CHAPTER 1

The Nobel Prize

On October 16, 1990, the Royal Swedish Academy of Sciences announced its selection for the Nobel Memorial Prize in Economic Science. For the first time since the prize for economics was established in 1968, the Royal Academy chose three individuals whose primary contributions were in finance and whose affiliations were not with arts and science schools, but rather with schools of business. Harry Markowitz was cited for his pioneering research in portfolio selection, while William Sharpe shared the award for developing an equilibrium theory of asset pricing. Merton Miller was a co-winner for his contributions in corporate finance, in which he showed, along with Franco Modigliani, that the value of a firm should be invariant to its capital structure and dividend policy.

The pioneering research of these individuals revolutionized finance and accelerated the application of quantitative methods to financial analysis.

PORTFOLIO SELECTION

In his classic article, "Portfolio Selection," Markowitz submitted that investors should not choose portfolios that maximize expected return, because this criterion by itself ignores the principle of diversification.[1] He proposed that investors should instead consider variances of return, along with expected returns, and choose portfolios that offer the highest expected return for a given level of variance. He called this rule the E-V maxim.

Markowitz showed that a portfolio's expected return is simply the weighted average of the expected returns of its component securities. A portfolio's variance is a more complicated concept, however. It depends on more than just the variances of the component securities.

The variance of an individual security is a measure of the dispersion of its returns. It is calculated by squaring the difference between each return in a series and the mean return for the series, then averaging these squared differences. The square root of the variance (the standard deviation) is often used in practice because it measures dispersion in the same units in which the underlying return is measured.

Variance provides a reasonable gauge of a security's risk, but the average of the variances of two securities will not necessarily give a good indication of the risk of a portfolio comprising these two securities. The portfolio's risk depends also on the extent to which the two securities move together—that is, the extent to which their prices react in like fashion to a particular event.

To quantify co-movement among security returns, Markowitz introduced the statistical concept of covariance. The covariance between two securities equals the standard deviation of the first times the standard deviation of the second times the correlation between the two.

The correlation, in this context, measures the association between the returns of two securities. It ranges in value from 1 to –1. If one security's returns are higher than its average return when another security's returns are higher than its average return, for example, the correlation coefficient will be positive, somewhere between 0 and 1. Alternatively, if one security's returns are lower than its average return when another security's returns are higher than its average return, then the correlation will be negative.

The correlation, by itself, is an inadequate measure of covariance because it measures only the direction and degree of association between securities' returns. It does not account for the magnitude of variability in each security's returns. Covariance captures magnitude by multiplying the correlation by the standard deviations of the securities' returns.

Consider, for example, the covariance of a security with itself. Obviously, the correlation in this case equals 1. A security's covariance with itself thus equals the standard deviation of its returns squared, which, of course, is its variance.

Finally, portfolio variance depends also on the weightings of its constituent securities—the proportion of a portfolio's market value invested in each. The variance of a portfolio consisting of two securities equals the variance of the first security times its weighting squared plus the variance of the second security times its weighting squared plus twice the covariance between the securities times each security's weighting. The standard deviation of this portfolio equals the square root of the variance.

From this formulation of portfolio risk, Markowitz was able to offer two key insights. First, unless the securities in a portfolio are perfectly inversely correlated (that is, have a correlation of –1), it is not possible to eliminate portfolio risk entirely through diversification. If we divide a portfolio equally among its component securities, for example, as the number of securities in the portfolio increases, the portfolio's risk will tend not toward zero but, rather, toward the average covariance of the component securities.

Second, unless all the securities in a portfolio are perfectly positively correlated with each other (a correlation of 1), a portfolio's standard deviation will always be less than the weighted average standard deviation of its component securities. Consider, for example, a portfolio consisting of two securities, both of which have expected returns of 10 percent and standard deviations of 20 percent and which are uncorrelated with each other. If we allocate portfolio assets equally between these two securities, the portfolio's expected return will equal 10 percent, while its standard deviation will equal 14.14 percent. The portfolio offers a reduction in risk of nearly 30 percent relative to investment in either of the two securities separately. Moreover, this risk reduction is achieved without any sacrifice of expected return.

Markowitz also demonstrated that, for given levels of risk, we can identify particular combinations of securities that maximize expected return. He deemed these portfolios "efficient" and referred to a continuum of such portfolios in dimensions of expected return and standard deviation as the efficient frontier. According to Markowitz's E-V maxim, investors should choose portfolios located along the efficient frontier. It is almost always the case that there exists some portfolio on the efficient frontier that offers a higher expected return and less risk than the least risky of its component securities (assuming the least risky security is not completely riskless).

The financial community was slow to implement Markowitz's theory, in large part because of a practical constraint. In order to estimate the risk of a portfolio of securities, one must estimate the variances of every security, along with the covariances between every pair of securities. For a portfolio of 100 securities, this means calculating 100 variances and 4,950 covariances—5,050 risk estimates! In general, the number of required risk estimates (variances and covariances) equals $n(n + 1)/2$, where n equals the number of securities in the portfolio.[2] In 1952, when Markowitz published "Portfolio Selection," the sheer number of calculations formed an obstacle in the way of acceptance. It was in part the challenge of this obstacle that motivated William Sharpe to develop a single index measure of a security's risk.

THE CAPITAL ASSET PRICING MODEL

James Tobin, the 1981 winner of the Nobel Prize in economics, showed that the investment process can be separated into two distinct steps: (1) the construction of an efficient portfolio, as described by Markowitz, and (2) the decision to combine this efficient portfolio with a riskless investment. This two-step process is the famed separation theorem.[3]

Sharpe extended Markowitz's and Tobin's insights to develop a theory of market equilibrium under conditions of risk.[4] First, Sharpe showed that there is along the efficient frontier a unique portfolio that, when combined with lending or borrowing at the riskless interest rate, dominates all other combinations of efficient portfolios and lending or borrowing.

Figure 1.1 shows a two-dimensional graph, with risk represented by the horizontal axis and expected return represented by the vertical axis. The efficient frontier appears as the positively sloped concave curve. The straight line emanating from the vertical axis at the riskless rate illustrates the efficient frontier with borrowing and lending. The segment of the line between the vertical axis and the efficient portfolio curve represents some combination of the efficient portfolio M and lending at the riskless rate, while points along the straight line to the right represent some combination of the efficient portfolio and borrowing at the riskless rate. Combinations of portfolio M and lending or borrowing at the riskless rate will always offer the highest expected rate of return for a given level of risk.

With two assumptions, Sharpe demonstrated that in equilibrium investors will prefer points along the line emanating from the riskless rate that is tangent to M. The requisite assumptions are (1) there exists a single

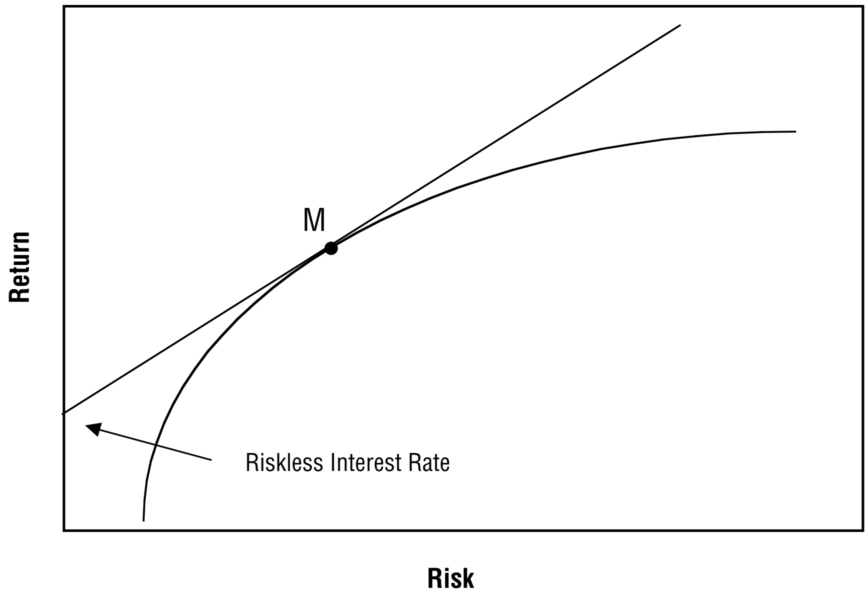

FIGURE 1.1 Efficient frontier with borrowing and lending

riskless rate at which investors can lend and borrow in unlimited amounts, and (2) investors have homogeneous expectations regarding expected returns, variances, and covariances. Under these assumptions, Sharpe showed that portfolio M is the market portfolio, which represents the maximum achievable diversification.

Within this model, Sharpe proceeded to demonstrate that risk can be partitioned into two sources—that caused by changes in the value of the market portfolio, which cannot be diversified away, and that caused by nonmarket factors, which is diversified away in the market portfolio. He labeled the nondiversifiable risk systematic risk and the diversifiable risk unsystematic risk.

Sharpe also showed that a security's systematic risk can be estimated by regressing its returns (less the riskless rate) against the market portfolio's returns (less riskless rate). The slope from this regression equation, which Sharpe called beta, quantifies the security's systematic risk when multiplied by the market risk. The unexplained variation in the security's return (the residuals from the regression equation) represents the security's unsystematic risk. He then asserted that, in an efficient market, investors are only compensated for bearing systematic risk, because it cannot be diversified away, and the expected return of a security is, through beta, linearly related to the market's expected return.

It is important to distinguish between a single index model and the Capital Asset Pricing Model (CAPM). A single index model does not require the intercept of the regression equation (alpha) to equal 0 percent. It simply posits a single source of systematic, or common, risk. Stated differently, the residuals from the regression equation are uncorrelated with each other. The important practical implication is that it is not necessary to estimate covariances between securities. Each security's contribution to portfolio risk is captured through its beta coefficient. The CAPM, by contrast, does require the intercept of the regression equation to equal 0 percent in an efficient market. The CAPM itself does not necessarily assume a single source of systematic risk. This is tantamount to allowing for some correlation among the residuals.

INVARIANCE PROPOSITIONS

Between the publication of Markowitz's theory of portfolio selection and Sharpe's equilibrium theory of asset pricing, Franco Modigliani (the 1985 Nobel Prize winner in economics) and Merton Miller published two related articles in which they expounded their now famous invariance propositions. The first, "The Cost of Capital, Corporation Finance, and the Theory of Investment," appeared in 1958.[5] It challenged the then conventional wisdom that a firm's value depends on its capital structure (i.e., its debt/equity mix).

In challenging this traditional view, Modigliani and Miller invoked the notion of arbitrage. They argued that if a leveraged firm is undervalued, investors can purchase its debt and its shares. The interest paid by the firm is offset by the interest received by the investors, so the investors end up holding a pure equity stream. Alternatively, if an unleveraged firm is undervalued, investors can borrow funds to purchase its shares. The substitutability of individual debt for corporate debt guarantees that firms in the same risk class will be valued the same, regardless of their respective capital structures. In essence, Modigliani and Miller argued in favor of the law of one price.

In a subsequent article, "Dividend Policy, Growth, and the Valuation of Shares," Modigliani and Miller proposed that a firm's value is invariant, not only to its capital structure, but also to its dividend policy (assuming the firm's investment decision is set independently).[6] Again, they invoked the notion of substitutability, arguing that repurchasing shares has the same effect as paying dividends; thus issuing shares and paying dividends is a wash. Although the cash component of an investor's return may differ as a function of dividend policy, the investor's total return, including price change, should not change with dividend policy.

Modigliani and Miller's invariance propositions provoked an enormous amount of debate and research. Much of the sometimes spirited debate centered on the assumption of perfect capital markets. In the real world, where investors cannot borrow and lend at the riskless rate of interest, where both corporations and individuals pay taxes, and where investors do not share equal access with management to relevant information, there is only spotty evidence to support Modigliani and Miller's invariance propositions.

But the value of the contributions of these Nobel laureates does not depend on the degree to which their theories hold in an imperfect market environment. It depends, rather, on the degree to which they changed the financial community's understanding of the capital markets. Markowitz taught us how to evaluate investment opportunities probabilistically, while Sharpe provided us with an equilibrium theory of asset pricing, enabling us to distinguish between risk that is rewarded and risk that is not rewarded. Miller, in collaboration with Modigliani, demonstrated how the simple notion of arbitrage can be applied to determine value, which subsequently was extended to option valuation—yet another innovation that proved worthy of the Nobel Prize.