

# APPLIED FINANCE

Lecture 5



What is Monte Carlo simulation?

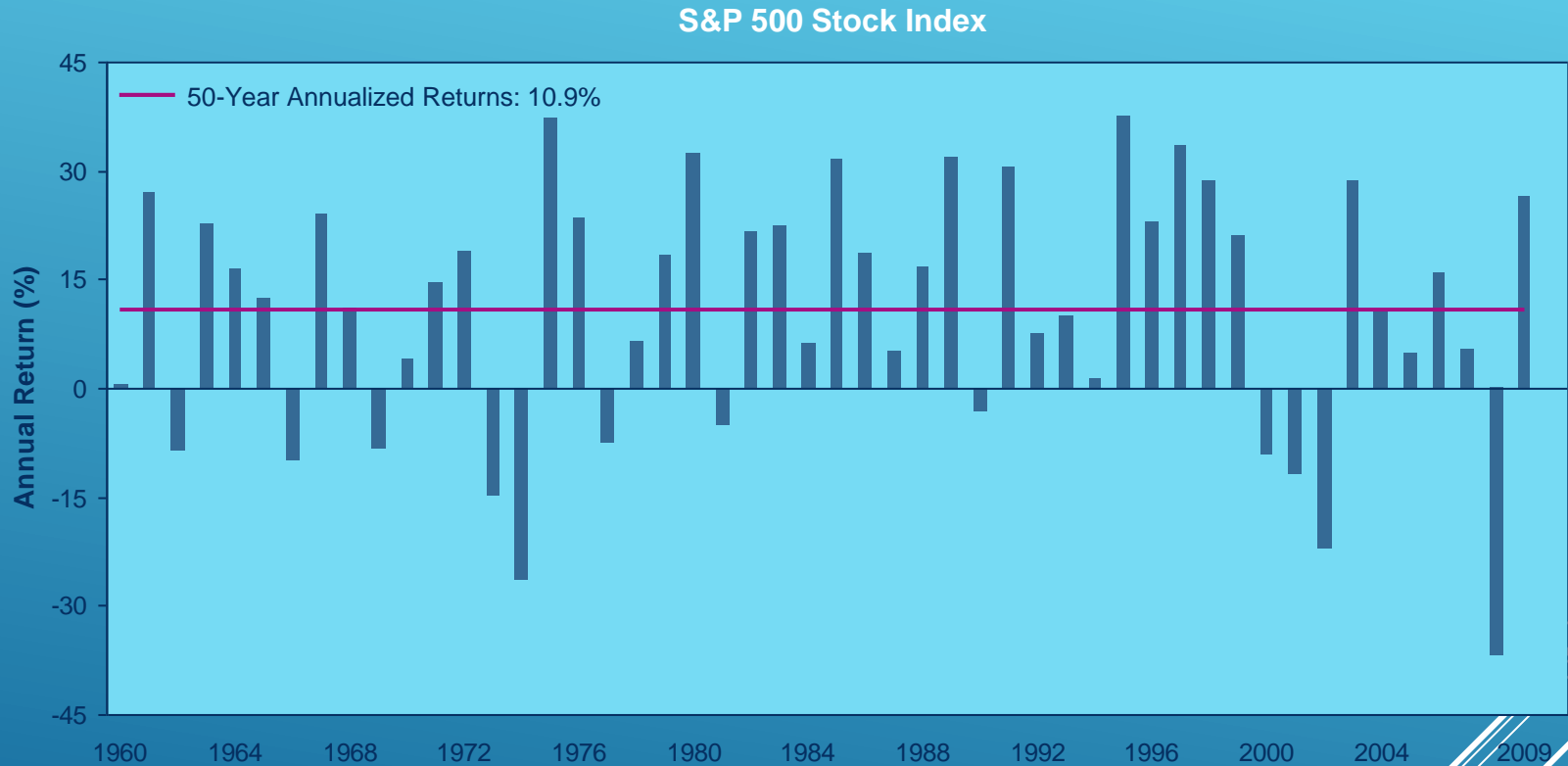
- ▶ Why use it?
- ▶ What factors affect Monte Carlo simulation?
- ▶ How does it work?
- ▶ What questions can Monte Carlo simulation help answer?

# MONTE CARLO SIMULATION

- ▶ Analytical tool for modeling future uncertainty
- ▶ First used in scientific computing when developing the hydrogen bomb

## WHAT IS MONTE CARLO SIMULATION?

# WHY USE MONTE CARLO SIMULATION?

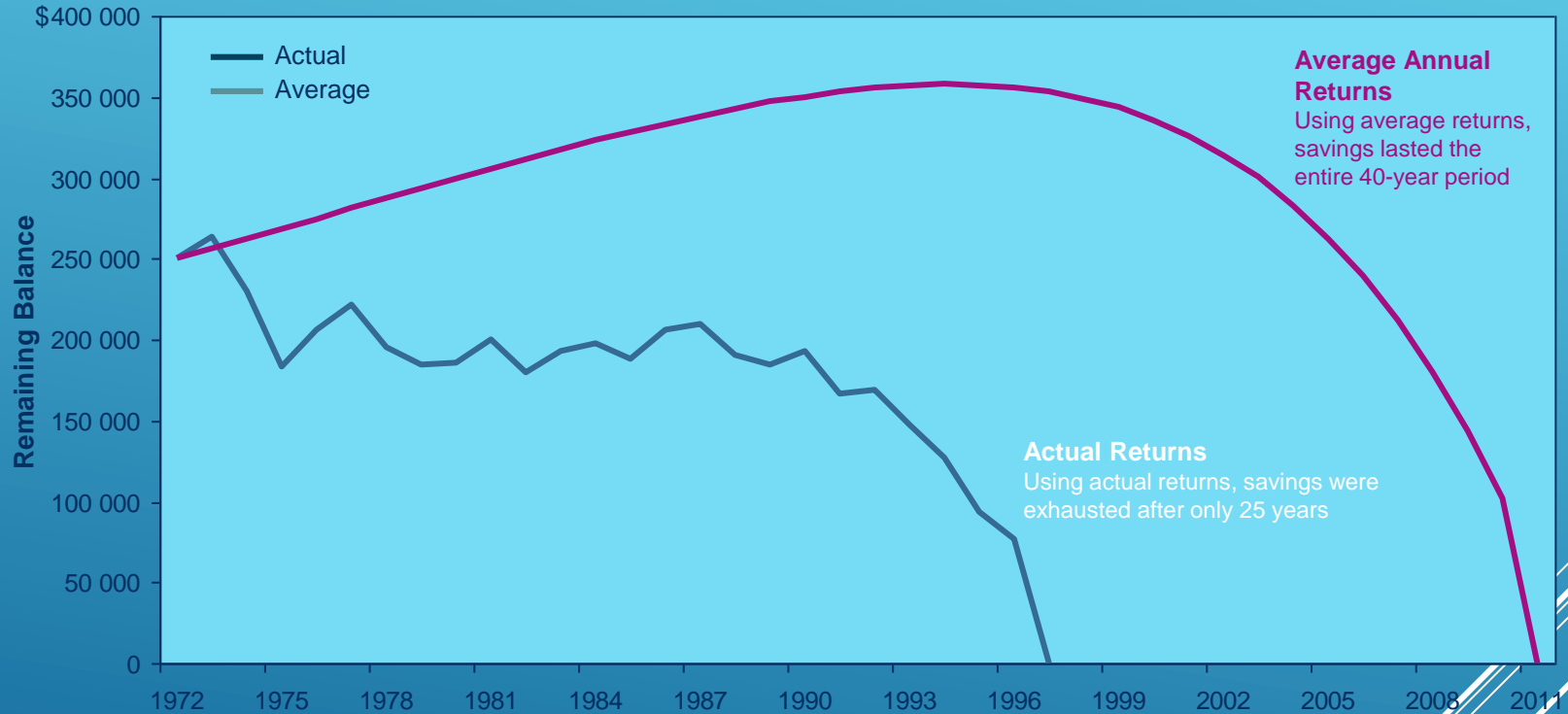


Using the average returns for analyses may be risky since there are only two years when the annual returns are at the 50-year average of 10.9%.

4

# AVERAGE AND ACTUAL RETURNS TELL DIFFERENT STORIES

Drawdown Strategies  
40 Years of Actual Annual Returns vs. Average Annual Returns



Assumes a \$250,000 portfolio and a 6.83% initial withdrawal amount increased by 3% each year for inflation. Withdrawals are made at the start of each year. Taxes on any investments and required minimum distributions for tax-deferred assets are not considered in this illustration. Portfolio performance is based on historical returns of a portfolio composed of 60% S&P 500 Index, 30% intermediate government bonds, and 10% 30-day Treasury bills. Assumes annual rebalancing.

Sources: Ibbotson, T. Rowe Price

## Simulation factors:

- ▶ Universe of asset classes
- ▶ Expected returns for asset classes (net of expenses)
- ▶ Standard deviations for asset classes
- ▶ Correlations between asset classes
- ▶ Annual rate of inflation
- ▶ Number of simulations

# WHAT FACTORS AFFECT MONTE CARLO SIMULATION?

Simulates the future of an “investment strategy”

Asset allocation only

Asset allocation + contributions

Asset allocation + distributions

Asset allocation + contributions + distributions

Step 1: Create thousands of hypothetical market scenarios using the same underlying assumptions

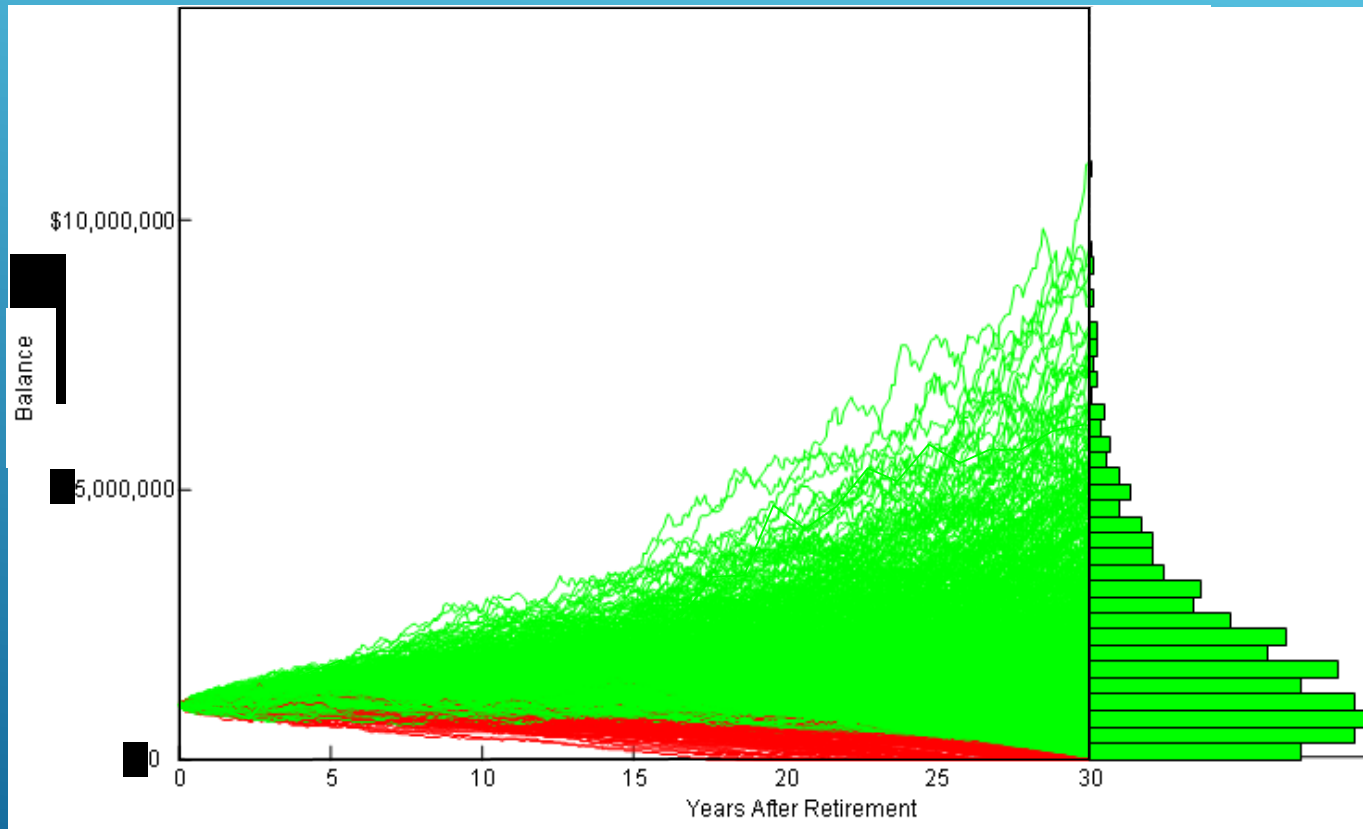
Step 2: Compare results of each investment strategy when projected across all market scenarios

HOW DOES MONTE CARLO  
SIMULATION WORK?

# HOW DOES MONTE CARLO SIMULATION WORK?

## Illustrated simulation of one investment strategy:

- A specific asset allocation
- Initial withdrawal amount



- Success = having a non-zero balance in the account at the end of 30 years
- Simulation success rate (SSR) = Count the lines (simulations) that fulfill your requirement of success divided by the total number of lines

# HOW DOES MONTE CARLO SIMULATION WORK?

## 30-Year Retirement

## Likelihood of Success of Each Strategy

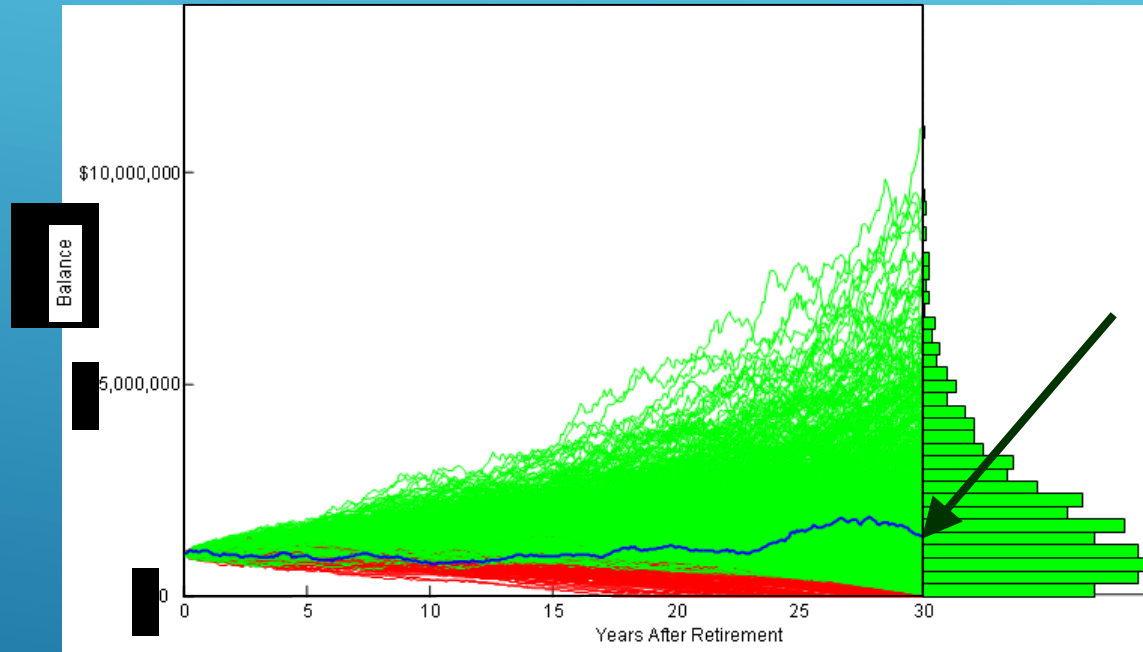
Initial Withdrawal Amount <sup>1</sup>	Stock/Bond <sup>2</sup> Mix				
	100/0	80/20	60/40	40/60	20/80
4%	77%	79%	80%	80%	74%
5%	60%	60%	56%	46%	28%
6%	44%	40%	32%	19%	5%

- Each retirement strategy includes an initial withdrawal amount and an allocation to stocks and bonds
- Use the table to understand the impact of asset allocation and withdrawal amounts on the SSR—having a non-zero balance remaining

<sup>1</sup> The initial withdrawal amount is the percentage of the initial investment value withdrawn in the first year; in each subsequent year, the amount withdrawn is adjusted to reflect a 3% annual rate of inflation. The entire amount is withdrawn the first day of each year. These results are not predictions, but they should be viewed as reasonable estimates. See Monte Carlo disclosure page for more information.

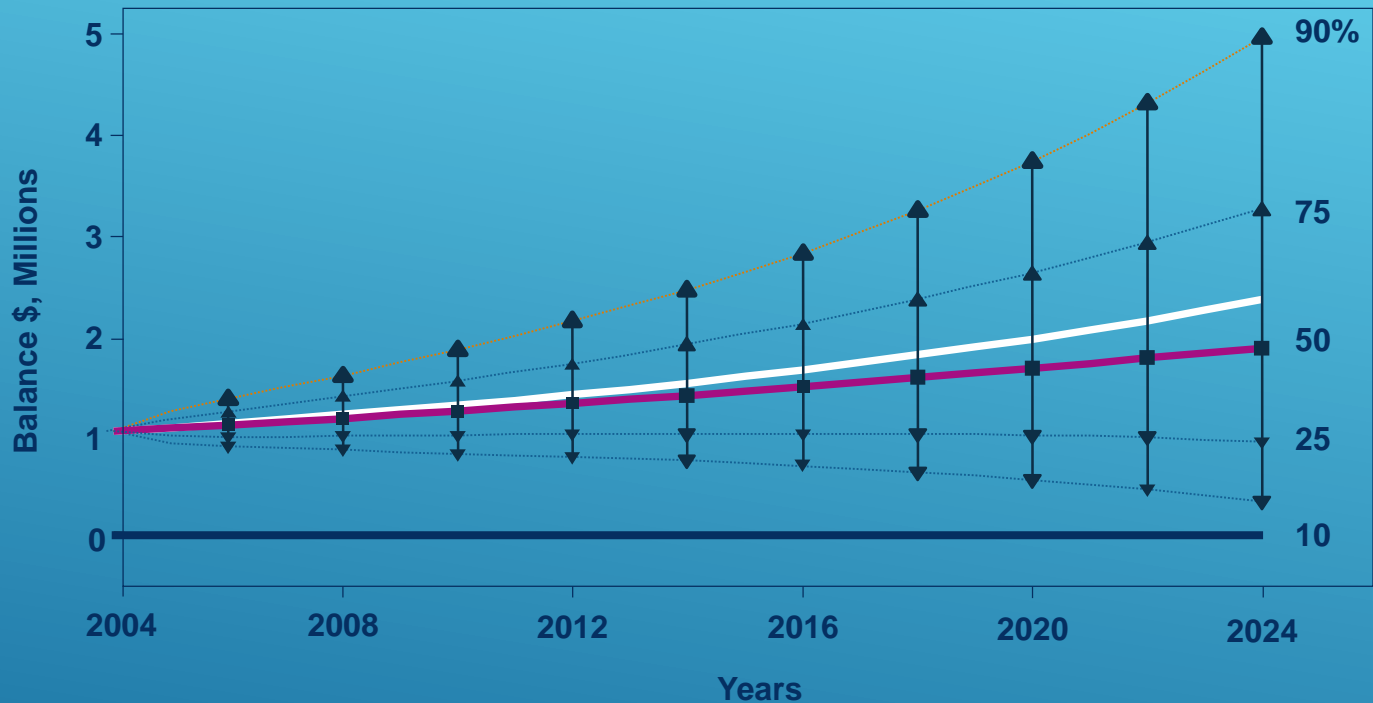
<sup>2</sup> The following allocations include short-term bonds: 60/40 is 60% stocks, 30% bonds, and 10% short-term bonds; 40/60 is 40% stocks, 40% bonds, and 20% short-term bonds; 20/80 is 20% stocks, 50% bonds, and 30% short-term bonds.

# MEDIAN PURCHASING POWER



- Goal: to determine the median amount of purchasing power you may have after 30 years
- Median legacy wealth = median final balance at the end of retirement period (end of blue line)

# HOW DOES MONTE CARLO SIMULATION WORK?



- Average outcome (blue line) is above the 50th percentile (teal line). Thus, more than 50% of the scenarios resulted in values lower than the average
- There may be a risk in providing investors with average outcomes

# MEDIAN PURCHASING POWER

## Example:

Initial retirement assets	\$1,000,000
Initial withdrawal = 4% (increased by 3% annually)	\$40,000
Retirement period	30 years

Portfolio	Median Purchasing Power <sup>2</sup>	Median Nominal Balance <sup>3</sup>
80/20	80%	\$1,941,810
60/40 <sup>1</sup>	61%	\$1,480,630
40/60 <sup>1</sup>	40%	\$970,905

<sup>1</sup> The following allocations include short-term bonds: 60/40 is 60% stocks, 30% bonds, and 10% short-term bonds; 40/60 is 40% stocks, 40% bonds, and 20% short-term bonds. These results are not predictions, but they should be viewed as reasonable estimates. See Monte Carlo disclosure page for more information.

<sup>2</sup> Median purchasing power is the 50th percentile value of assets remaining in current dollars (assuming 3% discount rate) at the end of the retirement period, expressed as a percentage of the original balance's purchasing power.

<sup>3</sup> Median Nominal Balance is the 50th percentile value of assets remaining in dollar terms (not discounted for inflation) at the end of the retirement period.

# MEDIAN PURCHASING POWER

## 30-Year Retirement

## Median Purchasing Power at End of Retirement

Initial Withdrawal Amount <sup>1</sup>	Stock/Bond <sup>2</sup> Mix				
	100/0	80/20	60/40	40/60	20/80
4%	93%	80%	61%	40%	21%
5%	35%	26%	11%	—	—
6%	—	—	—	—	—

More Likely
Less Likely

Use table to understand impact of asset allocation and withdrawal amounts on median purchasing power at end of retirement

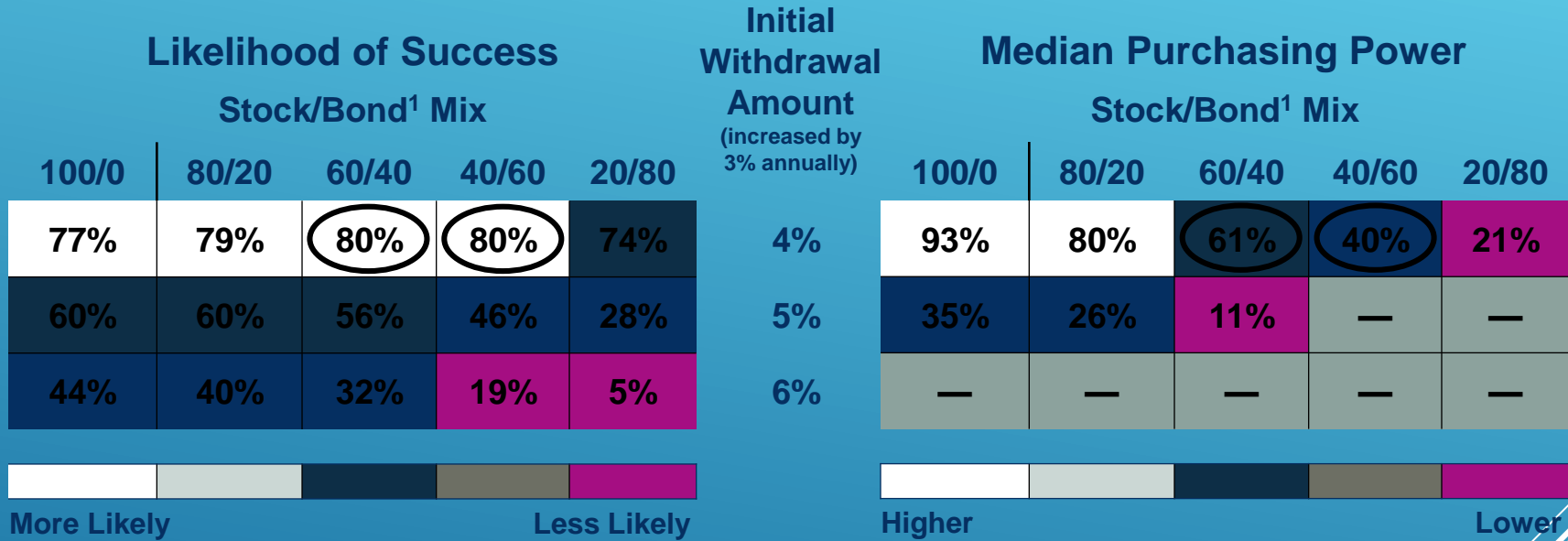
<sup>1</sup> The initial withdrawal amount is the percentage of the initial investment value withdrawn in the first year; in each subsequent year, the amount withdrawn is adjusted to reflect a 3% annual rate of inflation. The entire amount is withdrawn the first day of each year. These results are not predictions, but they should be viewed as reasonable estimates. See Monte Carlo disclosure page for more information.

<sup>2</sup> The following allocations include short-term bonds: 60/40 is 60% stocks, 30% bonds, and 10% short-term bonds; 40/60 is 40% stocks, 40% bonds, and 20% short-term bonds; 20/80 is 20% stocks, 50% bonds, and 30% short-term bonds.

Source: T. Rowe Price Associates, Inc.

# DISTINGUISHING BETWEEN SIMILAR SIMULATION SUCCESS RATES

## 30-Year Retirement



Median purchasing power data distinguish between two portfolios with similar success rates

- ▶ Understanding Monte Carlo simulation
- ▶ Why use it
- ▶ How does it work
- ▶ Factors affecting the simulations
- ▶ Financial planning questions Monte Carlo simulation helps answer

## REVIEW: MONTE CARLO ANALYSIS

## **Retirement strategy and actionable recommendations (best use of Monte Carlo):**

- ▶ How should I allocate my assets?
- ▶ How much should I save?
- ▶ How much retirement income can I withdraw with a reasonable expectation of success<sup>1</sup>?

## **Discussions of retirement outcomes (use with caution):**

- ▶ What's a reasonable expectation for how long my retirement investments will last?
- ▶ What is the likelihood of my assets lasting until the end of my retirement?
- ▶ What's a reasonable expectation for my remaining wealth at the end of my retirement period?

QUESTIONS MONTE CARLO  
HELPS ANSWER

# MANAGING EXPECTATIONS WHEN COMMUNICATING MONTE CARLO RESULTS TO YOUR CLIENTS

- ▶ Monte Carlo results are reasonable estimates of likely outcomes—they do not represent forecasts, and they are definitely not certain and are not guaranteed.
- ▶ Investment decisions should never be based solely on Monte Carlo simulations, since no Monte Carlo model can cover all the risks a client needs to consider (e.g., behavioral risk, inflation or health care risk, risk of living longer than 30 years, etc.)
- ▶ Monte Carlo calculations are best used to develop a retirement strategy in terms of **actionable recommendations** that are under the investor's control (e.g., asset allocation, contribution/withdrawal amounts, etc.). These recommended strategies tend to be less sensitive to specific assumptions than estimates of the absolute level of retirement **outcomes** (such as the amount of monetary assets at any point in the future or for how long a given withdrawal strategy can be sustained). The asset allocation the investor ultimately chooses needs to be appropriate for his or her investment time horizon and his or her personal investment risk tolerance (i.e., his or her comfort with the potential short-term volatility of the portfolio).
- ▶ The use of Monte Carlo calculations requires a truly long-term perspective (10+ years), as investor experience during any shorter individual periods can be strongly at odds with the long-term recommendations and outcomes of the model.
- ▶ The desired success rate is a key driver behind your client recommendation and guidance: If the strategy is based on a 80% success rate, there is implicit acknowledgment of a 20% likelihood that the client will run out of money (unless the retirement strategy is adjusted during the withdrawal period).
- ▶ This dependence on, for example, a 90% desired success rate is not inherently dictated by the Monte Carlo model itself, but results from financial planning considerations that go beyond the modeling approach chosen (Monte Carlo or other):
  - ▶ In addition, retirement strategies can fail for reasons outside the Monte Carlo model (such as behavioral risks, large-scale emergency expenses, etc.). Capping success rates, therefore, also serves to avoid giving clients a false sense of security regarding life risks not embodied in the model.
- ▶ Monte Carlo analysis is a valuable tool for personal financial planners. It enables them to help their clients focus on the fact that the future is uncertain, and that no financial plan can be relied on forever. Instead, each year they need to assess the likelihood that their savings or withdrawal and investment strategy is still "on track" and make changes if necessary.

# MONTE CARLO DISCLOSURE

## Monte Carlo Simulation

Monte Carlo simulations model future uncertainty. In contrast to tools generating average outcomes, Monte Carlo analyses produce outcome ranges based on probability, thus incorporating future uncertainty.

### Material Assumptions Include:

- ▶ Underlying long-term expected annual returns for the asset classes are not based on historical returns. Rather, they represent assumptions that take into account, among other things, historical returns. They also represent our estimates for reinvested dividends and capital gains.
- ▶ These assumptions, as well as an assumed degree of fluctuation of returns around these long-term rates, are used to generate random monthly returns for each asset class over specified time periods.
- ▶ The monthly returns are then used to generate 10,000 scenarios, representing a spectrum of possible return outcomes for the modeled asset classes. Analysis results are directly based on these scenarios.

### Material Limitations Include:

- ▶ The analysis relies on certain assumptions, combined with a return model that generates a wide range of possible return scenarios for these assumptions. Despite our best efforts, there is no certainty that the assumptions for the model will accurately estimate asset class return rates going forward. As a consequence, the results of the analysis should be viewed as approximations, and users should allow a margin of error and not place too much reliance on the apparent precision of the results.
- ▶ Extreme market movements may occur more often than in the model.
- ▶ Some asset classes have relatively short histories. Actual long-term results for each asset class may differ from our assumptions, with those for classes with limited histories potentially diverging more.
- ▶ Market crises can cause asset classes to perform similarly, lowering the accuracy of our return assumptions and diminishing the benefits of diversification (that is, using many different asset classes) in ways not captured by the analysis. As a result, returns actually experienced by the investor may be more volatile than those used in our analysis.
- ▶ The model does not take into consideration short-term correlations among asset class returns (correlation is a measure of the degree in which returns are related or dependent upon each other). It does not reflect the average periods of bull and bear markets, which can be longer than those modeled.
- ▶ Inflation is assumed to be constant, so variations are not reflected in our calculations.
- ▶ The analysis does not use all asset classes. Other asset classes may provide different returns or outcomes than those used.
- ▶ Taxes are not taken into account, nor are early withdrawal penalties.
- ▶ The analysis models asset classes, not investment products. As a result, the actual experience of an investor in a given investment product (e.g., a mutual fund) may differ from the range generated by the simulation, even if the broad asset allocation of the investment product is similar to the one being modeled. Possible reasons for divergence include, but are not limited to, active management by the manager of the investment product or the costs, fees, and other expenses associated with the investment product. Active management for any particular investment product—the selection of a portfolio of individual securities that differs from the broad asset classes modeled in the analysis—can lead to the investment product having higher or lower returns than the range used in this analysis.

# MONTE CARLO DISCLOSURE

## Modeling Assumptions:

- ▶ The primary asset classes used for this analysis are stocks, bonds, and short-term bonds. An effectively diversified portfolio theoretically involves all investable asset classes including stocks, bonds, real estate, foreign investments, commodities, precious metals, currencies, and others. Since it is unlikely that investors will own all of these assets, we selected the ones we believed to be the most appropriate for long-term investors.
- ▶ T. Rowe Price has analyzed a variety of retirement savings strategies using computer simulations to determine the likelihood of "success" (having at least \$1 remaining in the portfolio at the end of the retirement period) of each strategy, shown as a percentage in each grid. The initial withdrawal amount is the percentage of the initial value of the investments withdrawn in the first year where the entire amount is withdrawn on the first day of the year; in each subsequent year, the amount withdrawn is adjusted to reflect a 3% annual rate of inflation. The simulation success rates are based on simulating 10,000 possible future market scenarios and various retirement income strategies.
- ▶ Results of the analysis are driven primarily by the assumed long-term, compound rates of return of each asset class in the scenarios. Our corresponding assumptions, all presented in excess of 3% inflation, are as follows: for stocks, 4.90%; for bonds, 2.23%; and for short-term bonds, 1.38%.
- ▶ Investment expenses in the form of an expense ratio are subtracted from the return assumption as follows: for stocks, 0.70%; for bonds, 0.60%; and for short-term bonds, 0.55%. These expenses represent what we believe to be a reasonable approximation of investing in these asset classes through a professionally managed mutual fund or other pooled investment product.

**IMPORTANT: The information regarding the likelihood of various investment outcomes are hypothetical in nature, do not reflect actual investment results, and are not guarantees of future results. The simulations are based on assumptions. There can be no assurance that the results shown will be achieved or sustained. The charts present only a range of possible outcomes. Actual results will vary, and such results may be better or worse than the simulated scenarios. Clients should be aware that the potential for loss (or gain) may be greater than demonstrated in the simulations.**

The results are not predictions, but they should be viewed as reasonable estimates. Source: T. Rowe Price Associates, Inc.

Copyright 2011, T. Rowe Price Investment Services, Inc., Distributor. All rights reserved.