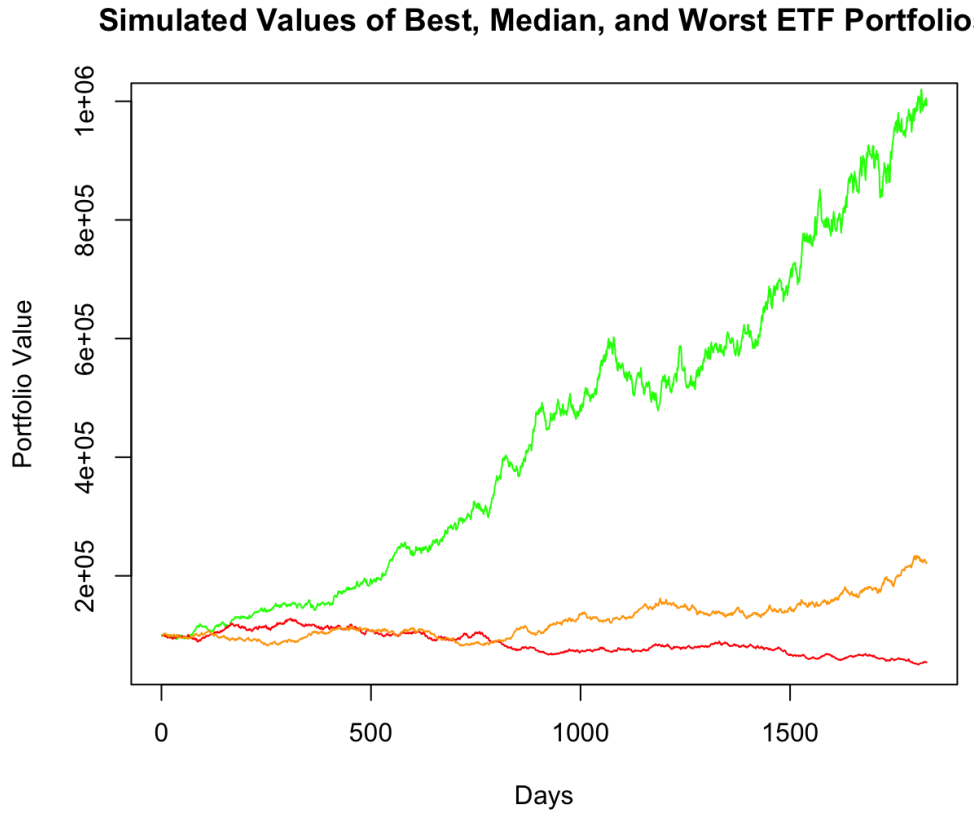

Figure 6. Graph of Best, Median, and Worst ETF Portfolios

4. Conclusion

All things considered, both syles of portfolio consdtruction are profitable, and both are used everyday by investors around the world. This paper has gone to show the extreme risks associated with investing, and how diversification can minimize said risk and provide some consistency. As the simulated ETF portfolio had a small standard deviation of 1.249715, meaning the variance in results was relatively small. Ultimately, in general ETF investing is safer in the long run, which is why the over 30% of retail investors use this strategy. However, this paper proved that if you pick the right company returns can be exponential, as with company such as Apple gaining over 200% in just 5 years. Nevertheless, this paper drives home the point that money in the market is better than money sitting in banks, as both portfolios had exceptional returns that now 5 year CD or savings account could match.