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Analysis of Growth Performance of Actively and Passively Managed Retirement Portfolios

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A. Project Highlights

A1. Research Question

When comparing historical data of a group of Target Date Retirement funds against a group of index fund Exchange Traded Funds (ETF), is there a noticeable difference in theoretical returns? When conducting simulations of contributions to these funds, do the practical results (simulation) reinforce the theoretical results?

Context and Background

Using tax-advantaged retirement accounts to invest in "Target Date Retirement Funds" or index fund ETFs can both be considered viable "hands-off" approaches when it comes to saving for retirement. The "hands-off" and "set it and forget it" philosophies entail contributing to a fund (or fund portfolio) for a consistent long-term basis. Using this approach, there is typically no selling of securities until it is time for an overall portfolio rebalance as one nears retirement. This practice applies the concept of having "time in the market" rather than "timing the market", under the assumption that, generally, the value of stocks will increase over time. If there is a significant difference in performance in a certain group of funds compared to the other, it may be worth exploring options within that group of funds in order to maximize potential returns over time.

A2. Project Scope

This project analyzes performance of a select group of "Target Date Retirement Funds" for active funds and a select group of index and ETFs as passive funds. A ten-year range of historical data will be used for all securities within each group of funds. The scope of this project excludes all other stocks and funds that were not selected for analysis. To gauge hypothetical performance and growth, the difference in market 'Close' price between the start of the selected time period and end of the selected time period will be used. A percentage change calculation will be appropriate for this. To measure the performance of simulated returns, we can use the market value of our simulated holdings for each simulation. This can be derived by multiplying simulated number of purchased shares by the 'Close' price at the end of the simulated range.

A3. Project Overview

To conduct our analysis and testing, the Python programming language and a Jupyter Notebook environment will be used. This will allow us to execute segments of code while providing easily readable documentation as well as visualizations. To determine whether there is a significant difference between each group of funds, we can confirm that the datasets follow a normal distribution and use an independent t-test. If we find that the distributions are not normal, we can use bootstrapping as an alternative testing method.

B. Project Execution

B1. Project Plan

The Project Plan is detailed below:

Goal: The goal of this project is to compare performance of various stock market securities falling into two categories, actively managed funds and passively managed funds, in order to determine whether there was a significant difference in performance over a set period of time.

- Objective 1.1: Data Retrieval
    - Deliverable 1.1.1: Downloaded and cleansed a dataset containing historical passively managed fund closing prices.
    - Deliverable 1.1.2: Downloaded and cleansed a dataset containing historical actively managed fund closing prices.
- Objective 1.2: Simulate Investments
    - Deliverable 1.2.1: Dataset containing simulated investment contributions into passively managed funds at historical closing prices.
    - Deliverable 1.2.2: Dataset containing simulated investment contributions into actively managed funds at historical closing prices.
- Objective 1.3 Conduct Statistical Analysis of Datasets
    - Deliverable 1.3.1: Descriptive summary statistics, t-test results, and visualizations of historical stock market closing prices, showing potential returns.
    - Deliverable 1.3.2: Descriptive summary statistics, t-test results, and visualizations of simulated returns.

Since each step of the implementation yielded the expected results, I did not need to deviate from this plan. All execution steps were documented in the Jupyter notebook and visualizations were provided for each stage of the process.

B2. Project Planning Methodology

The learning and development methodology used for this project is the ADDIE framework. The acronym ADDIE can be expanded to Analyze, Design, Develop, Implement, and Evaluate. When conducting research for this project, I was on the Analyze step. This document itself is part of the Design process. While developing the application to retrieve the necessary datasets and apply transformations, I was in the Develop phase of the process. The final analytics and testing are the implementation stage, and the evaluation phase is being executed through this document.

B3. Project Timeline and Milestones

The resulting timeline of the project matched up to the planned timeline and can be viewed below:

Milestone or deliverable	Duration (Hours or days)	Actual start date	Actual end date
Retrieve and clean datasets (Objective 1.1)	8 hours	*8/29/2023*	*8/29/2023*
Simulate investment contributions (Objective 1.2)	24 hours	*8/29/2023*	*8/30/2023*

Conduct analysis and testing, including visualizations (Objective 1.3)	48 hours	*8/29/2023*	*8/31/2023*

C. Data Collection Process

The data was collected by utilizing the yfinance library in Python. I developed a python module that contains functions to accept parameters specifying a time range as well as ticker symbols and retrieves the historical market data for that ticker over the specified time range.

The yfinance and Yahoo Finance application program interfaces (API) do have limitations so I ensured that I use a cache to prevent unnecessary API requests that may have exceeded any limits and produced corrupted data. There were no deviations from the project plan in this aspect, as I conducted the necessary research prior to execution and was able to plan accordingly.

C.1 Advantages and Limitations of Data Set

An advantage of the dataset that was selected was that the yfinance library produced all necessary data in a dataframe that is ready for cleansing, processing, and analysis. Another advantage is that the data was easily accessible. A disadvantage of the dataset is that there are rate and request limits when retrieving the data; however, this was handled by caching and no problems were encountered as a result of this.

D. Data Extraction and Preparation

For data processing, there were numerous steps required. The raw data was in great shape when retrieved from yfinance; however, analysis and processing needed to be conducted in order to determine which ticker symbols and which date ranges to use for analysis. I tickers and date ranges where there was an even number of tickers within each fund group that had sufficient data over a ten-year range. Dumbbell plots and line plots help visualize the data during the process.

Once the base dataset was prepared, different processing steps were required for each statistical test. The hypothetical performance required comparing 'Close' prices for each ticker at the beginning and end of the target date range and calculating the percentage change. Since the stock market is volatile and prices fluctuate, I used a 30-day moving average to help smooth the data. The simulated data required creating a dataframe where investments were made, and shares were purchased on evenly spaced dates throughout the dataframe. This required developing multiple functions to create the dataframe; however, the execution of these functions resulted in a dataframe that was ready for analysis and testing.

E. Data Analysis Process

E.1 Data Analysis Methods

To visualize the performance of each fund category, I used various visualizations including boxplots and kernel density estimators. The boxplots help visualize the spread and central tendency of each dataset and provide a way to compare the different categories against one another. The kernel density estimator can provide a more nuanced approach compared to a histogram when dealing with smaller distributions. The kernel density estimator also helps ensure that our data follows a normal distribution, which makes the t-test an appropriate choice for comparing the datasets.
For statistical testing, I conducted an independent t-test to generate p-value for all datasets. Using industry standards, I set an alpha threshold of .05. If the p-value exceeds the alpha, it indicates acceptance of the null hypothesis whereas a p-value less than the alpha rejects the null hypothesis.

E.2 Advantages and Limitations of Tools and Techniques

The primary tool that I used for this study is the Python programming language. I also utilized a Jupyter notebook environment to help document the process and visualize any plots. Some key advantages to these tools are:

- Python
    - Lightweight
    - Numerous statistical, data processing, and data visualization libraries that provide a lot of functionality with very little code required.
- Jupyter Notebook
    - Facilitates executing code in cells or reproducible chunks.
    - Allows documentation and visualizations alongside code.

There are some disadvantages as well:

- Python:
    - Inefficient performance compared to compiled programming languages.
- Jupyter Notebook:
    - A lot of overhead required due to dependencies.

The t-test itself can also have limitations in that it may not be very accurate when used on datasets that do not follow the normal distribution.

E.3 Application of Analytical Methods

The following analytical methods and steps were used:

- Used visualizations to deduce the best date range and best ticker symbols to use for testing.

- Visualized distributions of each fund group's data to understand differences from each dataset (showing that passively managed funds tended to outperform actively managed funds).
- Generated simulated investment contribution dataset based on individual retirement account (IRA) contribution limits and market 'Close' prices on specific date intervals.
- Conducted verifications of datasets to ensure that all processing and analytic steps were accurate and did not unintentionally corrupt or skew the data.
- Visualized distribution of simulated datasets to ensure conformity and that it was appropriate for a t-test.
- Conducted independent t-tests and compared p-values to alpha values to determine whether differences in data were significant.

F Data Analysis Results

F.1 Statistical Significance

There were two separate statistical tests conducted during this study, both being independent t-tests. The first was a test of hypothetical growth for both fund categories, active and passive. The second test was conducted on simulated returns for each fund category. For each test, if the calculated p-values were less than the alpha value of .05, it would indicate rejection of the null hypothesis, which states "no significant difference in performance between each category of funds". However, if the p-values exceeded the alpha, it would indicate acceptance of the null hypothesis.

Furthermore, the sign of the t-statistic that is output from the test would indicate which dataset had a higher mean. This, combined with a p-value less than the alpha, would help identify which group of funds may have performed better of the historical time range.

The results of both tests produced p-values less than the alpha and also generated negative t-statistics. Based on our aforementioned testing conditions, I was able to conclude that passively managed funds did significantly outperform actively managed funds during the date range in scope. This is in line with the original hypothesis.

F.2 Practical Significance

While this study was not intended to provide any financial, tax, or legal advice or recommendations, it can be a useful starting point when determining where to invest retirement funds in order to maximize growth. In real life applications, I would use this approach created for this project and conduct further research, attempting to include additional funds and longer date ranges. If additional testing reinforces the results this study produced it can be a good indicator of which type of funds to consider investing in when attempting to maximize returns of retirement contributions over time.

F.3 Overall Success

Due to the research conducted prior to starting this project, the strategic data processing, and appropriate testing completed I would consider this project to be a successful analysis of Target Date Retirement Fund performance compared to index fund ETF performance. The results of the study have inspired me to continue my research to conduct more in-depth analytics on a broader scope of market securities and date ranges.

G. Conclusion

G.1 Summary of Conclusions

The key takeaway from the results of this project and testing that was conducted are that for the time period and ticker symbols analyzed, passively managed index fund ETFs significantly outperformed actively managed Target Date Retirement Funds. While past performance does not always guarantee future results, this study does provide good evidence that the index fund ETFs have more spread and can generate greater returns over time compared to the actively managed funds that were analyzed.

G.2 Effective Storytelling

The data visualizations generated during this project helped us understand the data during each stage of processing as well as provided visual evidence that supported the results from statistical testing. The dumbbell chart and line charts showing which funds had data for which ticker symbols over time were instrumental in deciding an optimal date range and selection of ticker symbols to use for the project.

The distribution of returns was plotted as boxplots which showed much higher returns overall for passively managed funds when compared to the active funds. The kernel density estimator helped visualize the curve of the distributions and also provided insight into where each fund type had more or less density when measuring returns.

G.3 Recommended Courses of Action

Since I am using this project as a steppingstone for more complex and in-depth analysis, I can provide details of my plan of action. The first course to take would be to identify larger groups of ticker symbols for each fund type. Methods can be applied to handle missing data so that we can utilize larger date ranges and still include securities that may not have historical market data over the entire range. The second course would be to take this larger dataset and conduct more complex analysis. Not only can we analyze historical performance, but we can also estimate and forecast future performance by using the multitude of data science libraries available. This subsequent testing can either further support the results of this project or can actually challenge the results. The output of the testing can help drive actionable insights when it comes to maximizing growth when investing for retirement.

H Panopto Presentation

Panopto Link: https://wgu.hosted.panopto.com/Panopto/Pages/Viewer.aspx?id=110a38e5-839f-42d3-

Appendix A

References

Python yfinance library: https://pypi.org/project/yfinance/