

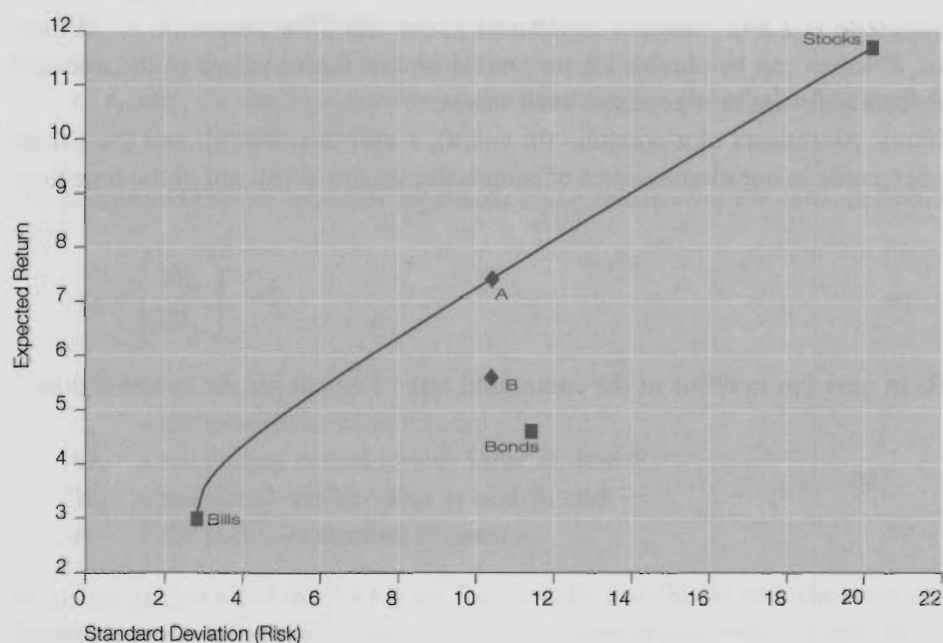
requires forecasts of the return and standard deviation of each asset, and the correlation of each asset with every other asset.¹

In the 1950s, Harry Markowitz developed both the concept of the efficient frontier and the mathematical means of constructing it (mean-variance optimization)². Currently, there are a number of commercially available mean-variance optimization software packages, including Ibbotson Associates' *Portfolio Strategist*[®] and *EnCorr*[®] *Optimizer*.³

Graph 9-1

Efficient Frontier

Large Company Stocks, Long-Term Government Bonds, and U.S. Treasury Bills



Estimating the Means, Standard Deviations, and Correlations of Asset Returns

To simulate future probability distributions of asset and portfolio returns, one typically estimates parameters of the historical return data. The parameters that are required to simulate returns on an asset are its mean and standard deviation. To simulate returns on portfolios of assets, one must also estimate the correlation of each asset in the portfolio with every other asset. Thus, the parameters required to conduct a simulation are the same as those required as inputs into a mean-variance optimization.⁴

¹ The standard deviation is the square root of the variance; hence the term "mean-variance" in describing this form of the optimization problem.

² Markowitz, Harry M., *Portfolio Selection: Efficient Diversification of Investments*, New York: John Wiley & Sons, 1959.

³ For additional information regarding *Portfolio Strategist* and *EnCorr* software, refer to the Product Information page at the back of this book.

⁴ It is also possible to conduct a simulation using entire data sets, that is, without estimating the statistical parameters of the data sets. Typically, in such a nonparametric simulation, the frequency of an event occurring in the simulated history is equal to the frequency of the event occurring in the actual history used to construct the data set.