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MONTE CARLO IS NOT JUST A CASINO IN MONACO

Monte Carlo simulation was popularized by mathematicians Stanislaw Ulam, John von Neumann, Nicholas Metropolis and physicist Enrico Fermi, in the 1940s. The computational method was named Monte Carlo after the famous casino in Monaco by Stanislaw Ulam in honor of his uncle who was a gambler, because of the technique's use of random numbers.

Today, we will discuss the following:

- Clarify what is meant by Monte Carlo simulation
- Discuss some of the uses of Monte Carlo at TIAA-CREF such as with our Life Cycle Funds
- Explore the features of Monte Carlo which have made it such a widespread and successful technique

Monte Carlo simulation is used to approximate the value of unknown quantities, say a future portfolio return ending 20 years from now. The Monte Carlo method works by transforming the unknown quantity into a sum of numbers or variables that are picked randomly according to certain rules. In effect, by drawing values from a statistical distribution over and over—say 5,000 or 10,000 times—a Monte Carlo simulation tries to approximate the chances that a certain outcome will occur. Alternatively, it can be used to find the most likely outcome.



Since the 1940s, there has been exponential growth in the use and application of the technique. This growth has been significantly aided by the availability of increasingly powerful computers. Monte Carlo simulation has many applications in finance but is also used to solve problems in physics, mathematics, statistics, biology, and other fields. It might be worth noting that Monte Carlo simulation (or technique) is a general computational method that is not owned by anyone. However, there are many proprietary applications, such as the Ibbotson advice model used at TIAA-CREF and derivatives pricing models, that are sold which use Monte Carlo simulation as a tool to perform calculations. In addition, Monte Carlo simulation is not the only estimation technique in use; in fact, there are other estimation techniques that do not employ random numbers.

In finance, Monte Carlo simulation has been used with great success to address asset allocation issues. An example of this is our use of Monte Carlo simulation during our recent research assessing the Life Cycle Fund allocations. Overall, Monte Carlo simulation was used to compare the performance/risk or return/volatility characteristics of the Life Cycle fund using various asset allocation mixes. The result of this analysis was incorporated with business constraints to determine optimal weights for the underlying assets within our Life Cycle fund.

For example, Monte Carlo simulation was used to assess various Life Cycle fund designs in terms of the chances that a Life Cycle fund would be able to replace an adequate portion of a participant's final salary. It was also used to assess Life Cycle fund risks, including the fund's expected volatility, as well as its chances of being "underwater" (accumulated assets in the Life Cycle fund will be less than total contributed premiums at any point over the life of the fund.) These calculations were done to compare the effects of using different asset allocation mixes.

Monte Carlo simulations were also used to calculate the estimated distribution of fund returns at the end of each year over the life of the fund and the distribution of accumulated assets at end of each year of the fund's life.

Another area where Monte Carlo simulation has been applied is risk management, where the technique has

been used to quantify market risk. In this application, risk managers wish to understand how the value of an investment portfolio changes in response to changes in the underlying sources of risk, such as:

- Economic factors—interest rates, inflation, gross domestic product, etc;
- Financial factors—market indices, yield curves, exchange rates, etc; and
- Fundamental factors—price/earnings ratios, dividend yields, etc.

To analyze market risk, Monte Carlo simulation is used to estimate the chances that a portfolio will gain or lose money over some fixed horizon. Such an analysis could be used to meet an internal risk management or external regulatory requirement.

Yet another very important area in finance where Monte Carlo simulation is widely used is asset pricing. The following example illustrates how the Monte Carlo method is used to determine the price of a stock option, one example of a derivative security. Derivatives are financial instruments that derive their value from an underlying security, in this case the price of the underlying stock. The Monte Carlo simulation process to price a stock option consist of three steps:

Step (1)—use random numbers to simulate the movement of the stock price between now and some fixed future date

Step (2)—calculate the present (i.e., discounted) value of the option payoff (or value) for each simulation

Step (3)—repeat Steps (1) and (2) 10,000 times and then average all the present values and this gives you the price of the stock option.

Monte Carlo simulation has a number of highly desirable features that have contributed to its widespread use and success. Some of these properties are as follows:

- Flexibility to solve problems that are very difficult to solve by other means

- Ability to obtain more precision in approximating possible outcomes
- Availability of techniques to increase speed and efficiency
- Non degradation of accuracy with increasing problem complexity

In summary, the Monte Carlo method is a very flexible tool that transforms complex (difficult-to-solve or possibly intractable) problems into (easy-to-solve) random problems. The method is widely accepted and used in finance and it has proved helpful at TIAA-CREF and elsewhere in improving products and services for institutions and individuals, such as Life Cycle Fund design, asset allocation models, and derivatives pricing.

IMPORTANT: Please note that while mathematical simulations can be useful tools in portfolio management, no method of simulation can accurately predict future outcomes or guarantee a profit or protect against loss.

You should consider the investment objectives, risks, charges and expenses carefully before investing. Please call 877-518-9161 or go to www.tiaa-cref.org for a current prospectus that contains this and other information. Please read the prospectus carefully before investing.

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