Monte Carlo Simulations for Retirement Planning

Submitted by

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Chapter 1

Introduction

1.1 Problem Statement

In today's uncertain economic environment, planning for retirement has become more complex than ever. Individuals need robust tools to project their financial future, accounting for variables such as investment returns, inflation, and spending patterns. This project aims to address this need by developing a comprehensive Monte Carlo simulation tool to assist individuals in both pre-retirement and retirement planning stages. By utilizing probabilistic modeling, this tool provides a realistic picture of financial outcomes, helping users make informed decisions.

1.2 Dataset Description

Two primary datasets are used in this project: DeathProbsE_M_Alt2_TR2022.csv and DeathProbsE_F_Alt2_TR2022.csv. These datasets contain mortality projections for males and females, respectively, sourced from Social Security data. The datasets include:

- Age: The age of individuals, ranging from 0 to 119 years.
- Probability: The probability of death for each age, representing the likelihood that individuals of a certain age will die within the next year.
- Year: The year for which the probability is calculated.
- Gender: Included in the data to differentiate between male and female mortality probabilities.

These mortality projections are essential for modeling retirement scenarios, particularly for estimating the probability of an individual's survival each year. The datasets are processed and transformed into a long format for easier analysis, creating a comprehensive view of mortality probabilities by age and gender. Additional datasets for stock and bond return distributions, as well as inflation rates, are synthesized based on historical data and user inputs to create realistic scenarios for financial growth and spending.

1.3 Objective

The objective of this project is to develop an interactive Shiny application that enables users to run Monte Carlo simulations for both pre-retirement and retirement phases. Users can input their financial data, such as current age, income, spending, and investment allocations, and receive a detailed analysis of potential outcomes. The application aims to provide a clear, visual representation of the likelihood of achieving financial independence, sustaining retirement spending, and the risks of running out of money.

1.4 Novelty

This project stands out from existing solutions by offering a comprehensive, user-friendly tool that integrates both pre-retirement and retirement planning into a single application. While many financial planning tools focus solely on one phase, this tool provides a seamless transition from accumulation to decumulation, ensuring continuity in planning. Furthermore, the use of Monte Carlo simulations adds a layer of sophistication by modeling a wide range of possible outcomes, allowing users to see not just the most likely scenario, but also the best and worst-case scenarios.

Chapter 2

Justification of Approach

2.1 Why Monte Carlo?

Monte Carlo simulations were chosen for this project due to their ability to model financial uncertainty in a robust and comprehensive manner. Financial planning for retirement involves numerous unpredictable factors, including stock and bond returns, inflation rates, and changes in personal spending. Traditional deterministic models often provide a single projected outcome based on fixed inputs, failing to account for the inherent variability in these factors. Monte Carlo simulations, however, use random sampling to generate a multitude of possible scenarios, offering a more realistic and nuanced view of potential futures.

2.2 FIRE (Financial Independence, Retire Early)

FIRE is a movement that emphasizes extreme savings and investment to achieve financial independence and retire significantly earlier than traditional retirement ages. The core principle of FIRE is to accumulate sufficient wealth so that investment returns can cover living expenses, allowing individuals to retire early and pursue other interests without the need for paid employment.

Key components of FIRE include:

- **Aggressive Savings:** A high savings rate, often 50-70% of income, is maintained to rapidly build a substantial investment portfolio.
- **Frugality:** Emphasis on minimizing expenses to maximize savings.
- **Investing:** Investing in a diversified portfolio, typically including stocks, bonds, and real estate, to grow wealth over time.
- **Withdrawal Rate:** Using a safe withdrawal rate (commonly 3-4%) to determine how much can be withdrawn from the investment portfolio annually without depleting the principal.

2.3 How FIRE is Used?

In this project, the concept of FIRE is integrated into the Monte Carlo simulations to help users plan for early retirement. The simulations assess whether users can achieve financial independence by projecting their investment growth, income, and spending patterns over time. Key aspects of FIRE incorporated in the simulations include:

- **Savings and Investments:** The simulations model the growth of savings and investments, considering contributions from income and returns from the stock and bond markets.
- **Spending:** Annual spending is adjusted for inflation, and the impact of spending on the investment portfolio is analyzed.
- **FIRE Target:** The simulations calculate a FIRE target, representing the amount of savings

needed to support a user's desired retirement spending through investment returns. This target is adjusted for inflation over time.
- **Withdrawal Rate:** The project models the safe withdrawal rate during retirement to ensure the sustainability of the user's portfolio.

By using Monte Carlo simulations, the project provides a realistic and probabilistic assessment of the likelihood of achieving FIRE, accounting for various uncertainties in financial markets and personal circumstances.

Chapter 3

Simulations

3.1 Parameters and Variables

3.1.1 User Inputs

- Current Age: The starting age of the simulation.
- Retirement Age: The age at which the individual plans to retire.
- Gender: The gender of the individual, used for mortality projections.

3.1.2 Financial Parameters

- Yearly Income ($): The annual income before retirement.
- Yearly Pre-Retirement Spending ($): The annual spending before retirement.
- Income Growth Percentage: The annual growth rate of income, representing expected increases in earnings.
- Brokerage Investments ($): The current amount invested in brokerage accounts, serving as the starting value for investment growth.
- Brokerage Stock Percentage: The percentage of brokerage investments allocated to stocks.
- Average Tax Rate Percentage: The average tax rate applied to income and investments.

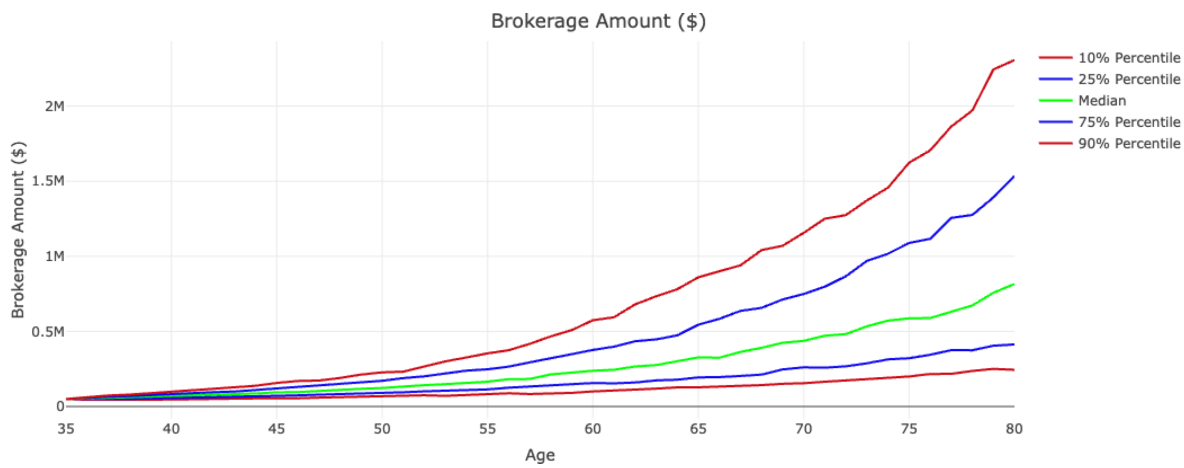
3.1.3 Simulation Parameters

- Average Stock Return Percentage: The mean annual return on stocks, representing the average expected performance of stock investments.
- Stock Return Percentage Standard Deviation: The volatility of stock returns, indicating how much stock returns are expected to fluctuate around the average.
- Average Bond Return Percentage: The mean annual return on bonds, representing the average expected performance of bond investments.
- Bond Return Percentage Standard Deviation: The volatility of bond returns, indicating how much bond returns are expected to fluctuate around the average.
- Average Inflation Percentage: The mean annual inflation rate, used to adjust future spending and the FIRE target.
- Inflation Percentage Standard Deviation: The volatility of inflation rates, indicating how much inflation rates are expected to fluctuate around the average.
- Target Withdrawal Rate Percentage: The desired annual withdrawal rate in retirement, used to calculate the FIRE target.
- Yearly Retirement Spending ($): The expected annual spending in retirement.

3.2 Pre-Retirement Simulation

The pre-retirement simulation is a crucial part of the financial planning tool, designed to model the financial trajectory of an individual from their current age until they reach retirement. This simulation helps users understand how their investments might grow over time, how their income and savings might change, and whether they will meet their Financial Independence, Retire Early (FIRE) target. These are example graphs that represent the simulations.

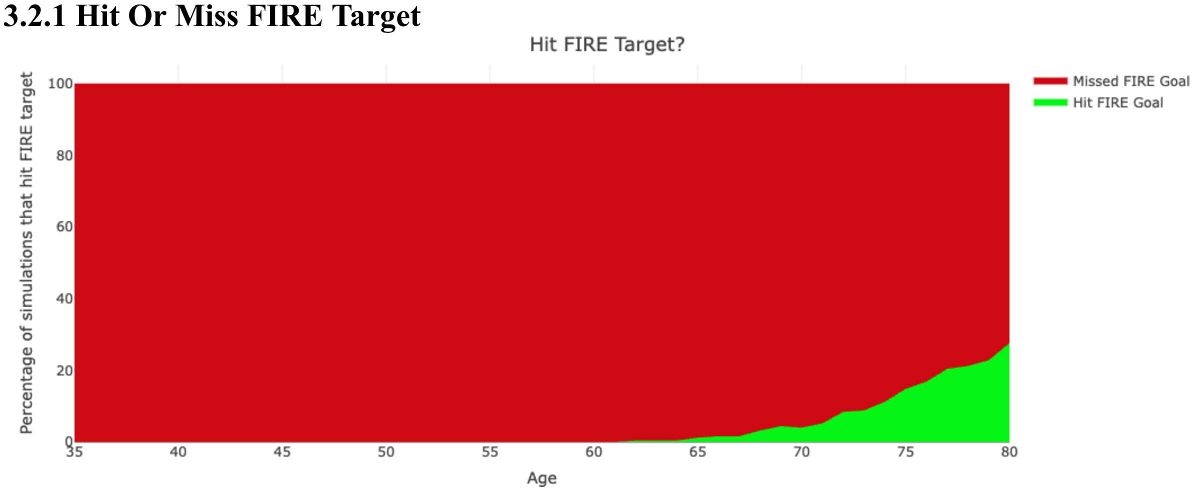
3.2.1 Brokerage Amount Percentiles Before Retirement



This plot displays the brokerage amount at different percentiles over time, from the starting age (e.g., 35) to retirement age (e.g., 80).

Example: 10th Percentile (Red Line): Represents the value below which 10% of the simulations fall. It shows the worst-case scenario for brokerage growth.

3.2.1 Hit Or Miss FIRE Target



This plot shows the percentage of simulations that hit the FIRE target at different ages.

- Missed FIRE Goal (Red Area): Represents the percentage of simulations that did not meet the FIRE target.

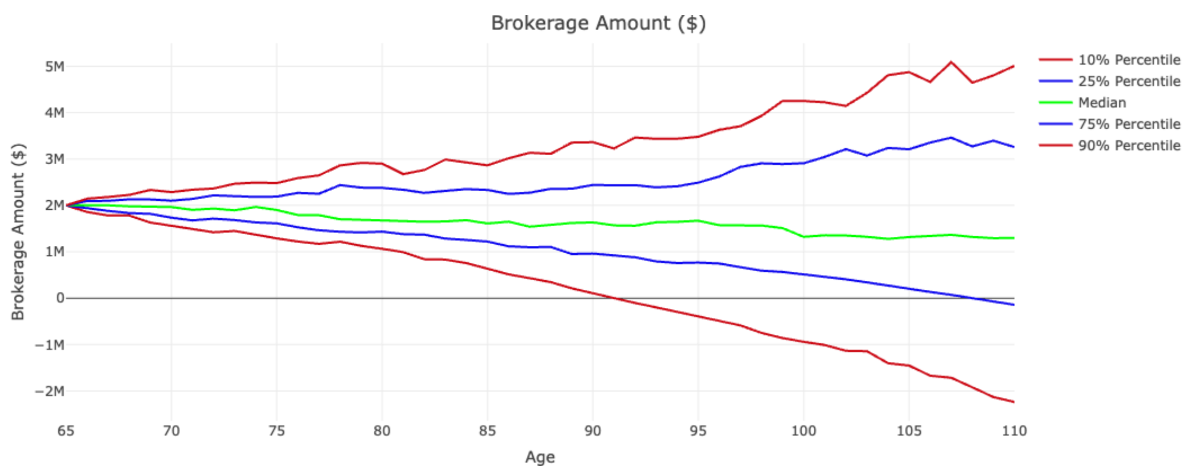
0 Hit FIRE Goal (Green Area): Represents the percentage of simulations that met or exceeded the FIRE target.

This plot illustrates how likely it is for the user to achieve financial independence at various ages, based on their current savings, income, spending, and investment returns.

3.3 Pre-Retirement Simulation

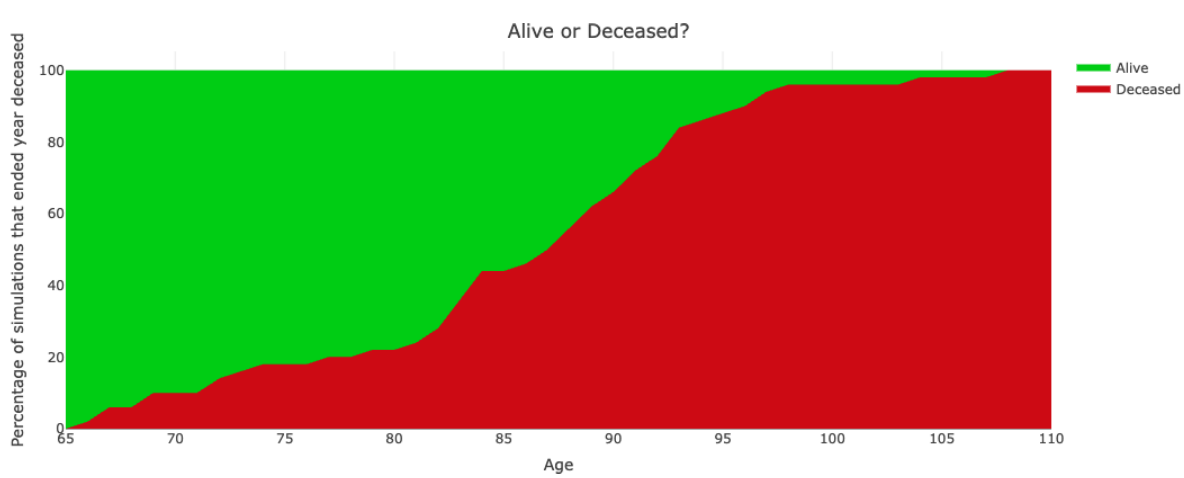
The retirement simulation is an essential part of the financial planning tool, designed to model the financial trajectory of an individual from the point of retirement until the end of life. This simulation helps users understand how their investments might deplete over time, how inflation impacts their spending, and the probability of running out of money during retirement. The following sections provide a detailed explanation of the retirement simulation process, including the function description, parameters and variables, key calculations, and visualizations to illustrate the outcomes. These are example graphs that represent the simulations.

3.3.1 Brokerage Amount Percentiles During Retirement



This plot displays the brokerage amount at different percentiles over time, from the point of retirement (e.g., age 65) to the end of life (e.g., age 110).
This plot helps users understand the range of potential brokerage values they might have during retirement, considering the variability in stock and bond returns and annual withdrawals.

3.3.2 Probability of Being Alive or Deceased



This plot shows the percentage of simulations where the individual is alive or deceased at different ages.

- Alive (Green Area): Represents the percentage of simulations where the individual is alive.
- Deceased (Red Area): Represents the percentage of simulations where the individual has passed away.

This plot illustrates the mortality risk at various ages, helping users understand the likelihood of survival year by year during retirement.

3.3.3 Probability of Asset Depletion

This plot shows the percentage of simulations where the retirement savings are depleted at different ages.

- Available Money (Green Area): Represents the percentage of simulations where the brokerage amount remains positive.
- Broke (Red Area): Represents the percentage of simulations where the brokerage amount is depleted.

This plot illustrates the risk of running out of money during retirement, helping users understand how long their savings might last under different scenarios.

Chapter 4

Limitations & Future Directions

4.1 Limitations

4.1.1 Scope and Accuracy

- Assumptions: Simulations rely on constant mean returns and standard deviations, which may not reflect real market variability.
- Data Limitations: Historical data may not represent future market conditions; mortality data may not account for future trends.
- Simplifications: The model assumes constant withdrawal rates and yearly rebalancing, which may not match actual behaviors.
- Potential Inaccuracies: Using normal distributions may miss extreme events, leading to inaccurate risk assessments.

4.1.2 Impact on Performance

- Predictive Accuracy: Assumptions and simplifications may cause discrepancies between simulated and real-life outcomes.
- Risk Assessment: Missing extreme events can result in incomplete risk assessments, risking unexpected financial shortfalls.
- User Confidence: Potential inaccuracies may affect user confidence in the results; clear communication of limitations is essential.

4.2 Future Directions

4.2.1 Improvements

- Enhanced Data Sources: Use broader historical data and updated life expectancy data to improve accuracy.
- Advanced Modeling: Implement stochastic processes or fat-tailed distributions for better risk assessment.
- Dynamic Spending Models: Include models for changing spending behaviors during retirement.
- Personalization: Allow more personalized inputs, such as different investment strategies and tax considerations.
- UI Enhancements: Improve visualizations and add features like scenario comparison and sensitivity analysis.

4.2.2 Applications

- Comprehensive Planning: Adapt the tool for other long-term goals like education savings and home purchases.
- Risk Management: Provide more accurate risk assessments for better financial strategies.
- Financial Education: Use the tool to educate users on financial planning and investment strategies.
- Policy Analysis: Help policymakers and advisors analyze the impact of policy changes on retirement planning.
- Customized Advice: Enable financial advisors to offer tailored advice based on improved simulations.