Advanced Algorithmic Trading and Portfolio Management

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Lecture - 05

Portfolio theory and capital asset pricing model. Stock market is considered risky, because there is a possibility of multiple outcomes. The spread in these multiple outcomes is measured using variance or standard deviation. This variance or standard deviation spreads has two components first stock specific or diversifiable risk. This risk is specific to the stock then there is market risk which is related to the sensitivity of the stock to Broad market-wide movements.

Investors can eliminate this specific risk by holding a well-diversified stock portfolio, but they cannot eliminate this market risk. All the risk of a fully diversified portfolio is market risk. A stock's contribution to the risk of this diversified portfolio is determined by the sensitivity of the stock to market movements. This sensitivity is often defined as beta a well-diversified portfolio of Securities that has beta 1 will be considered as having an average risk that is same as Market risk.

The standard deviation of this portfolio will be same as the broad market index for example listed by S&P 500 or Nifty 50**.** A well-diversified portfolio of securities with beta of 0.5 is considered to have below average market risk. The standard deviation of this portfolio will be half of the market's standard deviation and an on average its movements will be half of markets movement in the same direction.

In this lesson we will consolidate our understanding of risk written framework. We will apply these theories to understand various surprising models such as capital asset pricing model CAPM.
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Investment performance and return distribution.

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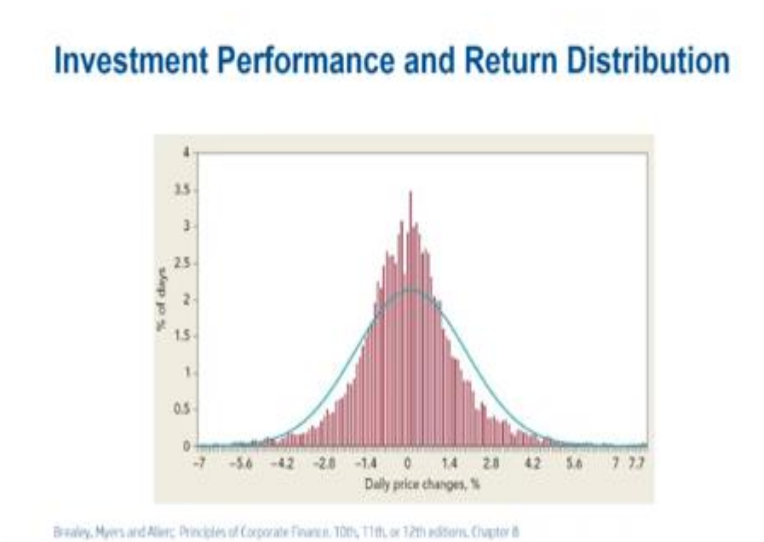

We discussed why normal distribution is important in modeling security returns. We also discussed the investment performance of securities. If we plot the histogram of daily returns it appears similar to the one shown here. One can also superimpose a bell-shaped normal distribution on these returns, it appears as if the historical returns confirm fairly closely to a normal distribution.

This eases the job of financial analyst. This is so because normal distributions can be very easily defined by just two parameters that is expected or average returns and standard deviation or variance. This also gives us the intuition why we devoted so much time in understanding the computation of return and standard deviation. When the returns are distributed closely to a normal distribution then investor needs only these two measures that is expected returns and standard deviation to define the performance of a security.

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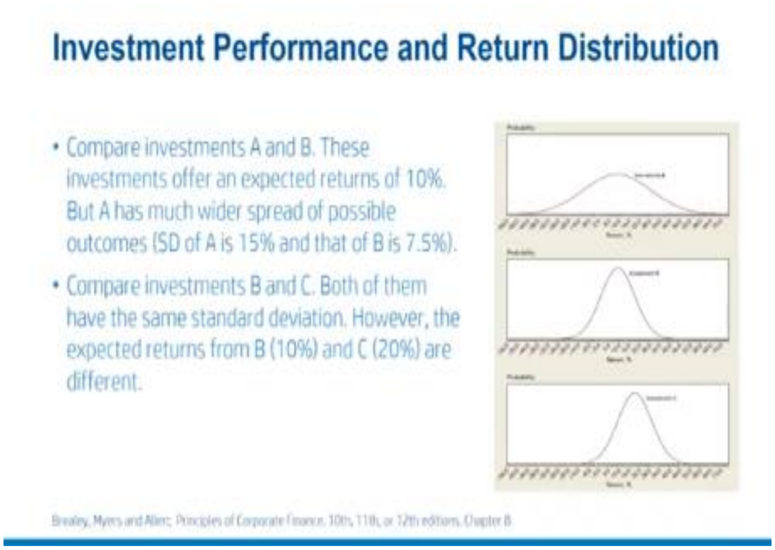

Now we understand why normal distribution is important. It is completely defined by these two parameters that is mean and standard deviation. Compare the Investments A, B and C shown here in the figure. These figures show the distribution of possible returns from the investments A, B and C. Compare investments A and B, these investments offer unexpected returns of 10 percent but A has much wider spread of possible outcomes.

Its standard deviation is 15 percent and the standard deviation of B 7.5 percent. Investors do not like risk and would of course prefer B to A. Now let us compare investments B and C. Both of them have the same standard deviation however the expected returns from B that is 10 percent and C that is 20 percent are different. Investors prefer higher expected returns and therefore would prefer C to B.

To summarize in this video, we discussed the role of normal distribution in modeling security returns. Normal distributions are easily defined with the help of just two parameters that is mean and standard deviation. Therefore, normal distributions are very useful in modeling security returns. Investors prefer securities that offer a higher level of returns for a given level of risk. Also for a given level of returns they prefer stocks with lower level of risk.

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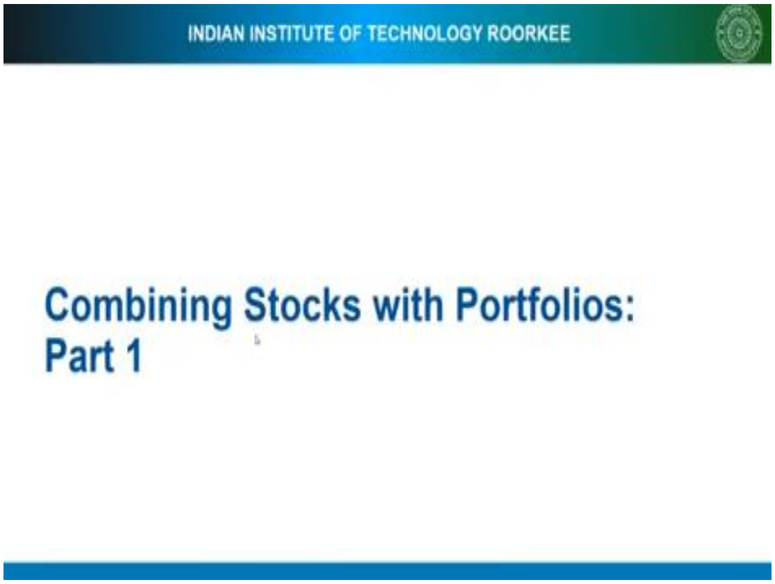

Combining stocks with portfolios part 1. We discussed the concept of diversification with the help of portfolios. We examine a portfolio of two stocks and see if diversification reduces the risk of this portfolio. Then we extend the learning of this two-stock portfolio to multiple stock portfolios and examine if there are a set of portfolios that are most efficient that is they offer the best combination of risk written across all the portfolios.

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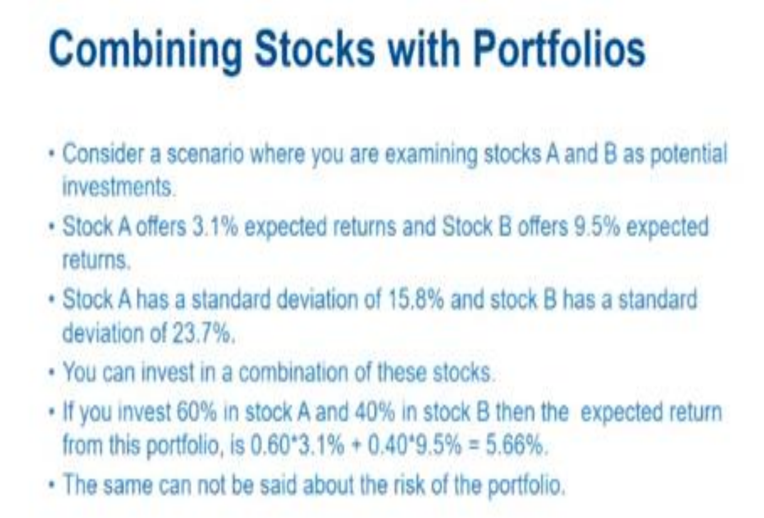

Consider a scenario where you are examining the stocks A and B as potential investments. Stock A offers 3.1 percent expected returns and stock B offers 9.5 percent expected returns. You also observed that stock A has a standard deviation of 15.8 percent and Stock B has a standard deviation of 23.7 percent. Stock B while offers a higher expected return also has a higher standard deviation however, you need not invest in only one of these stocks.

For example, you can invest in a combination of these stocks. If you invest 60 percent in stock A and 40 percent stock B then you would get an expected return from this portfolio which is $0.60 * 3.1\% + 0.40 * 9.5\% = 5.66\%$ This expected return is simply a weighted average of expected returns on the two stocks.

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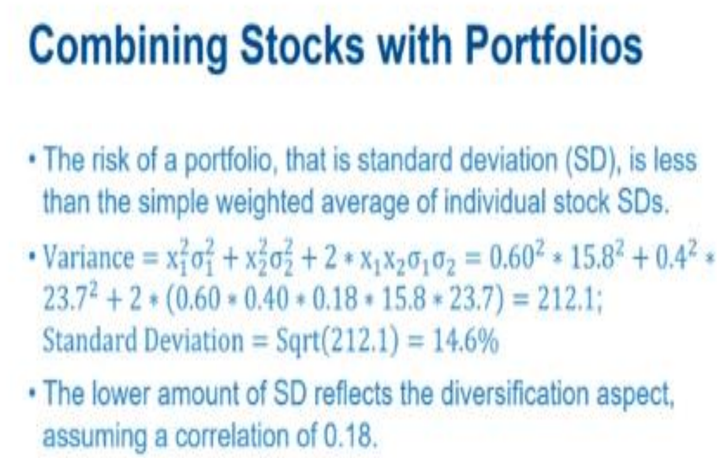

From our recently acquired portfolio knowledge we know that the risk of this portfolio that is standard deviation will be less than the simple weighted average of standard deviations. This is due to the concept of diversification. The risk of the portfolio can be computed as shown here Variance $= X_1^2\sigma_1^2 + X_2^2\sigma_2^2 + 2 * X_1X_2\sigma_1\sigma_2$, where sigma 1 and sigma 2 are the variances;

And x 1 and x 2 are the proportional weights invested in these securities then this is equal to $= 0.60^2 * 15.8^2 + 0.4^2 * 23.7^2 + 2 * (0.60 * 0.40 * 0.18 * 15.8 * 23.7) = 212.1$, this is the variance. Now standard deviation will be equal to $\sqrt{212.1}$ equal to 14.6 %. The risk of this portfolio is 14.6 percent.

The lower the amount of standard deviation it reflects diversification aspect assuming the correlation of 0.18.

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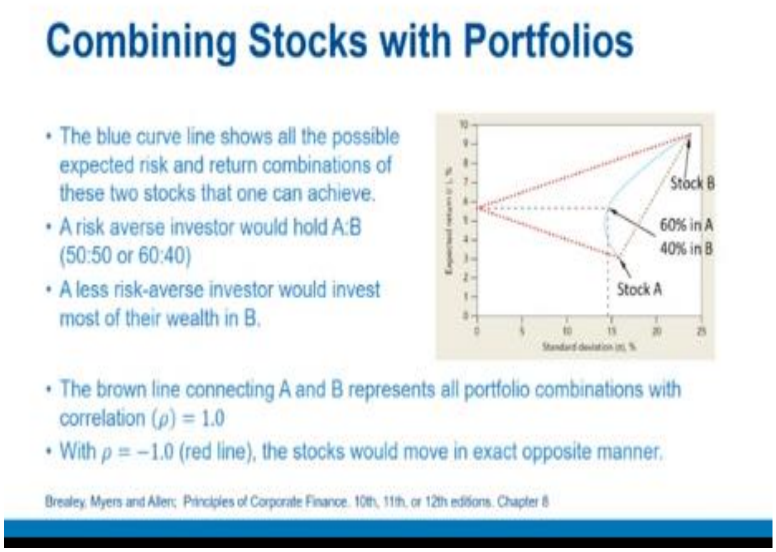

Consider the diagram shown here. The blue curve line shows all the possible expected return and this combinations of these two stocks that one can achieve. However, for different investors different combinations are more suitable. For example, individuals are often considered as risk loving, risk neutral or risk averse. Risk-loving individuals are those that like to take more risk. Risk neutral individuals are those that are indifferent to the risk aspect of a proposition, for example investment in a security.

And risk averse investors that do not like risk at all. Predominantly investors are considered to be rational individuals that do not like risk that is they are risk averse. For rational investor who is extremely risk covers she would rather like to hold a portfolio of A and B that is around mid of the blue curve maybe A is to B of 50 50 or 60 40. For a risk covers less risk covers investor who wants to take more risk and increase their stakes can invest the entire or most of the money in Stock B.

We know now that the level of diversification that is elimination of stock specific risk depends on the level of correlation between the two stocks. Assume that the correlation between stocks A and B is rather low at rho equal to 0.18. This low correlation results in the blue line curve representing all the possible combinations in the portfolio. If the correlation was 1 they would move exactly in a log step manner, there would be no gains from diversification at all.

This would result in a brown dotted straight line that is the resulting risk in the portfolio is exactly the weighted average of the standard deviation from the two stocks, conversely the red line exhibits another extreme case where correlation rho equal to -1 that is the two stocks move in exactly opposite manner. In this case maximum diversification will be achieved in fact at a certain investment proportion the risk of the portfolio becomes 0. However, this is an extremely theoretical case as stocks do not exhibit perfect negative correlations.

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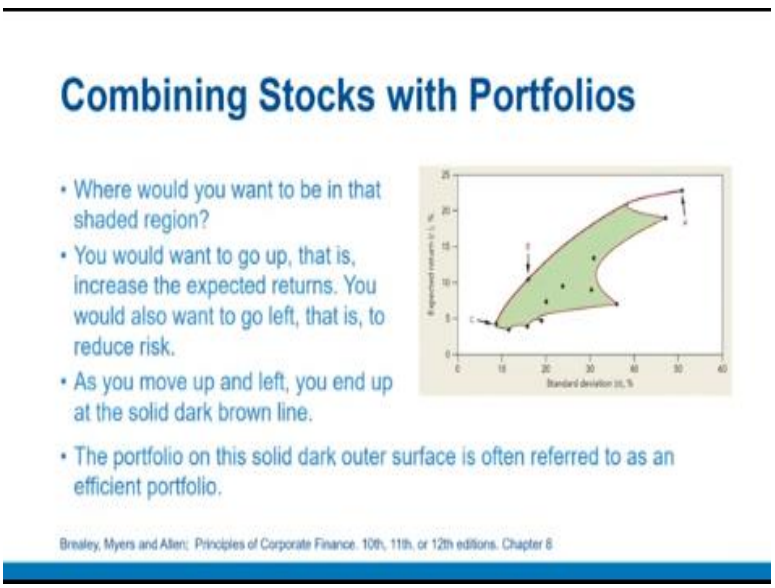

In practice you do not limit yourself to investing in just two stocks, for example you can invest in many stocks after analyzing the risk written related properties of these securities. Once you are aware about the risk and expected returns of the securities obtained from the historical data then you would carefully examine the data and choose the securities that are more suitable by holding portfolio of many securities maybe 10 15 20 etcetera, you can obtain a very wide selection of risk in return.

For example, consider a portfolio of 10 Securities plotted here using risk return data. In this figure each diamond shows the expected return and standard deviation of 10 stocks that are selected for the portfolio Construction. The Shaded region shows the possible combinations of expected risk and standard deviation by investing a mixture of these stocks. Observe the possibilities available to you as investor you can obtain any position in the shaded region.

But where would you want to be in that shaded region this is an extremely interesting problem in which direction you would want to go in the shaded region. The answer is quite intuitive. You would want to go up that is increase the expected returns. You would also want to go to left that is to reduce the risk. However, as you move up and left you end up with a solid dark brown line. The portfolio on this solid dark outer surface are often referred to as efficient portfolios a term coined by Harry Markowitz.

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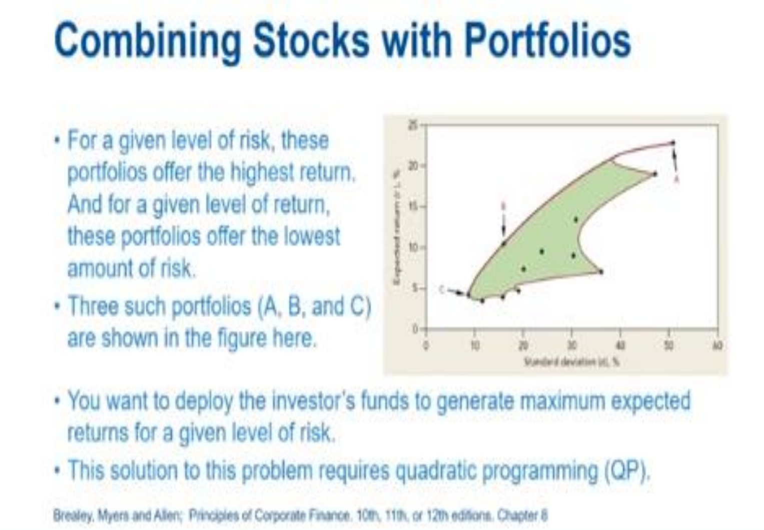

For a given level of risk these portfolios offer the highest return and for a given level of return these portfolios offer the lowest amount of risk. Three set portfolios A, B and C are shown in the figure here. We are not calculating these efficient portfolios here that will be done in more advanced courses of this specialization. The investment problem discussed here is similar to Capital rationing problem.

You want to deploy the investors fund to generate maximum expected returns for a given level of risk that is standard deviation. While graphical interpretation may give us the intuition to select the optimum portfolios, the actual mathematical solution of the problem requires quadratic programming. The key variables employed in this quadratic programming require expected return and standard deviation of each stock in the portfolio and correlation between each pair of stocks.

The set of efficient portfolios can be solved using standard deviation quadratic computer program. From this exercise we obtain efficient portfolios A, B and C. In the diagram provided here the possible combinations of these 10 securities are plotted and as can be seen from the diagram portfolio A offers the highest expected return portfolio C offers the minimum risk. One interesting insight comes out of this exercise is as follows.

Sum of combinations of these portfolios have lower risk than the least risky stock in the sample. This is quite intuitive and ascribed to the fact that some of these stocks may have extremely low correlations with other stocks in the sample. Large institutional investors invest in hundreds of stocks and are able to obtain much wider choices related to risk and return that is a wider feasible region.

This choice can be shown in diagram below the diagram shows the feasible region as a smooth echoed shape. To summarize in this video, we show the that the combinations of portfolios resulting from stocks with different weights and correlations we noticed two special cases of correlations that is 1 and -1. We observe that maximum diversification is obtained when correlation is -1 and no diversification is obtained when correlation is +1.

We also identify the portfolio possibility curve or feasible region which contains all the possible combinations of available securities. On this region we systematically identify a set of portfolios that are better than all the others for the given level of return or for a given level of risk these are called efficient portfolios and they lie on efficient frontier.

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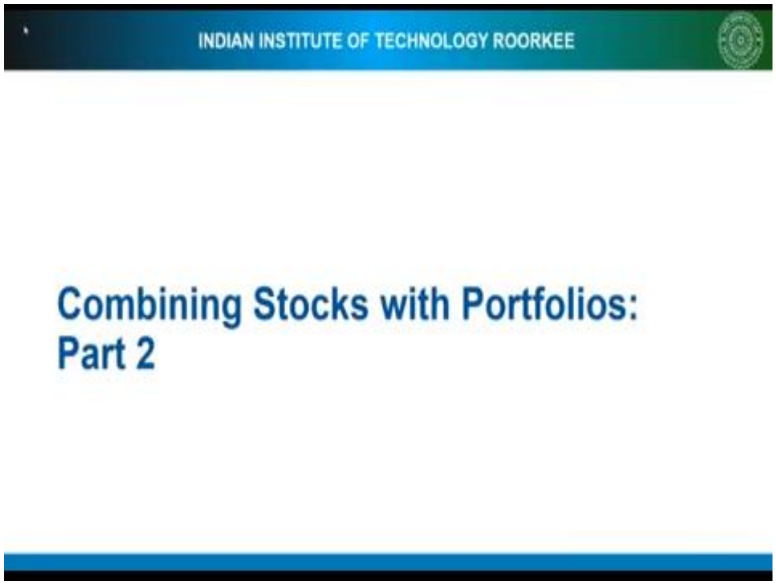

Combining stocks with portfolios part 2. We will extend our understanding of portfolio concepts and find a set of optimum portfolios that are suitable for a large class of investors as per their risk averseness. These portfolios are identified with the help of a disk free borrowing and lending rates.

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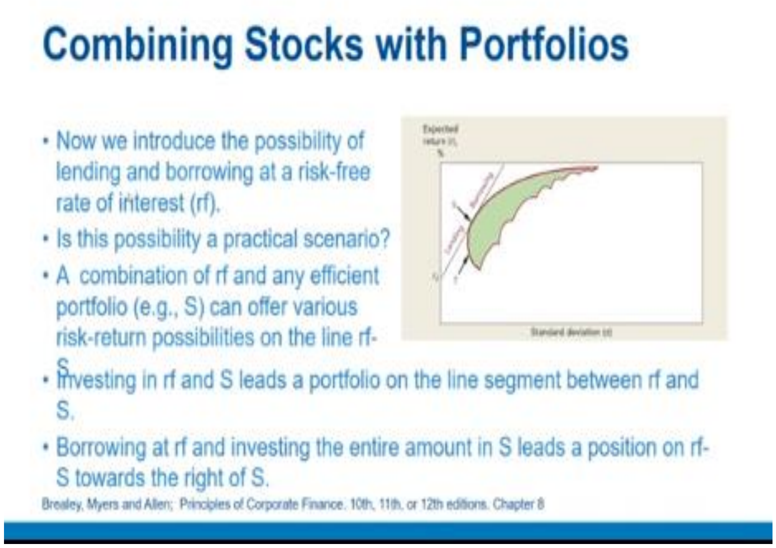

Let us introduce the possibility of lending and borrowing at risk free rate of interest RF. Deposits into government-owned Banks investment into money market mutual funds can be considered as one source to obtain risk-free rates. However, it is a purely theoretical argument to suggest that one can lend and borrow at the same risk-free rates. Assume that risky rate is available at RF for Lending and borrowing then a portfolio with some investment in this risk-free asset and remaining in a common stock portfolio can offer you any combination of risk return that lies along with the straight line joining rf and S as shown in the figure here. Also, a combination of borrowing at rf and taking a leverage rate position in s can be easily determined since borrowing is essentially negative lending. This will only extend the range of possibilities to the right of portfolio S as shown in the figure here.

This is obtained by borrowing a tariff and investing the original wealth as well as this borrowed money at rf in the portfolio S. To understand this, consider; the example shown here.

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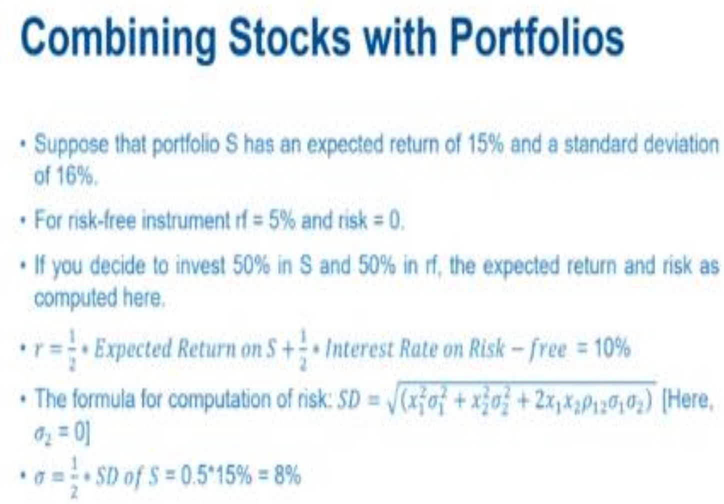

We will put some numbers on this. Suppose that portfolio S has an expected return of 15 percent and the standard deviation of 16 percent, the risk-free instrument that is for example treasury bill offers an interest rate r f maybe that is 5 percent and of course can be considered as risk free, that is a standard deviation which is 0. If you decide to invest half of your money in portfolio S and invest remaining amount at 5 percent in the risk-free instrument, the return on your portfolio can be easily computed as shown here.

To build the intuition kindly refer to the following computation. Consider the following formula for computation of standard deviation for a two-stock portfolio, where

$$SD = \sqrt{(x_1^2\sigma_1^2 + x_2^2\sigma_2^2 + 2x_1x_2\rho_{12}\sigma_1\sigma_2)}$$

Here σ_1 and σ_2 are the standard deviations ρ_{12} is the correlation coefficient and x_1 x_2 are the proportionate weights or amounts invested in these two stocks.

Here that x_1 and x_2 are the weights of security 1 and 2 $\rho_{12}$is the correlation and σ_1 σ_2 is the risk if one of the security is a risk-free asset with σ_2 equal to 0, the resulting risk of this portfolio can be simplified as shown here that is standard deviation equal to x 1 sigma 1. So, in this case

$$r = \frac{1}{2} * Expected\ Return\ on\ S + \frac{1}{2} * Interest\ Rate\ on\ Risk - free = 10\%$$

What about the standard deviation? Standard deviation is 50 percent of the standard division of S this is so because standard deviation of treasury bill is 0 and therefore

$$\sigma = \frac{1}{2} * SD\ of\ S = 0.5 * 15\% = 8\%$$

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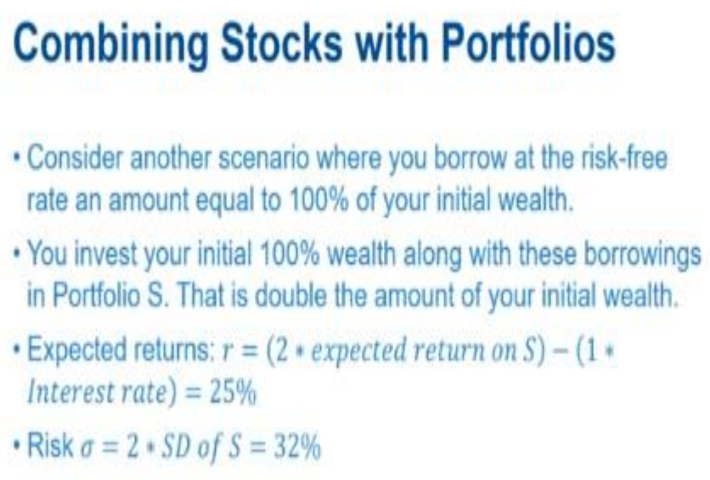

Consider another scenario where you borrow at the risk-free rate and an amount equal to 100 percent of initial wealth. You invest your initial 100 percent wealth along with these borrowings in portfolio S, that is double the amount of your initial wealth. So, you have to pay interest on the loan but now your expected return is computed as shown here

$$r = (2 * expected\ return\ on\ S) - (1 * Interest\ rate) = 25\%$$

also, the standard deviation of your portfolio can be computed as shown here which is

$\sigma = 2 * SD\ of\ S = 32\%$

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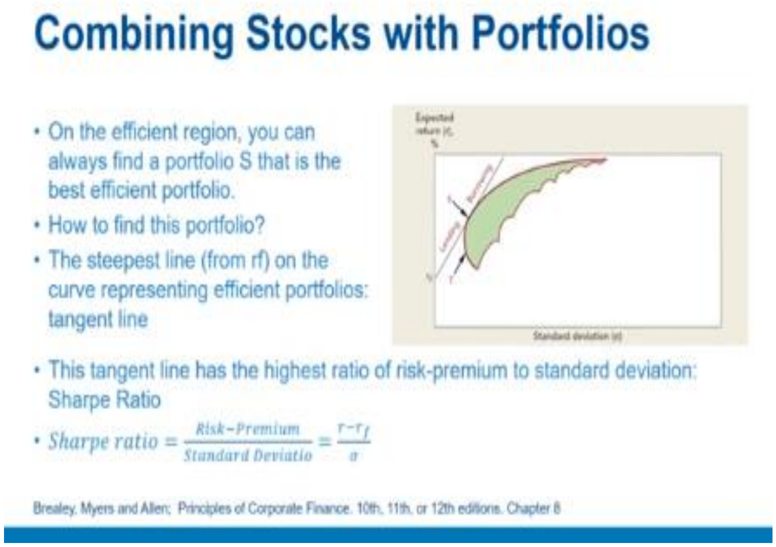

As we can see in the figure shown here when you invest in a portfolio a portion of money in rf and remaining in portfolio S you end up on the straight line joining rf and S as shown here between these points. Similarly if you borrow money at risk free rate you can extend the possibilities beyond S, that is on the right side of the straight line joining rf and S on the efficient region.

You can always find the portfolio as that is the best efficient portfolio which is a combination of r f and S that offers you the best expected risk return combination. This means that there is no other portfolio any portfolio T on the efficient Frontier that offers you a better combination of expected risk and return but how to find this portfolio? For example, if you have the data about all the efficient portfolios on the efficient Frontier, we can plot their different risk return combinations.

One can plot the steepest line from rf on the curve as shown here representing the efficient portfolios. This line will be tangent to the efficient portfolio curve this portfolio has a very important mathematical property. It has the highest ratio of risk premium to standard deviation this ratio is often called Sharpe ratio.

$$Sharpe\ ratio = \frac{Risk - Premium}{Standard\ Deviation} = \frac{r - r_f}{\sigma}$$

This is an extremely important ratio for investors. Investors track this ratio to measure the risk adjusted performance of securities and portfolio of investment managers.

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Theoretically this simplifies the investment manager's job considerably. First she needs to identify the best portfolio of common stocks that is portfolio S often called the market portfolio. Next this portfolio is mixed with the risk-free instrument. This risk-free instrument can be lending or borrowing according to the Investor's taste and risk averseness. For example, a risk averse investor would prefer to have a sizeable amount invested in risk free instrument. An extremely low risk of person may even decide to borrow at risk-free and invest in the portfolio as using this leverage.

Leverage here means a position that is higher than the initial wealth of the investor. This position is obtained by borrowing at risk free rate. Thus, each investor should put her money into these two instruments only a risky portfolio S and a risk free instrument that is either borrowing or lending. What is the nature of this S portfolio? If you have some better information about certain securities you would try to find security that are undervalued and these securities would form considerably large investments in your stock portfolio.

However, in a competitive market it would be difficult to find such securities assuming nobody has monopoly of good ideas then most of the investors will hold the same portfolio of stocks a very well diversified portfolio often referred to as the market portfolio. In practice also often it is observed that professional investors invest in Benchmark indices for example S & P 500 or nifty 50 and stay put for long term.

This is often referred to as a passive strategy of investment. So, now to summarize in this video we discussed that when a large number of stocks are added to a portfolio, we obtain a region of feasibility. This region of feasibility includes a set of portfolios that are most efficient in nature called efficient Frontier. If risk-free lending and borrowing is available then one can find a portfolio S that is most efficient among all.

This portfolio lies on the tangent line joining risk-free rate and the efficient Frontier. This portfolio has the higher sharpe ratio that is ratio of risk premium to standard deviation. A combination of this portfolio S and risk free rate provides different choices of risk return that are Optimum for investors having different risk averseness. For a more risk averse investor a higher amount of investment in risk free asset is desired. For a less risk averse investor borrowing at risky rate and the leverage position in portfolio S is more suitable. This simplifies the investment manager's decision problem considerably.

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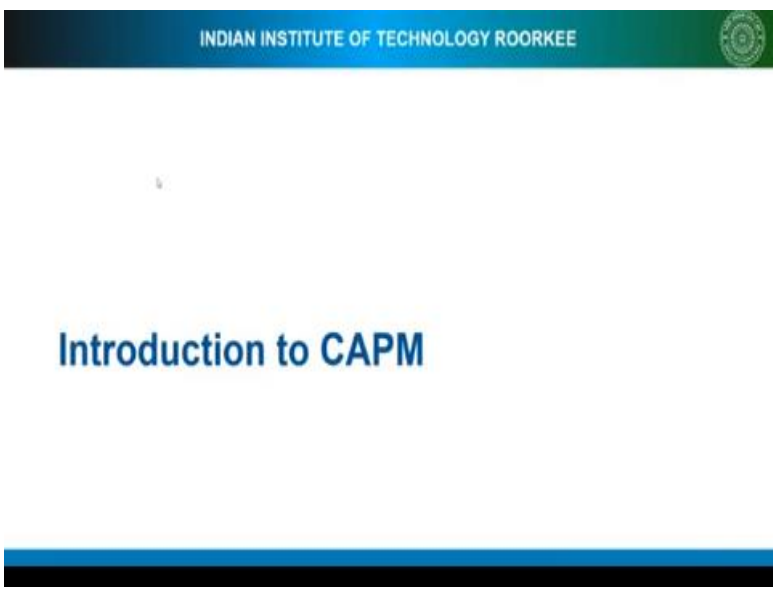

Introduction to CAPM. We examine the much-celebrated Capital asset pricing CAPM model and its role in determining the risk return relationship. We also discussed the concept of security market line.

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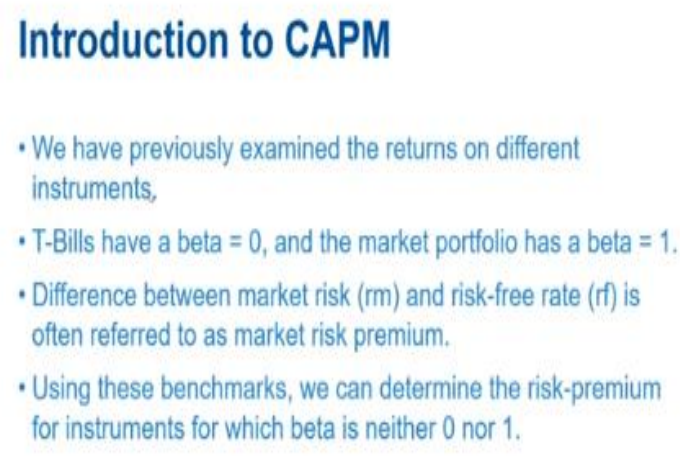

We have previously examined the Returns on various instruments. For example, government securities T-bills that are often considered as least risky. These instruments are largely unaffected by large Market movements, often it is said that their risk is zero that is standard deviation of 0 and beta equal to 0. Also, it is said that market portfolio has a beta of one since this market portfolio is risky investors demand higher returns from the market portfolio than T bills.

This difference in expected returns between the market and risk-free rate r_m minus r_f is often considered as Market risk premium. It is easy to see that T bills have a 0 risk premia since they are 0 risk instruments. The market portfolio that has a beta of one has a risk premium of r_m minus r_f. Thus, we have two different and relevant benchmarks or parameters for risk premium, using these benchmarks we can determine the risk premium for instruments for which beta is neither 0 nor 1, let us see how?

In 1960s three economist Sharpe, Lintner and Treynor came up with this model called CAPM, that provides an extremely simple and easy solution for the asset pricing problem. The model suggested that in a competitive economy the rest premium is directly proportional to its beta.

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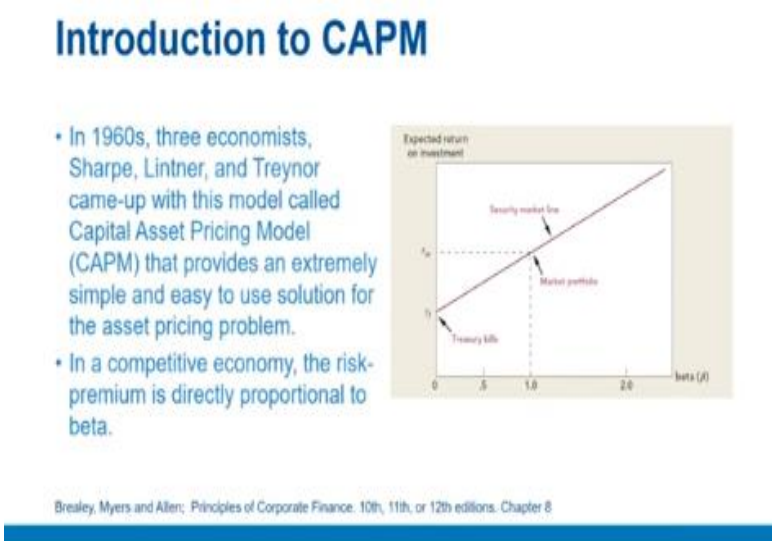

Consider the figure shown here. The figure incorporates the learnings of CAPM. It indicates that in equilibrium when no Arbitrage forces are active the risk premium on investment is proportional to its beta. That is each investment should lie on the line joining risk-free instrument for example T-bills and the market portfolio. The best efficient portfolio this is famously known as security Market line as it describes the behavior of security prices in market. So, the security Market line describes the behavior of security prices in the markets.

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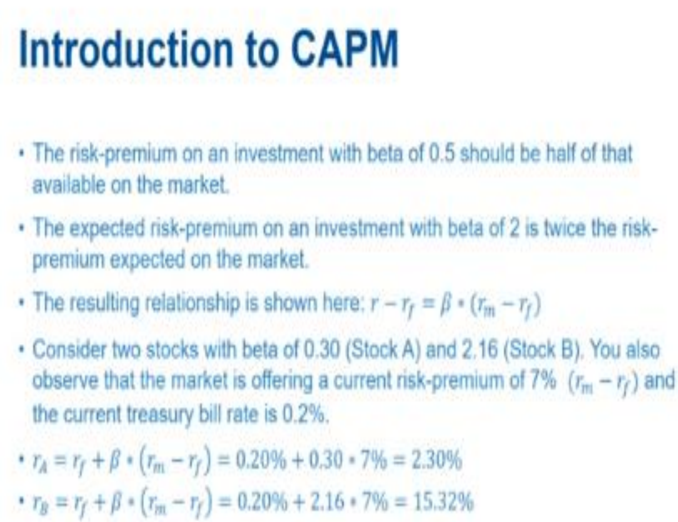

For example, the risk premium on investment with beta of 0.5 should be half of that available on Market. Similarly, the expected risk premium on investment with beta of 2 is twice the risk premium expected on the market. This relationship can be described easily as shown here expected as premium on the stock equal to beta into expected as premium on market or more formally

$$r - r_f = \beta * (r_m - r_f)$$

Here r is the expected return on the security in consideration r_f is the interest rate on risk free instrument and beta is the sensitivity of security to market movements and r_m is the interest rate on market. This formula helps us in estimating the expected returns from stocks. Consider two stocks with beta of 0.30 for stock A, 2.16 for Stock B. We also observed that the market is offering a current risk premium of 7 percent which is $r_m - r_f$ and the current treasury bill rate r_f is 0.2 percent.

Using CAPM, we can compute the expected returns from the stocks A and B. This is shown here

$$r_A = r_f + \beta * (r_m - r_f) = 0.20\% + 0.30 * 7\% = 2.30\%$$

$$r_B = r_f + \beta * (r_m - r_f) = 0.20\% + 2.16 * 7\% = 15.32\%$$

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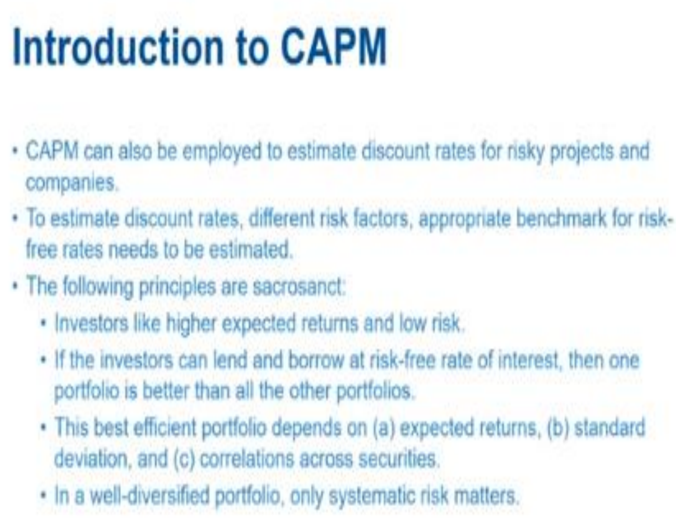

The utility of CAPM however is not restricted to predicting stock returns, it is also employed in estimating discount rate for various projects and unlisted companies. You find the Securities that have similar risk and using their expected returns estimated from CAPM you can find the appropriate discount rate. Estimating discount rates is always challenging, for example different

factors affect risk such as leverage, current market risk premium among others you need to appropriately account for these by estimating the risk of the security.
Finding accurate proxies to account for these risks in the risk of the security. Also, short- and long-term interest rates differ. Thus choosing appropriate Benchmark rf should it be short-term or long term is not easy. For short-term Investments investors are often contend with low returns, but for long-term Investments investors certainly demand a higher return.

That is cost of capital or opportunity cost or discount rate estimates based on short-term interest rates may not be very appropriate for long-term project investments. Let us review the basic principles of CAPM and portfolio selection. First Investors like higher expected returns and lower risk that is standard deviation. Security portfolios that are well diversified and offer the highest returns for a given level of risk are known as efficient portfolios.

Second if the investors can lend or borrow at risk free rate of interest then one portfolio is better than all the other portfolios. This portfolio has the highest Sharpe ratio that is risk premium to standard deviation. Our portfolio S, a risk covers investor will put part of his money in Risk free asset and remaining in efficient portfolio. A risk tolerant or less risk averse investor will put all of her money in this portfolio S, also she may try to borrow more at risk free interest rate and invest the additional amount that is a leverage position.

Third, this best efficient portfolio depends on expected returns, standard deviation, and correlation across securities. If everybody has the same information and assessment of expected return, standard deviation correlations and there is no Superior information available in the market then everybody should hold this best efficient portfolio or Market portfolio. Finally, in a well-diversified portfolio the individual risk of stocks do not matter. What matters is the contribution of this stock to portfolio risk. This contribution depends on Stock's sensitivity to changes in the value of the portfolio, that is beta of the stock a measure of stocks systematic risk.
As already discussed in this lesson if there is no Superior information then everybody holds that market portfolio and if beta measures the contribution of security to this portfolio risk, then it should be quite intuitive to observe that the risk premium demanded by investors from a securities is securities beta that is essentially the idea and theory behind CAPM.

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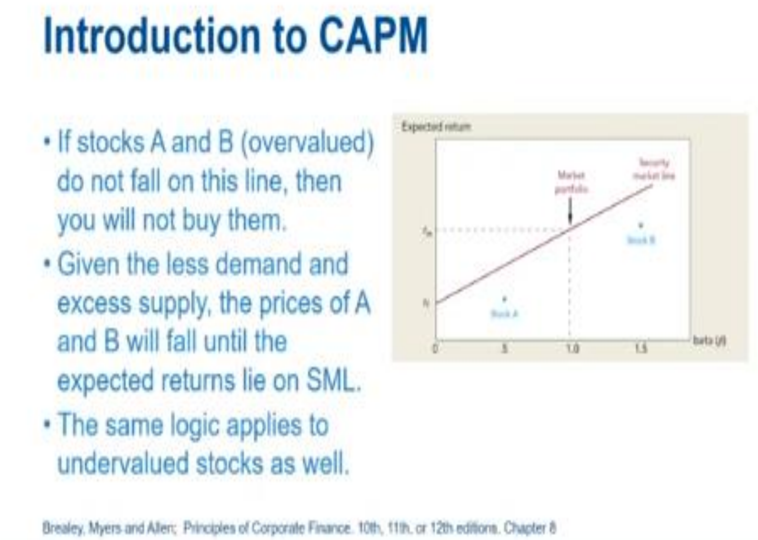

Consider the figure shown here, it appears that stocks A and B do not lie on security market line. Now in all probability you would not buy these stocks, for example if you want a stock with beta of 0.5, you can obtain higher expected return by taking a position of security market line with a beta of 0.5. This position can be obtained by investing 50 percent in $r\ f$ and 50 percent in market portfolio. If everybody shares your view then everybody will sell or short sell A.

Given this excess supply of A, the price of A will fall until its expected return matches with that of the equilibrium SML security market line. Similarly for B one can obtain a position on SML by borrowing 50 percent of your wealth at $r\ f$ and investing 150 percent of your wealth at market portfolio. Again, if everybody agrees with this then with the same logic Stock B will fall on SML, this also means that investors can hold a combination of market portfolio M and risk free rate r f to obtain an expected return that is

$$\bar{r} = r_f + \beta * (r_m - r_f)$$

In well functioning liquid and efficient markets nobody will hold a stock that offers anything less. We apply the same logic to an underpriced stock that is a stock that offers higher expected returns than those expected as per the SML security market line that is CAPM. This stock will lie above SML however there will be many takers for this stock. The demand for this stock will rise considerably as compared to the supply.

Thus, the price of this stock will rise and the stock will fall on SML. This also comes from the idea of equilibrium in financial markets. Equilibrium is obtained from the Arbitrage mechanism which drives prices towards efficient values that is towards this SML. To summarize in this video, we discussed how Capital asset pricing model, that is, CAPM will determine the risk return relationship. CAPM postulates that expected risk premium on stock that is beta into expected risk premium on market or more formally,

$$(r - r_f) = \beta * (r_m - r_f)$$

The formula indicates that market demands a risk premium which is beta times r_m minus r_f from every stock which is proportional to its risk as measured by beta. We also discussed the concept of security market line that is SML. All the fairly priced securities in liquid and efficient markets should lie on this SML. In efficient markets, it is expected that nobody has higher information to beat the market. In such markets securities are expected to lie on SML.

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Validity of CAPM. We examine the critiques of CAPM. More specifically, we examine the real world scenarios that do not follow the CAPM postulations such as size premium that is small CAP minus large CAP and value versus growth premium.

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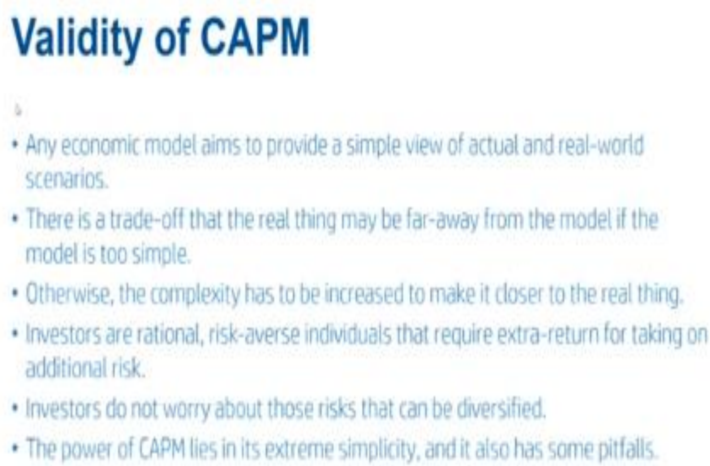

Any model that aims to provide a simple view of actual and real-world scenario require simplification. The simplification helps in understanding the correct picture. However, there is a trade-off that the real thing may be far away from the model if the model is too simple, otherwise the complexity has to be increased to make it more closer to the real thing. In the context of financial markets there are certain principles around which there is a broad agreement.

For example, investors are risk rational risk averse individuals that require extra return for taking on additional risk. That is why common stocks offer higher expected returns than T bills. If they offered same returns we would not invest in common stocks. Second, investors are not excessively worried about those stocks that they can eliminate with diversification. If they were not able to do; So, then we would observe that stock prices would increase whenever a firm diversified into different businesses or there was an imaginary acquisition activity between two different industry sector firms. Also, in that case companies that invested in the share of other firms are more valuable than the sum of the value of shares held by them, however we do not observe this. Mergers is just the diversification objective do not receive premium from the market. Also investment companies do not obtain higher valuations than the shares held by them.

All these ideas are very easily and in a simple manner captured by CAPM. That is why CAPM is very often used to estimate the cost of capital for projects with given cash flows. While the power of CAPM lies in its extreme simplicity it also has some pitfalls. We will have some of these pitfalls now discussed often researchers find that actual returns do not fall on security market line that is SML line predicted by CAPM.

Proponents of CAPM and claim that actual returns are different from expected returns. Actual returns also include a lot of real-world noise and therefore differ from expected returns. If one plots SML this noise will appear in the form of scattered nature of points around the SML. This noise makes the job of analysts and investors even more difficult. One solution to this problem is to increase the data being analyzed so that noise is averaged out over long horizons.

And the problem with CAPM is the presence of extra returns on small cap minus large cap portfolios. It has been observed that if you bought the firms with small market capitalizations and sold the firm with large Market capitalizations you would make certain positive extra return. This is called size premium. The size premium, that is constantly higher returns for small cap minus large cap portfolios, do not conform to CAPM model.

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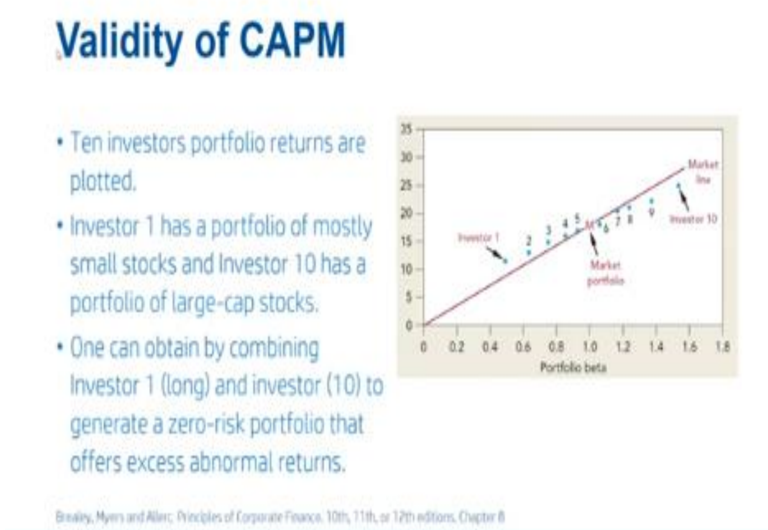

Consider the diagram shown here. 10 investors portfolio returns are plotted. Investor 1 has a portfolio of mostly small stocks and investor 10 has a portfolio of large cap stocks. Notice that investor one has its average returns above the SML line, investor 10 has its average return below SML line. This return that one can obtain by combining investor 1 that is long and investor 10 to generate a zero risk portfolio short that offers excess abnormal returns. This indicates that size indeed captures some kind of risk for which this premium is offered by the market.

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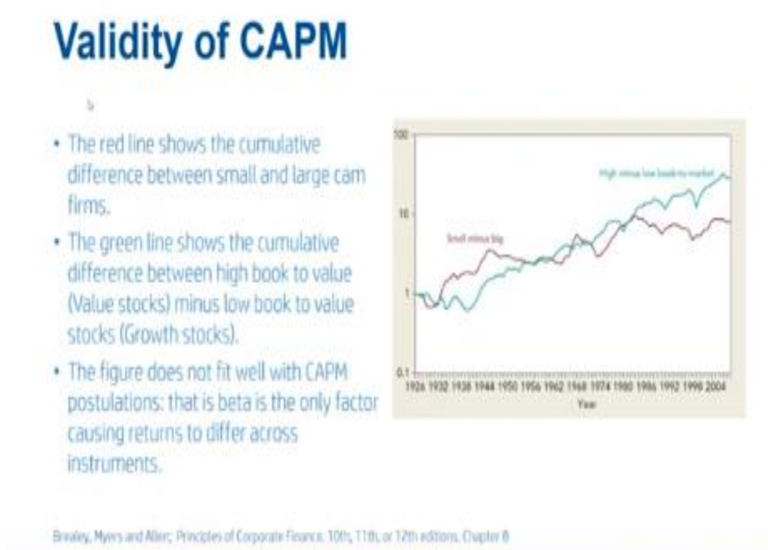

Consider a figure shown here, the red line shows the cumulative difference between small and large CAPM, the green line shows the cumulative difference between high book to value, that is, value stocks minus low book to value, that is growth stocks. The figure does not fit well with CAPM postulations that is beta is the only factor causing returns to differ across instruments. From this figure it appears that investors find small cap stocks risky as compared to large cap stocks.

They also find the value stocks riskier than growth stocks. These risks are probably not captured by beta. For example, value stocks are stocks of distress firm that are in trouble. If market was in trouble, these were the ones affected most badly. Thus, investors demanded certain compensation to hold these stocks as against the growth stocks. The relationship between expected returns from size and book to market ratio is well documented and damages the CAPM. Also, these are long lasting results and do not due to some data snooping or data mining inputs.

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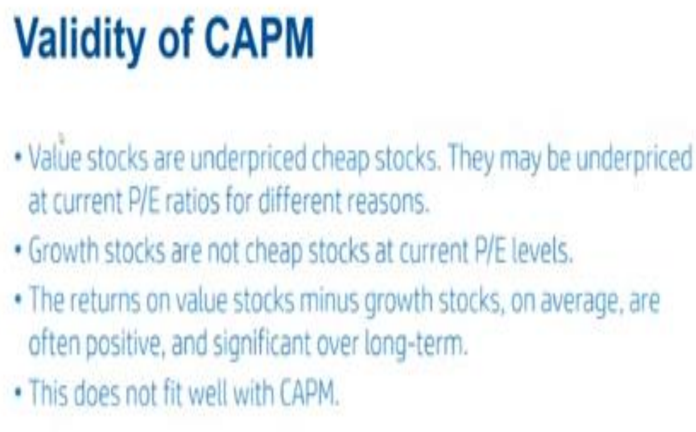

Next and very important value versus growth stocks. Value stocks are underpriced cheap stocks. They may be underpriced at current PE ratios for different reasons. For example, some bad news about the company may be creating negative sentiment in the market. In contrast, growth stocks are not cheap stocks at current PE levels, that is price to earnings levels. For example, a technology stock like Apple that is selling at a premium. However, you are more interested in the earnings component that is denominator of price to earning ratio.

You feel that the company is expected to grow significantly and therefore its price may increase. Researchers often observe what is called value growth premium. The returns on value stocks minus growth stocks are often positive and significant over long term. This also does not fit well with CAPM. As per CAPM, the only reason that expected returns may differ across stocks is their beta. It appears that small stock firms are perceived as riskier by investors than large cap firms.

Similarly, value firms are also perceived as riskier as compared to growth firms that means CAPM is not the whole truth here. Some additional dimensions of risk apart from beta are also playing their part. That is firm size and book to market ratios are capturing these additional dimensions of risk. To summarize in this video, we discussed that a portfolio of small stock offers excess returns as compared to the portfolio of large stocks.

Similarly, we also observed that value stock portfolios offer higher returns as compared to growth stock portfolios. This excess return premium cannot be explained by CAPM. It is argued that investors find small stocks riskier as compared to large stocks. Similarly they also find value stocks riskier as compared to growth stocks. This means that CAPM may not be the complete truth about asset pricing.

Nonetheless it provides a good Benchmark to start examining the asset prices given its simplicity and ability to provide intuition to a asset pricing frameworks.

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Alternative theories of asset pricing

We discuss other theories of asset pricing that compete with CAPM and augmented. We will discuss the Arbitrage pricing theory APT and three factor Fama French model and also contrast some of these properties with CAPM.

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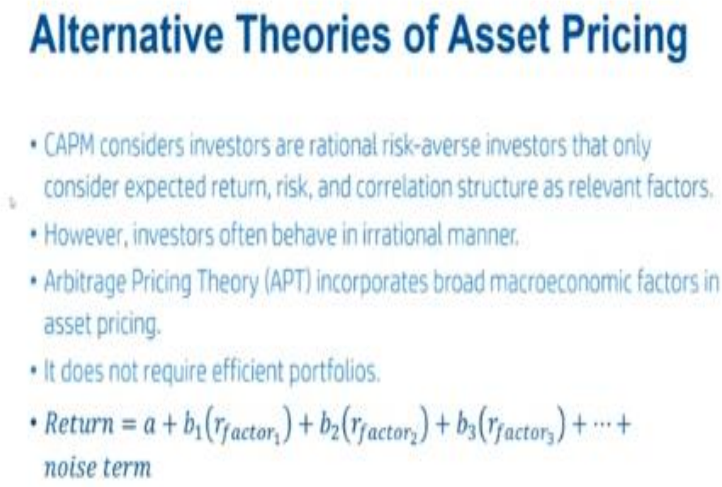

CAPM set pricing model pictures investors as solely concerned with the level and uncertainty of their future wealth, that is, they are purely rational investors with only expected return risk and correlations across stocks as key factors. However behavioral psychologists have pointed out that investors may not always behave in a rational manner. For example the fear of poverty may lead them to behave irrationally or increasing prices of holdings may make them extremely jubilant while falling prices May induce fear which may lead them to behave irrationally.

Thus, CAPM may lose its power when such features are introduced in the model that may demand more realistic picture one that is closer to real life scenarios. One such attempt is arbitrage pricing theory APT of Stephen Ross. APT does not depend on a set of efficient portfolios. It starts by assuming that each stock return partly depends on macroeconomic influences often referred to as factors in APT parlance and on noise that is random chance events. Thus, the return on any stock can be described easily with the following equation which is

$$Return = a + b_1(r_{factor1}) + b_2(r_{factor2}) + b_3(r_{factor3}) + \cdots + noise\ term$$

b_i's here are sensitivities to the factors like factor 1, factor 2 respectively.

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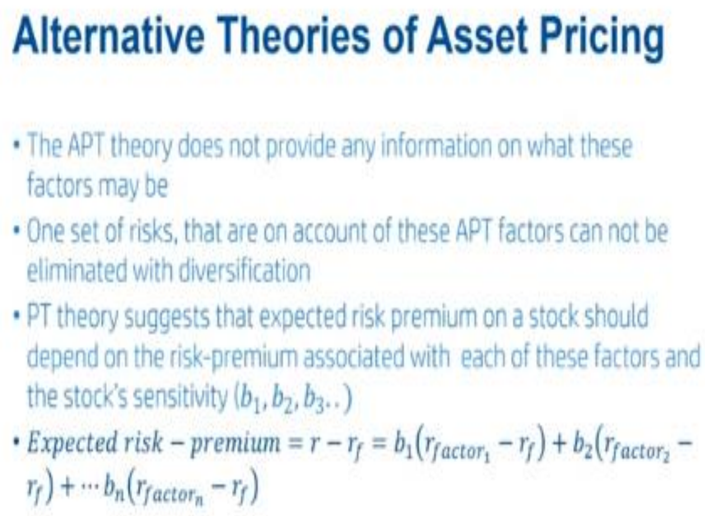

However, the APT Theory does not provide any information on what these factors may be. Very often people tend to include return on market portfolio proxies for example NIFTY 50 and or NIFTY 500 as one factor. Some stocks will be more sensitive to a particular factor than other stocks , for example ONGC will be more sensitive to oil and gas factor as compared to apple. For any stock there can be two possible sources of risk.

One set of risks that are on account of these factors for example market, oil, and gas etcetera. These risks cannot be eliminated with diversification. Second set of factors that are specific to company and can be eliminated with diversification. Therefore, investors that are well diversified are not much concerned about this stock specific risk component of the firm. The expected risk premium demanded on a stock is mostly affected by these systematic broad market wide and macroeconomic risk factors.

APT Theory suggests that expected risk premium on a stock should depend on the risk premium associated with each of these factors and stock sensitivities that is beta 1, beta 2, Beta 3 and so on to these factors. Thus, the resulting formula for expected risk premium is expected risk premium equal to

$$Expected\ risk - premium = r - r_f = b_1(r_{factor_1} - r_f) + b_2(r_{factor_2} - r_f) + \cdots\ b_n(r_{factor_n} - r_f)$$

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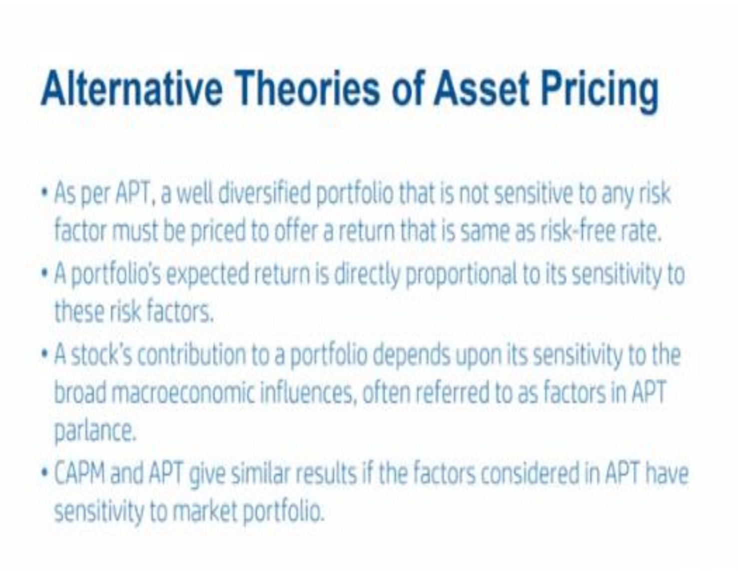

Notice that if all the bi's are 0 then the expected return premium on this stock is also 0. A well-diversified portfolio that is not sensitive to any of these factors must be price to offer interest rate equivalent to risk free rate. If anything, otherwise investors can conduct Arbitrage depending upon whether it is overvalued or undervalued which will drive the prices up or down and align them with the risk free rate of interest.

A diversified portfolio that is constructed to have exposure to some of these factors 1, 2, 3 etcetera will offer a risk premium that is directly proportional to portfolio sensitivity to this factor that is bi's. For example, if you construct two portfolios A and B assume that A is twice as sensitive as B to factor one, then portfolio A must offer twice risk premium as well for a given dollar investment.

If a stock is held in well-diversified portfolios, then the APT applies to stocks as well. Each stock must offer an expected return commensurate to its contribution to the portfolio risk. As per APT this contribution depends upon the sensitivity of stocks return to the changes in these broad market-wide factors. Like the capital asset pricing model Arbitrage pricing Theory stresses that expected return depends on the risk stemming from economy-wide influences and is not affected by specific risk.

CAPM and APT give similar results if the factor considered in APT exhibit some sensitivity bi to the market portfolio. In other cases, they will not. So it is not exactly correct to say that APT with various factors is inconsistent with market portfolio.

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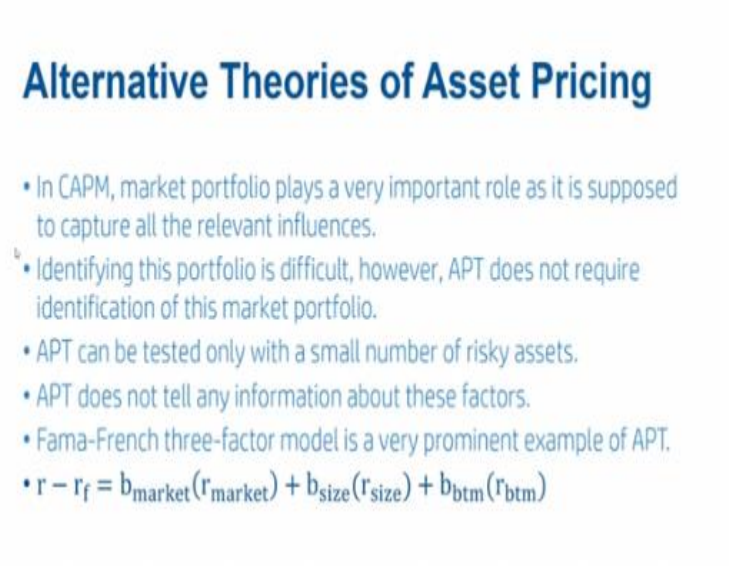

In the context of CAPM market portfolio plays a very important role. It is supposed to capture all the relevant influences in the single well-defined factor called market portfolio. Identification of this market portfolio is extremely difficult; however, this market portfolio does not figure in APT theory so we can test APT with only small sample of risky assets, that is, a considerable advantage over CAPM and where one needs to consider a large number of securities to identify CAPM.

However, unlike the market portfolio or factors in the parlance of APT, APT does not identify those factors and leaves it to the researchers and practitioners to identify the relevant influences. In this series we have another very prominent model called three factor Fama-French model. In their highly cited research articles developed and showed that stocks of small firms as compared to large firms and stocks with high book to market ratios as compared to those with low book to market ratios provided above average returns.

However, this is not a coincidence as research suggests that these factors may be indeed related to systematic risk factors affecting the form profitability. These factors may not be part of simple CAPM as Fama-French 3 factor model, the following equation may appropriately describe the expected security returns that is r minus r f which is risk premium equal to b market into r market factor + b size into r size factor + b book to market into r book to market factor.

Here b i is of the factor sensitivities and r factors are the risk premium on different factors, that is market size and book to market. This is also known as Fama-French 3 factor model. The application of this model to estimate the expected returns is same as application of APT theory with three factors. The following steps are needed to conduct the analysis and estimation. First identify the factors.

First market factor, this factor is proxy using expected returns on market minus risk free rate of interest. Second size factor, which is expected returns on small stocks minus, those on large stocks. Third is book to market factor which is returns on high book to market stocks less those on low book to market stocks. Next step is estimate the premium for each factor, which is r market factor, for example, is the risk premium for market factor.

And third and final step is estimate the factor sensitivity that is b_i's for all the factors. To summarize in this video, we discussed some of the pitfalls with CAPM for example small firm stocks offer higher expected returns as compared to large firm stocks. Also stocks with high book to market ratios offer on average higher returns than low book to market ratios. These extra returns do not confirm well with the CAPM which postulates that only consideration in asset pricing is its sensitivity to market portfolio.

More recent theory such as arbitrage pricing theory and Fama-French 3 factor models aim to resolve this and come closer to real life observed phenomena.
To summarize this lesson the basic principles of portfolio selection boil down to a common sense statement that investors try to increase the expected return on their portfolios and to reduce the standard deviation of that return. A portfolio that gives the highest expected return for a given standard deviation or the lowest standard deviation for a given expected return is known as an efficient portfolio.

To work out which portfolios are efficient an investor must be able to state the expected return on standard deviation of each stock and the degree of correlation between each pair of stocks. Investors who are restricted to holding common stocks should choose efficient portfolios that suit their attitudes to risk. But investors can also borrow and lend at rest free rate of interest should choose the best common stock portfolio regardless of their attitudes to risk.

Having done that they can then set the risk of their overall portfolio by deciding what proportion of their money they are willing to invest in stocks. The best efficient portfolio offers the highest ratio forecasted risk premium to portfolio standard deviation. For investor who has only the same opportunities and information as everybody else, the best stock portfolio is the same as the best stock portfolio for other investors.

In other words, he or she should invest in a mixture of market portfolio and a risk free instrument that is borrowing or lending. A stocks marginal contribution to portfolio risk is measured by its sensitivity to changes in the value of the portfolio. The marginal contribution of a stock to the risk of the market portfolio is measured by beta, that is the fundamental idea behind the capital asset pricing model CAPM which concludes that each securities expected risk premium should increase in proportion to its beta.

Expected risk premium is equal to beta time market risk premium that is r - r f equal to beta times r m - r. f. The CAPM theory is best known model or for risk return. It is plausible and widely used but far from perfect. Actual returns are related to beta over long run but the relationship is not as strong as CAPM predicts and other factor seems to explain the returns as well. The APT arbitrage pricing theory offers an alternate theory of risk and return.

It states that the expected risk premium on a stock should depend on the stocks exposure to several pervasive macroeconomic factors that affect stock returns. Arbitrage pricing theory does not see what these factors are. Fama-French have suggested three factors; first the return of the market portfolio less the risk free rate of interest, second the difference between return on small and large stock firms.

The difference between the return of stocks with high book to market ratios and stock with low book to market ratios is the third factor. In the Fama-French 3 factor model the expected return on each stock depends on its exposure to these three factors. Each of these different models of risk and return has its own fan club, however all financial economist agree on two basic ideas investors require extra expected return for taking on risk.

And second that they appear to be concerned predominantly with the risk that they cannot eliminate by diversification.