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A METHOD OF PROJECT SELECTION BASED ON CAPITAL ASSET PRICING THEORIES IN A FRAMEWORK OF MEAN-SEMI DEVIATION BEHAVIOR FOR PETROLEUM PROJECTS

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ABSTRACT

The competitiveness of a firm in the capital-intensive petroleum industry is highly dependent to a stream of successful and profitable projects. having simulated the financial outcomes of a project, analysis of the output of simulation is then an important task that demands efficient methods for evaluation and selection of projects. The method in this article considers semi-deviation of return as the measure of risk of projects that is more consistent with the definition of risk as "the probability of unwanted outcomes". Projects characterized by their expected return and semi-deviation of return are then entered into a project comparison system that is based on the Arbitrage Pricing Theory (APT). The primary advantage of this method of project selection is in the collective assessment of the firm's risk by all market participants.

Keywords: Investment Appraisal, Risk of Projects, Arbitrage Pricing Theory (APT).

Introduction

Project evaluation and selection in oil industry is a very high-risk and capital-intensive practice. The financial risk of failure in projects is usually of high concerns because the competitiveness of the companies is highly dependant on the success of the projects. A simulation based analysis of the return of the projects will yield a probability/frequency distribution of the possible returns on a project. This probability/frequency distribution is the basis of project evaluation and selection in this article.

The problem of project evaluation and selection was first developed in the field of engineering economy. The early practitioners had to consider the problem of selecting the economic choice between *executable alternative solutions*.

The major contributions made to the field of engineering economy is now present in works of DeGarmo E. P., and Canada J. R.[DeGarmo, 1973]; Grant E. P. [Grant, 1938]; Thuesen H. G., Farbrycky W. J [Thuesen, 1976]. The field of industrial project selection was born by the introduction of the question: *"What is the best for the firm, overall?"* [Bussey, 1978]. This field is normally concerned with the act of project selection in the context of "firm", i.e. the parent entity that tends to execute the project.

Success or failure of the projects is measured according to the goals of the parent firm. The concept of firm, as it is now accepted and used, was introduced in the mid 20th century by

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Barnard C. [Barnard, 1938]; Baumol W. J. [Baumol, 1959]; and Simon, H. [Simon, 1957].

The financial view point of the firm defines goals as the *maximization of the value of the shareholders*. This objective is also accepted as the goal of project evaluation and selection. Other related works in this field are due to Ezra Solomon [Solomon, 1955, 1959, 1963] and Weston, J. R. [Weston, 1972]. This trend in financial management also is developed by more recent works in [Neveu, 1989] and [Ross, 2004].

Portfolio theory was first introduced in a landmark paper, offered by Markowitz H. M. [Markowitz, 1959], led to wining the Nobel prize in economics. Markowitz proposed in his paper the concept of portfolio, correlation effects, and the effect of diversification in investment. He also made other contributions to the field until the year 1991 [Markowitz, 1991] and beyond. The portfolio theory was applied successfully to capital markets and explained its behavior first in a pioneering works of William F. Sharpe [Sharpe, 1964, 1970], John Lintner [Lintner, 1965] and Jan Mossin [Mossin, 1966].

A major classic reference in oil and gas project analysis is the book published by Newendorp in 1975 [Newendorp, 1975] and updated in 2000 [Newendorp, 2000]. Other major references in oil and gas exploration projects include a valuable book by Mian, M. A. [Mian, 2002] in two volumes and also works done by Larche, I. and Mackay, J. A. [Larche, 1999]. These technical resources have in fact been founded by earlier works in the field of industrial project selection and evaluation in which one integral reference of this type is the work of Bussey, L. E. [Bussey, 1978], and later the work of Stermole, F. J. and Stermole, J. M. [Stermole, 2000].

An Alternative Measure of Risk

In virtually all literature about investment, risk is defined as the volatility of returns, measured by standard deviation (or variance) of the probability distribution of return of the project or portfolio of projects. This dominance of definition in all scientific resources reflects the common belief of the academics and practitioners. On the other hand, if we refer to the basic definition of risk, "the probability of unwanted outcomes", some inconsistency would seem apparent. The standard deviation and variance consider risk as variations in both upward and downward directions, and rational investors (risk averse decision makers) would prefer lower risk to higher risk. This statement implies that for a rational investor, achieving higher than expected returns are also as undesirable as achieving lower than expected returns. This problem questions the use of variance and standard deviation as proper measures of risk, as they are used dominantly because of their simplicity.

All the concerns about inappropriateness of standard deviation would disappear if we deal with symmetrically distributed project returns, particularly in the form of normal distributions. In that case, the chances of positive outcome that is a certain distance away from the center of the distribution are just as great as the chances of negative outcome that is an equal distance in the opposite direction. In these situations, the standard deviation successfully describes the "bad" part of the project's return distribution.

But what if the project's return distribution is not normally distributed? In many project appraisal applications there is good reason that the bad outcomes are not exactly the mirror image of the good outcomes, i.e. we will be dealing with asymmetrical distributions of project return. If for example, we use standard deviation to measure risk in a right-skewed distribution of project NPV, we would ignore the fact that most of the project NPV is on the "good" side of the project's expected return.

The portfolio theory, and later, capital asset pricing model developed by Sharpe and others, are developed to analyze data collected in financial markets. Some assumptions made by both portfolio theory and *CAPM* need to be revisited to be applied to the project appraisal framework. The first place to start is to consider a proper measure for risk in projects. Because in practice we will be dealing with a limited number of projects to be analyzed, the problem of simplifying calculation will not matter. In fact project appraisal deals with analyzing projects that a large amount of capital will be allocated to them in case of approval and because of this extra care and attention should be focused on each project. The costs of analyzing and appraising the projects constitute a very small portion of the overall costs of the project and it will never matter to spend extra dollars in assessing each alternative.

The semivariance is more useful than the variance when the underlying distribution is asymmetric and just as useful when the underlying distribution is symmetric; in other words, the semivariance is at least as useful a measure of risk as variance. Moreover, the semivariance combines the information provided by two statistics, variance and skewness, into one measure[1].

In the alternative MSB framework, the investor's utility is given by $U = U(\mu_p, \Sigma_p)$, where Σ_p denotes the downside deviation of returns (semideviation for short) of the investor's project or portfolio. In this framework, the risk of project *i* taken individually is measured by the project's downside standard deviation of NPV. We will have:

$\Sigma_i = \sqrt{\ } (E\{ \min[(R_i - \mu_i),0]^2\})$

the above expression is in fact a special case of the semideviation, which can be generally expressed with respect to any benchmark NPV, called *B*. this Σ_{Bi} can be formulated as:

$\Sigma_{Bi} = \sqrt{\ } (E\{ \min[(R_i - B),0]^2\})$

Throughout this document we will use as the only benchmark for project *i* the arithmetic mean of the distribution of NPV and thus we will denote the semideviation of project *i* as Σ_i.

The above definitions may cause computational complexity for calculation of semideviation of projects' NPV. As there is the famous rule of thumb for estimating variance of a symmetric and close to normal distribution, a similar rule of thumb can also be derived for estimating semivariance and semideviation of a skewed distribution. The rule of thumb for variance estimation is;

$v_p = [1/6(N_{99\%} - N_{1\%})]^2$

Where; v_p = variance of the project NPV.

$N_{99\%}$ = the value of NPV, where 99% of the NPV values are below, and 1% of the values are above that value.

$N_{1\%}$ = the value of NPV, where 1% of the NPV values are below, and 99% of the values are above that value.

The rule for estimating semivariance and semideviation is derived directly from the assumption that skewed distributions obtained as the results of simulation consist of *3* semideviations between their mean value and their lowest value.

$\Sigma_i = 1/3\ [\mu_i - N_{1\%}]$

[1]?the semivariance of return (or of NPV) can be used to generate an alternative behavioral hypothesis, mean-semivariance behavior [Estrada, 2004]. This behavior is perfectly correlated with the expected utility (and with the utility of expected compounded return) and can therefore be defended along the same lines used by Levy and Markowitz [Levy and Markowitz, 1979], [Markowitz 1991] that defended Capital asset pricing and portfolio theories.

Project Selection Using Arbitrage Pricing Theory

The traditional way of determining the proper discount rate for a project, which is used to relate the future cash flows to the equivalent present amounts, is based on the calculation of *cost of capital*. This technique adds an implicit allowance for the risk, in addition to base interest rate. In the capital asset pricing methodology of project selection, projects are compared with a specific measure that contains all the information about the risk of a firm. This measure is the related market stock price, and as it is observed in near efficient market, all risks and future prospects are contained in market prices. In fact, by using equilibrium market prices we can incorporate all known risks of a firm into a proper criterion of project selection.

Portfolio theory is based on two attributes, the expected return and standard deviation of return. Based on these two attributes all the useful results of the portfolio theory have been developed and applied in various situations. By the introduction of semideviation into portfolio theory and modifying its fundamental assumptions, one can expect emergence of a new and undeveloped field in finance. Fortunately, as Estrada [Estrada, 2004] mentions, the new system of mean-semivariance is perfectly parallel with the previous system of mean-variance. According to these findings we can construct portfolios of risky securities similar to those constructed by Markowitz and use semideviation instead of standard deviation. The result will be a similar umbrella shaped region comprising of infinite number of portfolios.

All securities (and projects also) can be depicted in the $\mu - \Sigma$ system in a similar manner, and all discussions about market portfolio and capital market line will be still correct. The market portfolio will be comprised of all risky securities in the market (their risk designated by their semideviation of return) and will be the efficient portfolio that all investors in the market will choose to invest. Also the risk free asset in the market will be defined the same way as before; securities with zero risk, zero deviation, and of course zero semideviation.

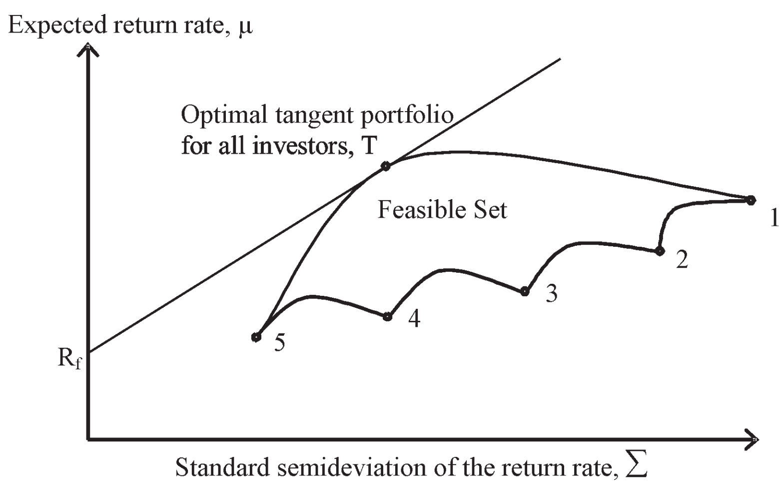

Figure 1: The risky securities can be combined with the risk free security to make a straight line of combined portfolios. The line R_f-T is comprised of portfolios that are partly risky and partly risk free. As the diagram illustrates, the line R_f-T dominates all other feasible portfolios.

If security *O* represents the firm's own equity shares, looking at the (μ_o, Σ_o) as the mean return rate and the semideviation of the return rate of the firm itself, then the straight line (shown in figure 2) becomes a market-established project selection criterion. All projects such as S having values (μ_s,Σ_s) lying above the firm's market line would yield expected return rates greater than those required by the firm's shareholders in the market place, and acceptance of such projects would increase the market value of the firm. On the other hand, if project K with values of (μ_k, Σ_k) lying below the firm's market line would tend to reduce the market value of the firm and should be rejected[2].

A project will be accepted if the slope of its risk equalization line[3], connecting the coordinate point $(\hat{\imath}_k, \Sigma_k)$ of the project with the riskless asset point $(R_f, 0)$, exceeds the slope of the firm's equity line. Such projects, even in their unequalized state, are accepted by the firm as good projects because they always lie on a higher indifference curve. the decision criterion would become:

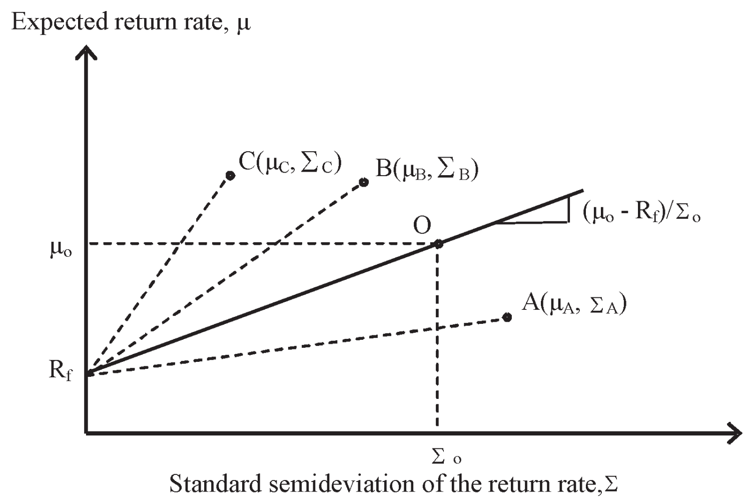

Figure 2: the firm's equity line as the decision criterion. This criterion can also be used to rank alternative investment projects. Project C appears to be the most attractive project, following by B. project A is not accepted in any ways because it may reduce the value of the firm.

Accept project K, if: $(\mu_k - R_f)/\Sigma_k > (\mu_o - R_f)/\Sigma_o$

The relationship $(\mu_k - R_f)/\Sigma_k$ can be named the *reward to risk ratio*. In its simple form, the reward to risk ratio for any project must be equal to or greater than the ratio the firm currently achieves from its existing projects.

The reward to risk ratio can also be constructed for the market portfolio. The relationship $(\mu_M - R_f)/\Sigma_M$ defines the slope of a straight line connecting point $M(\mu_M, \Sigma_M)$, the position of market portfolio, with the point $(R_f, 0)$. This line represents the equilibrium market condition. in the equilibrium state, all equity shares in the market must locate somewhere on this line, because if they don't, the buying and selling forces will exert them on the line.

In other than the equilibrium conditions, it is essentially possible (indeed, it is the general occurrence) that the price of a single firm's shares will be adjusted in such a way that the reward to risk ratio for the firm's equity shares, $(\mu_O - R_f)/\Sigma_O$, does not equal the reward to risk

[1] The Proof has been presented in Appendix 1.

[2] The Risk Equalization Line is defined in Appendix 1.

ratio of the market portfolio. If, for any reason, the relation ship:

$(\mu_O - R_f)/\Sigma_O > (\mu_M - R_f)/\Sigma_M$

Holds, it is said that the firm has outperformed the market. In situation, as the market portfolio contains only the systematic risk, it might be preferred to use the Reward to Risk ratio of the market portfolio as the project selection criterion.

Arbitrage is the process of earning riskless profits by taking advantage of the differential pricing for the same physical asset or security. As a widely applied investment tactic arbitrage typically entails the sale of a security, at a relatively high price; and simultaneous purchase of the same security (or its *functional equivalent*) at a relatively low price.

The nature of arbitrage is clear when discussing different prices for an individual security. However, “almost arbitrage” opportunities can involve *similar* securities or portfolios that are functionally equivalent for the specific investor. This similarity entails an interesting point because projects can be considered similar to market investments as they both provide return for investment. An arbitrage portfolio has three identical properties (1) it entails no risk, (2) it needs no additional investment, and (3) it has a positive expected return.

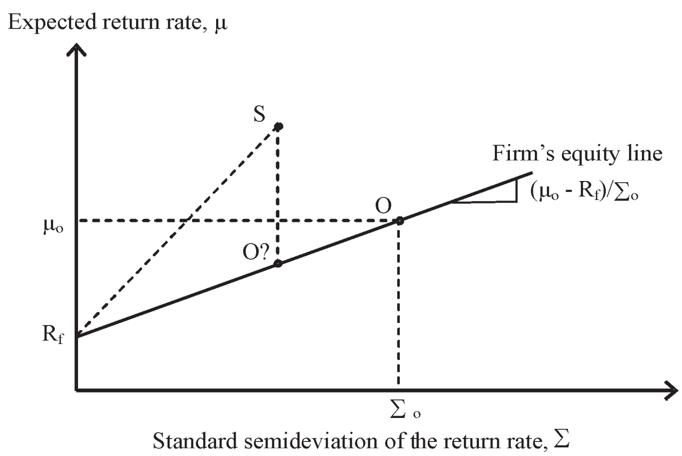

Figure 3. The arbitrage opportunity offered by project S, in respect to the firm’s equity line

While projects’ reward to risk ratio are compared with the market line, they essentially will not fall on the market line. As it was discussed, this situation will cause an arbitrage opportunity. The arbitrage opportunity is referred to an opportunity where investors can make profit by constructing zero-fund portfolios that will increase the expected return of investor’s portfolio without increasing its risk.

Figure 5 illustrates the firm’s equity line along with a project, named project S, with an acceptable reward to risk ratio. i.e. the project can be compared to the firm’s own equity (existing producing projects), and will prove profitable,

$(\mu_S - R_f)/\Sigma_S > (\mu_O - R_f)/\Sigma_O$

The arbitrage opportunity, provided by project *S*, can be shown in this diagram. As all points on the firm’s equity line represent portfolios constructed by combining the riskless security with firm’s equity share, point *O2* can be pointed out as a portfolio currently accessible to investors with the same standard semideviation as the project *S*. Investors can invest in project *S* and take advantage of an arbitrage opportunity because the differential arbitrage portfolio that will be constructed; (1) has zero risk because project *S* has the same risk as the *O2* , (2) needs no additional investment, and (3) has positive expected return.

Project Selection in Private Firms, Extension of the Model

In many industries, specifically in Oil, Gas and Petrochemical industry, the firms are engaged in competition with many publicly owned companies. One way of evaluating success of any firm is to make comparison against its competitors. Competitors or any other similar company that has almost similar working conditions to the firm under investigation, are called *pure plays*, and this comparison is called the *method of pure play*. If the firm has had a return on its investment that was as good, or better than its competitors, it is reasonable to assume that the firm is performing well in its investment decisions.

In order to make a basis for comparison, the average of equity shares form all competitors and similar publicly traded companies should be calculated. This average will form a virtual firm that all investment decisions would be compared to it. The equity market line for the virtual firm should then be calculated. Represented it by its slope, this value shows the basis for reward to risk ratio.

The process of averaging is consistent with the rational that, more of market worth proportion means more of the share's effect on the project selection and thus on the averaging process. This rational concludes that, the higher the worth of that particular firm, the greater its effect on the industry.

Application of this method in major Oil, Gas and Petrochemical project selection is a necessity because many active firms in this industry sector are not publicly owned companies. The true location of the firm's equity line may be below (in case the firm under investigation is not much competitive) or above the virtual firm's market line (in case the firm under investigation is highly competitive). This should be considered for marginal projects.

The smart selection of firms whose stock prices shall enter the calculations is a major concern in application of arbitrage pricing method in project selection. In selecting an industry for the construction of the virtual firm, certain requirements must be specified. One important statistic requirement (in order to make the results meaningful, and diversify the virtual portfolio to eliminate the unsystematic risk), is that the industry should have approximately 5 or more firms that are publicly owned. Incorporating up to 20 firms is considered practical, when more firms' stock prices are entered into the calculations, the result of this diversification is not significantly realized.

Some companies have other by-criteria that are used in investment projects decisions. Two most important of them are the requirements that return on accepted investments should exceed the cost of capital of the firm, and that the risk of projects accepted (or overall risk of group of projects) should not exceed a certain limit specified by the management. These by-criteria can also be incorporated into the Method of Project Selection.

In the above figure, marginal cost of capital (or alternatively weighted average cost of capital, WACC) and the firm's highest risk tolerance level are both incorporated into the previous model of project selection. The vertical line represents the firm's highest risk tolerance level. The projects that are located on the left of this line contain acceptable risk levels and are accepted by this criterion. In figure 3.18, this criterion clearly rejects projects *K* and *M*, and accepts projects *N* and *S*.

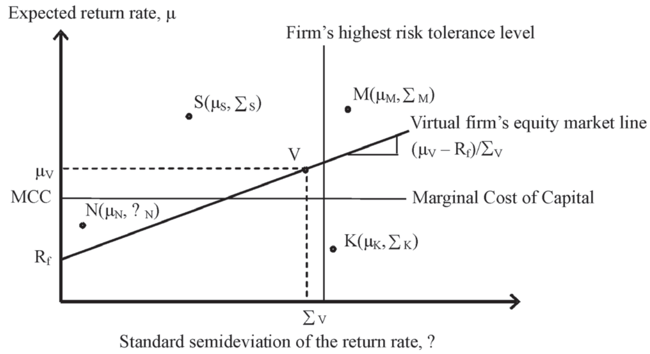

Figure 4: Incorporating the firm's marginal cost of capital and highest level of risk tolerance into the decision model

The horizontal line pointed out by MCC is the return rate of the marginal cost of capital. This criterion was traditionally applied in deterministic approaches similar to the minimum attractive rate of return criterion. All projects that their expected return exceeds this minimum limit are accepted by this criterion. In figure 3.18, according to the MCC criterion, projects *S* and *M* are accepted while projects *N* and *K* are rejected.

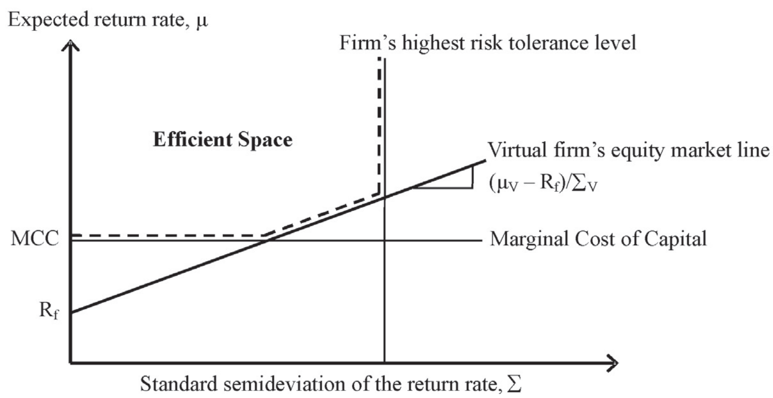

Figure 5: The efficient Space for project selection

If the three criteria are considered simultaneously, an efficient space will be derived from their collective acceptance-rejection criterion. This efficient space is the space that all three criteria accept projects and acceptance of these projects will add to the value of the firm.

Conclusion

We have examined the relative aspects of Capital Asset Pricing Models in the process of project selection. This project selection methodology has a fundamental advantage over previous methodologies because it implicitly takes into account the recognition of *market assessed* risk of both projects and the firm itself (reflected in the *price* of equity). Also the concept of risk is revisited and a more appropriate measure for risk (especially in Oil, Gas and Petrochemical projects) has been introduced. Using the market as a mediating mechanism for assessment is the major contribution of this approach to project selection.

The limitations of arbitrage pricing theory used in this approach are mainly due to the model inadequacy. The straight line model for the firm's equity market line and the two-parameter approach of mean-semivariance may not be sufficient in dealing with the difficult task of project selection.

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Appendix 1. Risk Equivalency

The market develops a unique risk level for the firm, as a result of the current pricing of the firm's shares and future expected dividend policy. This risk level is based on the collective ideas of the investors. Moreover, each individual investment project has its own riskiness. By accepting any project, the risk profile of the firm would also change in a complex form. The difference between the project risk and the firm's equity risk also forces the need to move from one indifference curve to another in order to determine the desirability one return-risk against one another. If we want to keep the market price of the firm's shares unaffected and compare them with the proposed investment project, we will need a method of "risk equivalency". Fortunately, Tuttle and Litzenberger developed a proper model of risk adjustment by combining borrowing and lending with equity capital to finance the proposed project.

Consider the project alternative *K*, with known expected return rate and known semideviation of return rate. Let:

μ_z = the expected return rate to equity from the project.

Σ_z = the estimated semideviation of the return rate to equity.

R_f = the riskfree borrowing and lending rate.

α = the financing ratio of the project (unity plus the debt-to-equity ratio).

μ_k = expected return rate from the project *k*.

Σ_k = expected semideviation of return from project *k*.

since $\Sigma_f = 0$, the estimate of return rate to equity is:

$$\Sigma_z = \alpha \Sigma_k$$

when *á* dollars per dollar of equity are invested in the project and $(1 - \alpha)$ dollars are borrowed per dollar equity, the expected return on equity from the project is $\acute{a}\grave{\imath}_k$, and the cost of borrowing is $(\alpha - 1)R_f$. because the total return is composed of the return to equity plus the return to borrowed capital, the expected return to equity is:

$$\mu_z = R_k + (\alpha - 1)\mu_k - (\alpha - 1)R_f$$

$$\mu_z = R_f + \alpha(\mu_k - R_f)$$

Recalling that $\alpha = \Sigma_z / \Sigma_i$, by differentiating the expected return rate with respect to semideviation, Σ_z, we will have:

$$d\mu_z/\Sigma_z = (\mu_k - R_f)/\Sigma_k$$

We can define $\alpha' = \Sigma_o / \Sigma_k$, in which Σ_o is the current risk of the firm. the risk effect of a project on the firm's return rate to equity can be equalized either through long-term lending of an amount equal to $[(1/\alpha 2) - 1]$ of the cost of investment project if $\Sigma_k > \Sigma_o$, or the long-term borrowing of $[1 - (1/\alpha 2)]$ of the cost of the project if $\Sigma_k < \Sigma_o$. the risk adjusted expected return rate on a project is:

$$\mu'_i = R_f + \alpha' (\mu_i - R_f)$$

Which is a *linear relationship* depicted in figure 9.

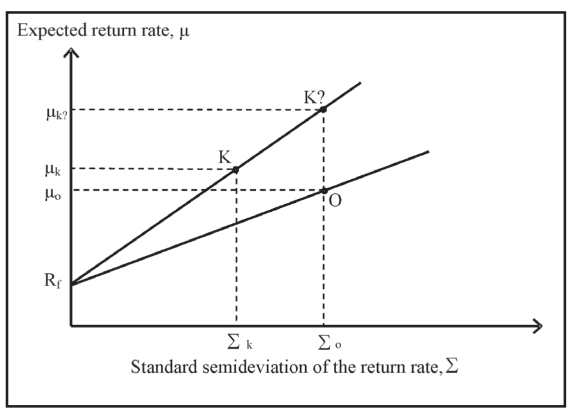

Figure 6: Risk adjustment of a project