Multivariate Models: The Monte Carlo Analysis

By Robert Stammers on February 26, 2009

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Research analysts use multivariate models to forecast investment outcomes to understand the possibilities surrounding their investment exposures and to better mitigate risks. Monte Carlo analysis is one specific multivariate modeling technique that allows researchers to run multiple trials and define all potential outcomes of an event or investment. Running a Monte Carlo model creates a probability distribution or risk assessment for a given investment or event under review. By comparing results against risk tolerances, managers can decide whether to proceed with certain investments or projects. (To learn more about Monte Carlo basics, see *Introduction To Monte Carlo Simulation* and *Monte Carlo Simulation With GBM*.)

Multivariate Models

Multivariate models can be thought of as complex, "What if?" scenarios. By changing the value of multiple variables, the modeler can ascertain his or her impact on the estimate being evaluated. These models are used by financial analysts to estimate cash flows and new product ideas. Portfolio managers and financial advisors use these models to determine the impact of investments on portfolio performance and risk. Insurance companies use these models to estimate the potential for claims and to price policies. Some of the best-known multivariate models are those used to value stock options. Multivariate models also help analysts determine the true drivers of value.

Monte Carlo Analysis

Monte Carlo analysis is named after the principality made famous by its casinos. With games of chance, all the possible outcomes and probabilities are known, but with most investments the set of future outcomes is unknown. It is up to the analyst to determine the set of outcomes and the probability that they will occur. In Monte Carlo modeling, the analyst runs multiple trials (often thousands) to determine all the possible outcomes and the probability that they will take place.

Monte Carlo analysis is useful for analysts because many investment and business decisions are made on the basis of one outcome. In other words, many analysts derive one possible scenario and then compare it to return hurdles to decide whether to proceed. Most pro forma estimates start with a base case. By inputting the highest probability assumption for each factor, an analyst can actually derive the highest probability outcome. However, making any decisions on the basis of a base case is problematic, and creating a forecast with only one outcome is insufficient because it says nothing about any other possible values that could occur. It also says nothing about the very real chance that the actual future value will be something other than the base case prediction. It is impossible to hedge or insure against a negative occurrence if the drivers and probabilities of these events are not calculated in advance. (To learn more about how to manage the risk in your portfolio, see our *Risk and Diversification* tutorial.)

Creating the Model

Once designed, executing a Monte Carlo model requires a tool that will randomly select factor values that are bound by certain predetermined conditions. By running a number of trials with variables constrained by their own independent probability of occurrence, an analyst creates a distribution that includes all the possible outcomes and the probability that they will occur. There are many random number generators in the marketplace. The two most common tools for designing and executing Monte Carlo models are @Risk and Crystal Ball. Both of these can be used as add-ins for spreadsheets and allow random sampling to be incorporated into established spreadsheet models.

The art in developing an appropriate Monte Carlo model is to determine the correct constraints for each variable and the correct relationship between variables. For example, because portfolio diversification is based on the correlation between assets, any model developed to create expected portfolio values must include the correlation between investments. (To learn more, read *The Importance of Diversification*.)

In order to choose the correct distribution for a variable, one must understand each of the possible distributions available. For example, the most common one is a normal distribution, also known as a bell curve. In a normal distribution, all the occurrences are equally distributed (symmetrical) around the mean. The mean is the most probable event. Natural phenomena, people's heights and inflation are some examples of inputs that are normally distributed.

In the Monte Carlo analysis, a random-number generator picks a random value for each variable (within the constraints set by the model) and produces a probability distribution for all possible outcomes. The standard deviation of that probability is a statistic that denotes the likelihood that the actual outcome being estimated will be something other than the mean or most probable event. Assuming a probability distribution is normally distributed, approximately 68% of the values will fall within one standard deviation of the mean, about 95% of the values will fall within two standard deviations and about 99.7 % will lie within three standard deviations of the mean. This is known as the "68-95-99.7 rule" or the "empirical rule".

Examples

Let us take for example two separate, normally distributed probability distributions derived from random-factor analysis or from multiple scenarios of a Monte Carlo model.

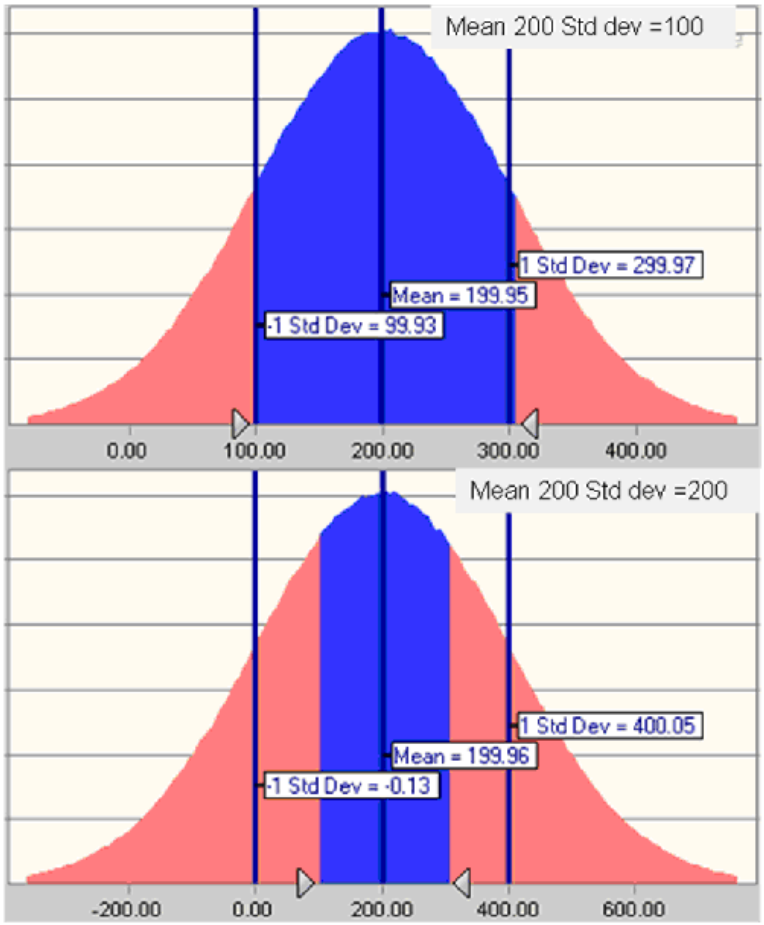

Figure 1

In both of the probability distributions (Figure 1), the expected value or base cases both equal 200. Without having performed scenario analysis, there would be no way to compare these two estimates and one could mistakenly conclude that they were equally beneficial. (To learn more, read *Scenario Analysis Provides Glimpse of Portfolio Potential*.)

In the two probability distributions, both have the same mean but one has a standard deviation of 100, while the other has a standard deviation of 200. This means that in the first scenario analysis there is a 68% chance that the outcome will be some number between 100 and 300, while in the second model there is a 68% chance that the outcome will be between 0 and 400. With all things being equal, the one with a standard deviation of 100 has the better risk-adjusted outcome. Here, by using Monte Carlo to derive the probability distributions, the analysis has given an investor a basis by which to compare the two initiatives.

Monte Carlo analysis can also help determine whether certain initiatives should be taken on by looking at the risk and return consequences of taking certain actions. Let us assume we want to place debt on our original investment.

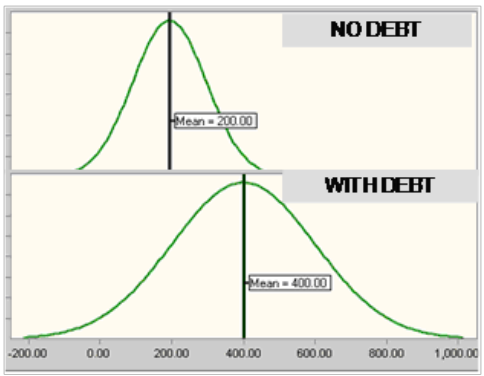

Figure 2

The distributions in Figure 2 show the original outcome and the outcome after modeling the effects of leverage. Our new leveraged analysis shows an increase in the expected value from 200 to 400, but with an increased financial risk of debt. Debt has increased the expected value by 200 but also the standard deviation. Before 1 standard deviation was a range from 100 to 300. Now with debt, 68% of values (1 standard deviation) fall between 0 and 400. By using scenario analysis an investor can now determine whether the additional increase in return equals or outweighs the additional risk (variability of potential outcomes) that comes with taking on the new initiative.

Conclusion

Monte Carlo analyses are not only conducted by finance professionals but also by many other businesses. It is a decision-making tool that integrates the concept that every decision will have some impact on overall risk. Every individual and institution has different risk/return tolerances. As such, it is important that the risk/return profile of any investment be calculated and compared to risk tolerances.

The probability distributions produced by a Monte Carlo model create a picture of risk. A picture is an easy way to convey the idea to others, such as superiors or prospective investors. Because of advances in software, very complex Monte Carlo models can be designed and executed by anyone with access to a personal computer.

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by Robert Stammers

Robert Stammers, CFA, is an independent consultant providing investment and marketing support to business owners and private investors. Previously, as a senior executive for several institutional fund managers, he was the portfolio manager for a $1 billion enhanced real estate fund, a private timber fund, and several pension fund separate accounts. Mr. Stammers holds The CFA Institute's Chartered Financial Analyst designation, a Bachelor of Arts in economics from Connecticut College, and a Master of Business Administration with honors from Emory University.

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