Mathematical Portfolio Theory
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Module – 08
Applications with market data
Lecture – 01
Asset allocation

Hello viewers, welcome to the last week of our lectures on this NPTEL MOOC course on Mathematical Portfolio Theory. Now, this week will be devoted to looking at some MATLAB usage in case of portfolio optimization problem. So, what I will do is that I will focus mostly on the MATLAB financial toolbox and we will use some in-built examples there which will help you learn how to design your own portfolios and for today's lecture, we will talk about an example of Asset allocation problem.

So, what we start off with is that we consider a specific example where you take into account several asset classes and then, we look at the various aspects of the problem beyond what we had done in case of the mean variance portfolio optimization techniques that we have learnt.

And we will go step by step eventually leading us to the weights of an optimized portfolio tailored to the requirements of an individual investors along with the investment strategy of buying and selling that is required in order to attain an optimized portfolio. So, let us begin this lecture by going into directly into the MATLAB's help page on this particular topic.

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So, we begin this lecture with a case study on asset allocation using MATLAB financial toolbox and this is a fairly exhaustive example on how to set up a basic asset allocation using the mean variance portfolio optimization. So, this example is covers many different perspective of asset allocation.

Firstly, in the paradigm of the mean variance portfolio optimization that we have already done and in addition to that it brings about more practical constraints that are applicable in a real life situation in order to determine your investment in optimal portfolio. So, this will involve several steps and I will talk about you know one step at a time. So, the 1st thing to do is to define the portfolio problem.

So, now, the goal is to manage an asset allocation fund. So, this means that you want to create a portfolio and the portfolio will not comprise just of individual stocks, but rather four asset classes and these four asset classes are bonds. So, that is the risk free part or the risk free asset component of the fund and there will be three components of equities namely large cap equities.

This you can view this as companies with large market capitalization, small cap equities that is smaller companies and emerging equities these are some of the smaller companies. Now, once we have decided that we are going to invest in these four asset classes, the constraint is that the fund is going to be long only. So that means you cannot take a short position as far as the equity component is concerned, so that means, your weights cannot be negative.

And there can also be no borrowing or leverage, so, no borrowing is allowed or using usage of borrowed money is allowed. So, in both in case of bond and the three classes of equities, you

are not allowed to have any negative weight. Also, the other constraint is that in order to ensure that the risk exposure is somewhat limited, the other constraint is that out of the total amount of money that you have at most 85 percent can be invested in the equity.

So, that means, the large cap equities and small cap equities and emerging equities the total amount of money that you invest in all of these three combined cannot be more than 85 percent of your initial investment and amongst the equities where there is an upper cap of 85 percent, you cannot put more than 35 percent of the total amount in emerging equities.

So, now there is always a trading cost. So, we have not discussed the trading cost in the regular class, but that is a practical consideration that has to be taken into account. So, the cost to trade in the first three assets namely the bond, the large and the small cap equities all three is 10 basis points.

So, 1 basis points so, you must have heard a lot about basis points whenever there is interest rate change in the market. So, the 10-basis point here. So, 1 basis point is 0.01 percent. So, 10 basis point is 0.1 percent, so that is the transaction cost. And in case of the emerging equities given the nature or extra risk riskiness that is associated with emerging equities, they will typically have a transaction cost that is four times higher so that is 40 basis points or 0.4 percent the that can be allowed in terms of the transaction cost.

Also, finally, the constraint is that you want to ensure that the average turnover is no more than 15 percent. So that means that eventually you should not actually be at any time liquidating more than 15 percent of the assets. So, now in order to solve this problem, you essentially you have to first set up the basic mean variance portfolio optimization problem and then, you slowly introduce the constraints.

And what are the constraints? The first constraint was that you cannot have any negative weights, the next constraint was that 85 percent of the portfolios can be inequities, so, at least 15 percent must be put in bonds and at most 35 percent can be put in the emerging equities and the transaction costs are 10 basis points for all the asset classes except emerging equities, where it is 40 basis point or 0.4 percent and finally, you want to incorporate the average turnover of that average turnover should not be more than 15 percent.

So, now, when I talk about asset class obviously, in this context I do not mean that you should be creating different classes yourself, but instead for yeah instead of investing in separate

equities stocks some of them in large cap, small cap and so on, you instead just invest in what are known as the exchange traded funds.

Now, this simple example sets forth that the portfolio, initial portfolio holdings that is the total amount invested in this four asset categories is going to be 7.5 million dollars and in addition, you should have the cash position of 60000 dollars that is for some exigencies and expenses that we see will appear later on.

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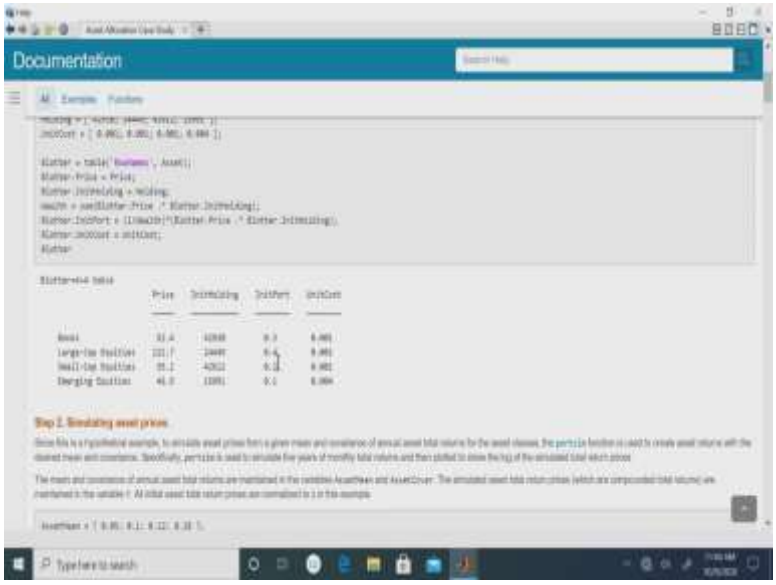

So, now, that the initial cost that is involved is set up and also you have specified what are the; what are the constraints that are to be applicable. So, the first thing we do is that we set up this asset, the entire structure in terms of the inputs. So, first of all, we identify the assets, and the assets are identified here as Bonds, Large-Cap Equities, Small-Cap Equities and Emerging Equities and then, the next row is the Price, so, this gives the current price for each of these asset categories.

So, this means that 54 point 52.4 is the price of the Bond, 122.7 is the price of Large-Cap Equities, 35.2 is the price for Small-Cap Equities and 46.9 is the price for Emerging Equities.

Now, the next thing that we talk about is the Holding. So, the holdings are these are four numbers that is 42938, 24449 and so on. So, this Holding indicates the number of units of each of those assets that you are holding as a part of the initial portfolio.

See it is like setting up some initial condition, so, you just buy some initial portfolio and if you observe carefully. So, this means that for example, if I look at 42612 this means that these are the number of units of some exchange traded fund on Small-Cap Equities that you have invested in.

And also, the UnitCost, so; the UnitCost here identifies the transaction cost for each of the asset class. So, remember that for the first three asset class it was 0.1 percent which when we divide by 100 becomes 0.001 and finally, for the emerging equities, you have 4 times the transaction cost, so, in this case we have 0.004. So, this is the cell array that actually gives you the basic you know parameters namely, the Price, the Holding and the transaction cost.

Now, we create a Blotter. So, Blotter is nothing but literally it means that it is a record of the trade detail. So, in the Blotter, what we do is that we create a table whose first column are going to be the RowNames, the second column which we identify as Blotter dot Price is going to be the price. So, it is going to be this column vector of these four quantities.

The third command that you have here this is the Blotter Initial Holding and this is equal to the Holding. So, this is the initial number of units of each asset that you are holding. So, once you have the Price and the Holding so, obviously, then what is going to be the total wealth? So, this command Blotter dot Price star dot Blotter Initial Holding what it does is that it takes the Blotter Price vector and the Blotter Initial Holding vector which are Price and Holdings and multiplies them component wise and adds them up.

So, if you do the multiplication manually, you will see that the wealth level turns out to be 7.5 million and then, what you do is that you take the Blotter Price dot Blotter initial holding. So, what it does is that it so, this Blotter Price dot Blotter Initial Holding this basically gives you a vector of size 4 whose each component will essentially give you the total amount of money that is invested in each of the assets. So, its components will be 52.4 into 42938 and so, likewise for the other components.

So, each of those four components when you divide by the total wealth, you will basically get what is going to be your initial weights for each of those components that you have identified here at the top and Blotter UnitCost is the transaction cost.

So, what we have done is in the Blotter, we have stored basically the price, the Holding and the UnitCost and in addition to that we have calculated the wealth and the reason we calculated the wealth is so that we can then calculate what is the weights of each of those holdings ok.

So, now when you are; when you are creating like this so, this first term that you have is a first component that you have is Blotter Price. So, this Blotter Price prints here in this column that you have here, this Price column, then Blotter Holding Initial Holding is the second column, then the Initial Portfolio this is going to be given by this so, this is the Blotter Initial Portfolio which gives the weight so, you see that the weights are 0.3, 0.4, 0.2 and 1 and the UnitCost is the last column that shows are.

So, observe carefully in the Initial Portfolio, we have satisfied the condition that bonds has to be at least 15 percent and the equities can at least can at most be 85 percent. So, in this case, 0.4 plus 0.2 plus 0.1 that adds up to 0.7, so, it is 70 percent and emerging equities is 10 percent which is obviously, much less than the 35 percent upper cap that is being used.

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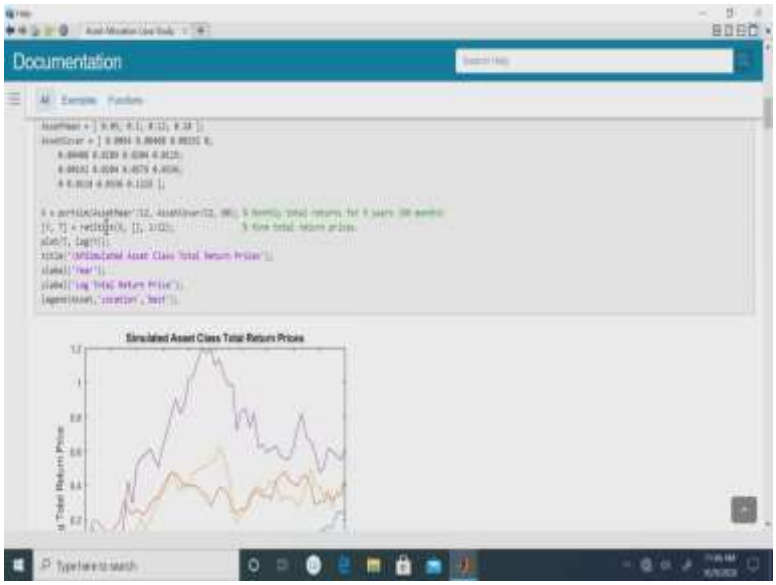

So, now, what you do is that once we have set up all this information at the current time point this information pertaining to our Initial Portfolio what we do is that we now need to simulate the Asset prices. So, in order to simulate the asset prices what you need to do is that we have to make use of the historical data.

So, we can make use of the historical data on a spreadsheet and you calculate what is the AssetMean that is the expected return for each of the asset class based on you know preceding returns over a certain period of time and this is going to be the AssetCovariance that you have that is the covariance between the different assets classes which is a 4 by 4 matrix.

Now, what you have is that we identify this variable X to be a portfolio simulation. So, X will basically simulate portfolio using some underlying modeling techniques perhaps you know it will use some index model, geometric Brownian motion and so on and what it does is that it basically simulates the projection of the future asset prices for each of the categories starting with the current mean and the covariance as estimated from the historical return.

So, here this AssetMean by 12 what it does is that the AssetMean by 12 here essentially gives you the monthly return. So, the values that we have here is basically these are the annual returns, the AssetMean and AssetCovariance that you have is the annual return so, basically you have to look at the past data to see what has been the yearly return so, and then, what you do is that you divide that by 12 so, that is going to give you some sort of an average of the monthly returns.

And then, what you do is that you essentially simulate this and simulate the projected price using the model parameters of the mean vector and the covariance matrix. So, what X does here is that X is going to basically be a portfolio simulation for 60 months that is for 5 years.

So, now what we do is that the value of X is the return value. So, you can convert that to the absolute value of the asset prices by using the command ret 2 tick and this is going to be 1 by 12.

So, this basically means the following that Y is going to be nothing, but a conversion of return to the price of the stocks that you have simulated and what you do is that and then, what you are doing is that you are converting X which is the stock price to the returned Y and these are going to be values that are projected on a monthly basis that is why you have the intervals of 1 by 12.

So, accordingly you see we have intervals of 1 by 12 so, you have 60 points that are being simulated and then you plot this T which is 1 by 12 and you take the corresponding value of log Y.

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So, these are basically the simulated values of the asset class of the simulated values being plotted. In fact, what we are plotting here is the log of the simulated prices ah, but we just have to keep into account that all this was done by setting the initial asset total returned prices to be normalized to 1. So, that is the reason why these log values are going to be equal to 0. So, we start off with so, basically this is the simulation of the values of the different asset class after having normalized.

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So, the next step is to set up a portfolio object. So, once we what we have done is that right now the only piece of information that we have is that we have looked at what is the mean, what is the covariance, what is the InitialPortfolio parameters and then, we have simulated the values.

So, now, we slowly need to start getting into incorporating the constraints that are specific to me as an individual. So, this constraint you know this advantage of this approach is that you can set up your constraint remember that this is just for illustrative purposes and you can set up your constraint as per your choice, you know some as a individual you might not like the 85 percent constraint on equity and you might prefer only 50 percent.

So, all you need to do is in the in the code, you have to just change this 85 to 50 percent and emerging equity you might not want more than 10 percent so, you can set this to be 10 percent instead of 35 percent.

So, this inbuilt setup is variably flexible from their point of view that it can accommodate and is amenable to the individual investor specific constraint and preferences. So, just to revisit so, coming back to the specific example under consideration so, what we do is that we consider the portfolio weights and these have to be non-negative.

Remember that there is no short selling, then no borrowing or leverage that is allowed and of course, the statutory constraints that the sum is going to be equal to 1 and also the three asset classes cannot have more than 85 percent of the total wealth being invested and finally, the emerging equity there is you cannot have among those each of those equity classes, the emerging equity you cannot have more than 35 percent of the portfolios.

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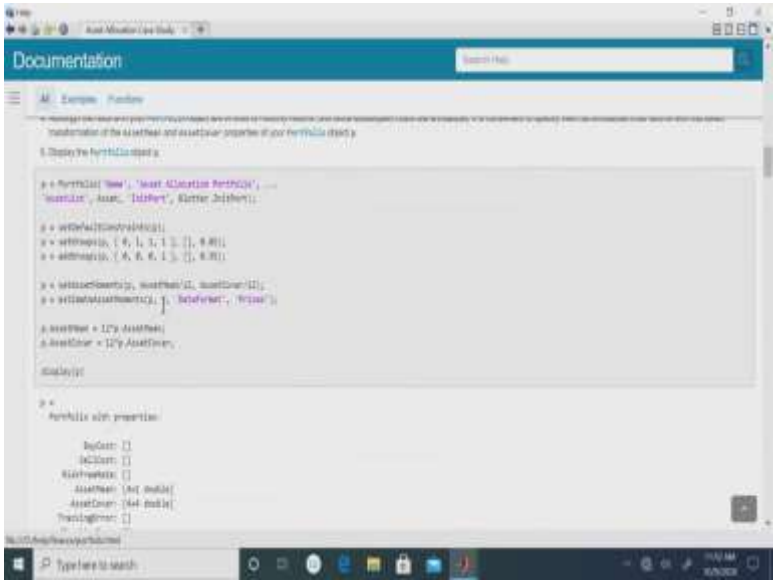

So, what you do now is we now create a portfolio object p using the portfolio command. So, in this case, we have the name, and we have the asset allocation portfolio and the asset list. So, what we have is that this portfolio command will call the name the asset and it will consider the asset allocation that was made and the asset lists and all the other relevant terminologies.

So, now, here so, just there are there are six things the name, the asset allocation portfolio, the asset list, the assets, the Initial Portfolio and the Blotter Initial Portfolio. So, now what we do is that first of all we set the default constraints on p whatever is there.

So, typically in MATLAB, you finish typically initiate with a default constraint and then, what I need to do is I need to bring so, what are the default constraints? So, the default constraints are essentially that the sum is equal to 1 and the portfolio weights are non-negative. Now, these two are the default constraints and on top of it what you do is that you now have to incorporate the two individual investor specific constraints of 85 and 35 percent.

So, accordingly you first set the group and you identify with 0, 1, 1, 1 so, these are basically identifiers of the each of the individual asset class where the 0 means that their constraint does not have to be allocated to that and 1, 1, 1 means that the constraint has to be allocated for the each of the three equity class and that constraint is set to be a maximum of 85 percent.

And then, we refine this a little more and say that on top of this constraint, I will have another constraint that only for the last asset class namely the emerging equities you can the weight can be at most 0.35. So, what you do is that now in p, you also incorporate the asset moments.

The asset moment is what it is the AssetMean by 12 and AssetCovariance by 12 which was basically the historical AssetMean and covariance on a monthly basis that was something that we had done earlier. Remember the 1 with 0.5, 0.1 so, this was the here we had the AssetMean and the AssetCovariance. So, we recapitulate that.

So, now, we estimate the asset moments and we incorporate Y which was the absolute value of the simulated and then, the annual AssetMean and covariance you can multiply 12 with AssetMean and covariance. So, essentially what the p does is that in this case, we are calculating the annual AssetMean and AssetCovariances using the simulated data in order to make your projection.

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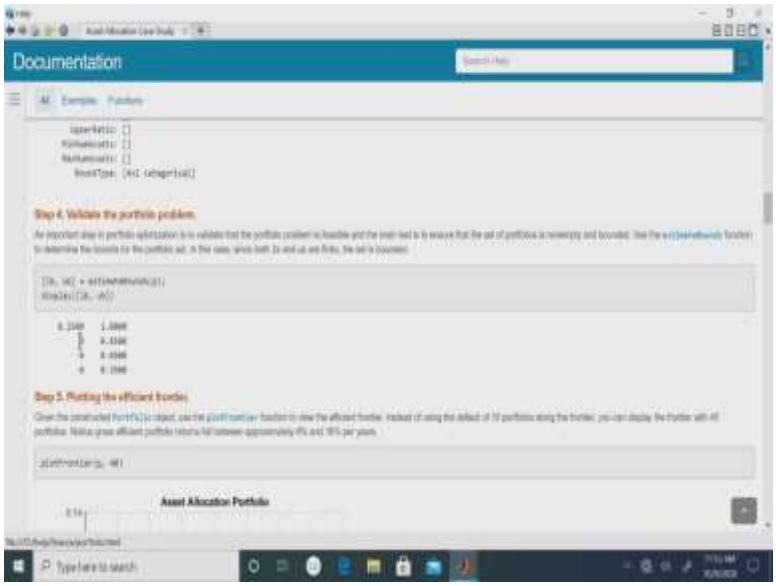

Now, once you have the first real non-trivial extension of what you have already done was essentially setting up these two particular constraints that we have here. So, now, we need to next check whether these constraints have actually been incorporated. So, accordingly, we estimate the bounds on p and the output will be displayed as a lower bound and the upper bound.

So, you see that the lower bound and upper bound are in the first and the second column and each of the rows gives us the asset class. So, you observe carefully that for the bonds, you have to invest at least 15 percent of your wealth. So, the lower bound on the weight is 0.15 and of course, you know you are free to invest your entire amount of money in the bond. So, which means the upper bound is 1.

Now, for the equity classes, I said that the sum of the assets in the equity class can be at most 85 percent and with no short selling allowed. So, that means, the minimum that you can have for the large and small cap equity class is going to be 85 percent and in case of the in emerging equities, the lower bound is 0 and since you can have at most a 35 percent investment in that.

So, the upper bound here is 0.35. So, this is just a validation or a check to see that the lower and upper bounds have been captured by p in a correct manner. So, now that we have the basic parameters set up and as well as the constraints that have been brought into the picture.

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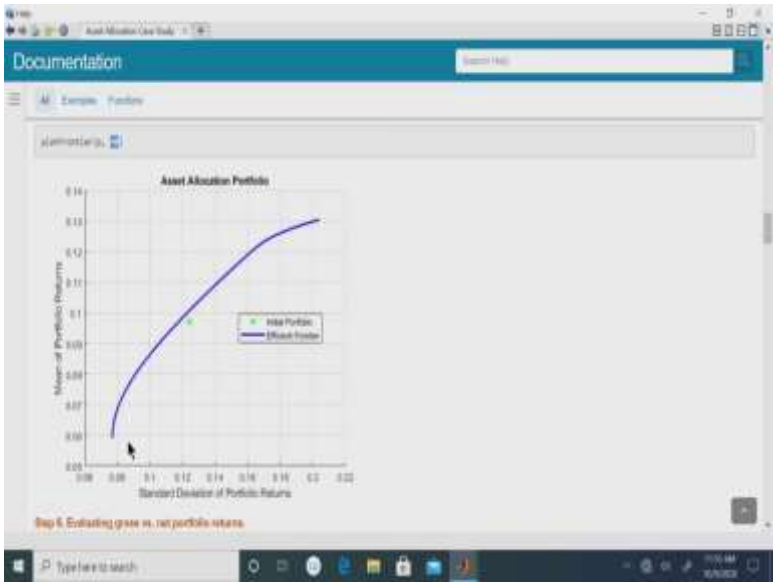

So, now, the next thing is to look at what is the plotting the efficient frontier. So, we construct the portfolio object, we create the efficient frontier which is of this particular form. So, typically what is going to happen is that you can the default number of portfolios that are plotted along the efficient frontier is 10, but if you want you can of course, choose a portfolio an efficient frontier which displays a large number of portfolios.

So, in this particular case, they have said that you plot the frontier. So, plotFrontier is going to plot the efficient frontier and this 40 indicates that you have 40 points and the Initial Portfolio lies somewhere here and of course, this is going to be the efficient portfolio and if you observe carefully at the lower end of the efficient portfolio, the return is 0.06 or that is 6 percent and on the upper end of course, you know it goes up to a much higher amount as you can see that this is closer to 13 percent ok.

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Now, let us now once we have this efficient portfolio, the next thing that we can look at is we can do the evaluation of the gross versus the net profit returns.

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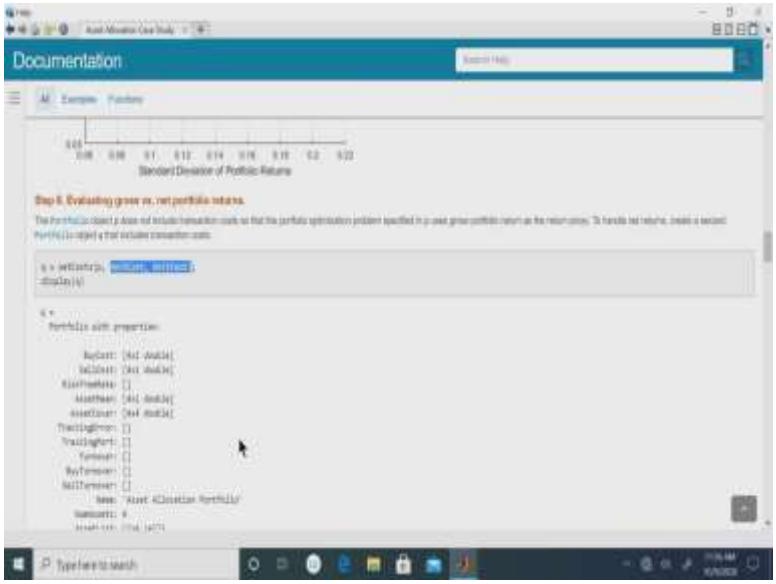

So, the portfolio object p that we have defined so far while it includes the transaction the transaction the limits on the weights specified the three limits that we had specified in addition to the statutory weight limit of sum being equal to 1, but however, it does not factor in the transaction cost that we had identified earlier.

Remember that we had a transaction cost of 10 basis points and for the first three asset classes and for the last asset class, we had a 40 percent a 40-basis point or 0.4 percent ah. So, what you do is that we create another portfolio object where you set costs on p by incorporating the UnitCost and we call this as q. So, remember that so, just to distinguish and to just do a recap, p is the portfolio where transaction costs are not included, and q is going to be the portfolio where the transaction costs are included.

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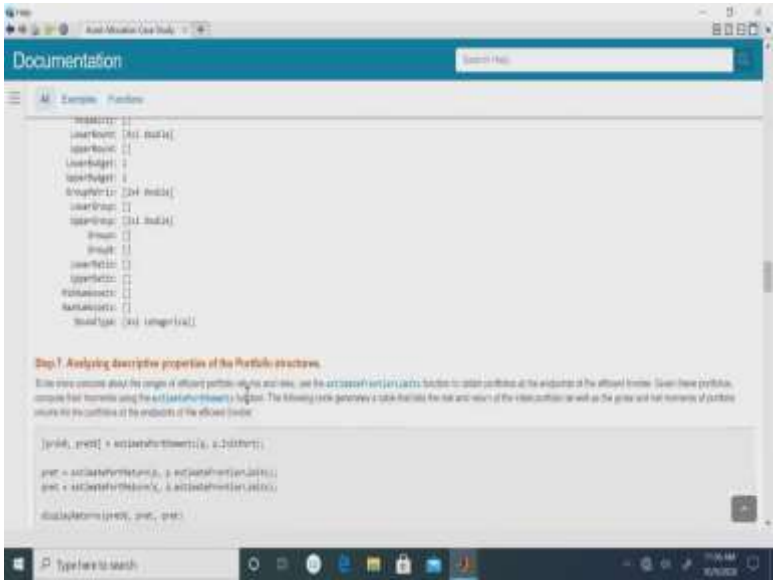

So, these are the outputs that you get out of this; this setting up of the transaction costs. So, now let us look at the analyzing the descriptive properties of the portfolio structure. So, what you would do is that we now focus more on the ranges of efficient portfolio returns and risk and then, we incorporate what is known as the efficient frontier limits to obtain portfolio at the ends of the efficient frontier.

So, essentially this estimate frontier limits what it does is that it will give you the extreme points, it will identify the extreme points and by identification of extreme points I here mean that it is going to identify. What is going to be the extreme return that you get for the efficient frontier in case of both p without the transaction cost and q with the transaction cost?.

So, accordingly what you do is that we estimate the estimate portfolio moments and what you do is that with pret and qret for p return and q return what it does is that it estimates the portfolio return for p and q for the extreme or the end points of the efficient frontier graph in case of p and q respectively.

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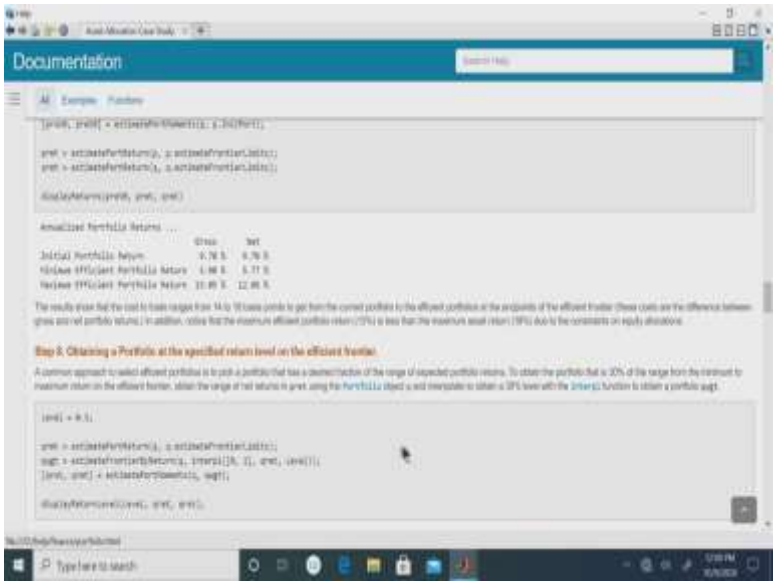

So, in this case what it does is that it is basically going to give you. So, when I display this pret0, pret and qret so, what it does is that it is going to give you the annualized portfolio returns and the first thing it will do is that what is the Initial Portfolio return that whatever is the Initial Portfolio that you have started off with, what is going to be the return of that and what is going to be the minimum return of the efficient portfolio that is what is going to be on the left-hand point of the efficient frontier.

So, basically it will identify what is going to be the return here, what is going to be the return here and what is going to be the return here at this particular point. So, each of those rows correspond to the returns. Those returns at the middle and at the bottom and at the top end and the returns are of two kinds; one is the gross return that comes from p and the other is the net return which comes from q.

So, you observe carefully that the Initial Portfolio return of course, you know it is going to be identical in terms of the gross and net return which stands at 9.7 percent in this specific example. In case of the portfolio p, you see that the minimum return that is 5.9 percent of the maximum return is 13.05 percent. So, this if you look at graphically so, this is somewhere where your 4.5 percent lies, and this is where some 13.05 percent lies. So, this point and this point are the ones which gives us 5.9 percent and 13.05 percent.

So, likewise if you draw the efficient frontier for q, then you get your net profit of 5.77 percent and 12.86 percent s,; obviously, as expected these net return for the minimum as well as the maximum efficient are going to be less than the gross because obviously, some of those returns

that you are going to get is going to be eroded in case of net because this is what you get after your transaction costs have been incorporated ok.

So, now that we have set up all these constraints barring one of one constraint regarding the turnover which is something that we will deal with at a later stage. So, now, you see that in this case, we show that the cost to the trade you know has been specified here that means, if the cost to state will basically give the difference between the gross and the net returns.

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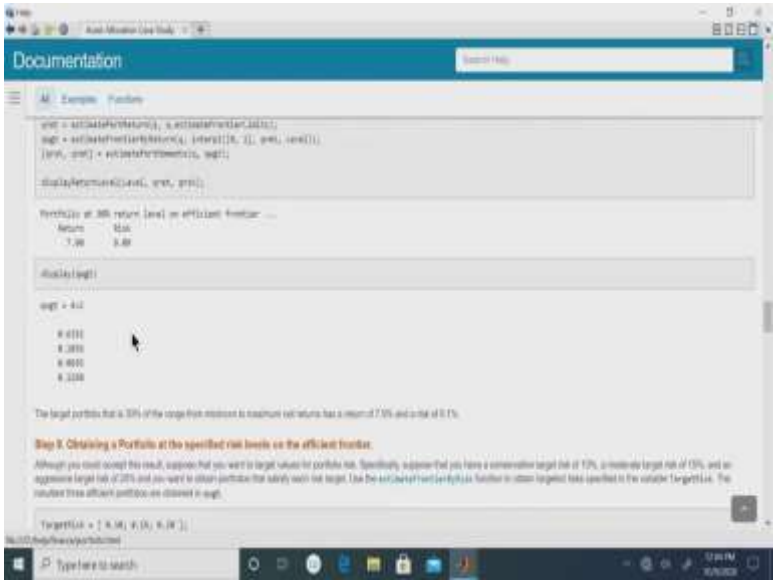

So, now what we do is now we go back and look at what is the basic motivation of a efficient frontier and remember that what was the efficient frontier. The efficient frontier was that for a given level of risk, it gives you the highest return or for a given level of return, it gives the minimum risk.

So, in the next two steps, what we will do is that we will look at obtaining a portfolio at a specified return level on the efficient frontier. So, what you do is that what is we identify what is q return. Remember that you have to use q return instead of p return because the transaction cost from the practical point of view the transaction cost has to be accounted for.

So, for at this point, we have to work with q return and then, what you do is that now when you say that we are going to obtain a portfolio at a specified level of return so, you can of course, specify your level of returns in terms of gross or net. So, if you are looking at net return which

is what matters, you can choose any level of return that you want between 5.77 and 12.86. So, this again gives you a flexibility of choice in terms of your investment level ah.

However, you know it is a common approach to select portfolio. So, what I am saying is that some we set this to be a 30 percent level of the two ends of the efficient frontier. So, if we go back to the efficient frontier, we choose a return level, that is 30 percent from this point and 70 percent from the right-hand side point and so, accordingly we set the level to be at 30 percent or 0.3. So, in order to obtain so, the goal is to obtain a portfolio and that is a 30 percent of the range from the minimum to the maximum return.

So, you have the q return and what you do is that so, you have q return which will store the efficient frontier limits and then, you have to then decide what is going to be the exact portfolio that you want to you get as a result of you deciding that you want to save set your expected return level to be 30 percent of the range from the minimum.

So, accordingly, the this portfolio moments are estimated. So, what you do is the following that qwgt so, wgt is for weight. So, the weights for the portfolio which satisfies this level of 30 percent that weight will be given by qwgt and what is going to be the corresponding return and risk? So, the corresponding return and risk associated with that particular portfolio will be stored as qrsk and q return.

So, it turns out that the weights that you have here that those weights for each of the 4 asset classes are 0.6252, 0.1856, 0.0695 and 0.1198 and for this particular weight being invested in each of the 4 assets that means, its 0.6252 into your total value so, that is the weighted sum that you get off into these returns so, that is going to give you an overall return of 7.90 and a risk of 9.09.

So, that means, this particular portfolio that is of interest to your 30 percent which will lie somewhere here as indicated by the cursor so, that is going to give you a return of 7.90 percent and a risk of 9.09.

But as I said that again you know this is the nice thing about this inbuilt software that you are setting the level at 30 percent and you are free as an investor to set your level as per your choice. If you want to have the extremely high returns, you can set the level to be 1 and then of course, you will get the highest possible return which of course, comes with the highest level of risk.

So, the summary is that that the portfolio at 30 percent is basically it is a return of 7.9 percent and a risk of 9.1 percent ok.

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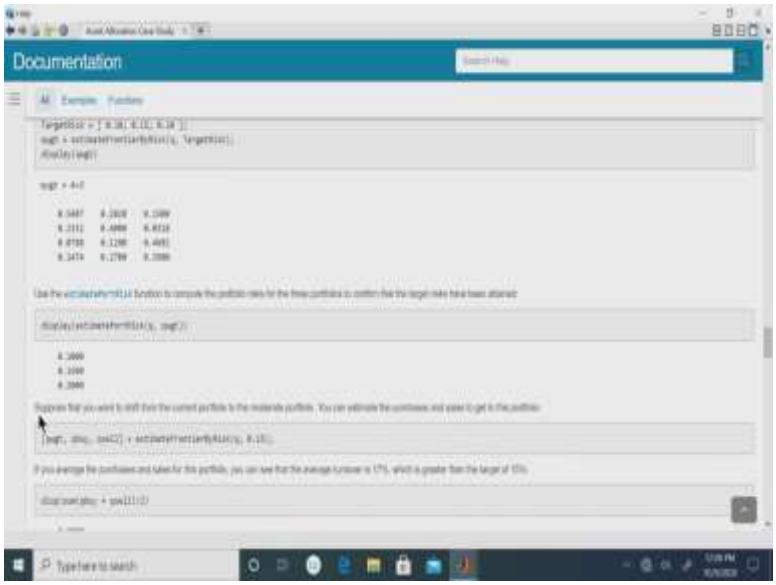

So, the next thing is that you know we have specified the return. So, the next the alternative approach would be to instead of specifying the return level, we specify the risk levels or the efficient frontier.

So, suppose that you want to target values of the portfolio risk and you can have different risks. So, you may choose a conservative TargetRisk which is set at 10 percent. If you are a moderate risk investor or a risk taker and you can set it for 15 percent and if you are more aggressive risk taker, then you can set your target to 20 percent.

So, again you know you can choose your risk level and here, we are setting the target at all three just for comparative purposes, but of course, you can just set your TargetRisk to a single one. So, again this offers you flexibility. So, here when you set the target risks so, what you do is that once you have set the target risk, then you can determine the corresponding weight of estimating the efficient FrontierByRisk.

So, here you observe that this estimate frontier by return means that it is a command that is going to give you the weights of the portfolio for a specified return level and estimate FrontierByRisk it is going to give you the weights of a portfolio for a specified risk level. So, which in this case have been given as 10, 15 and 20 percent.

So, once this has been calculated, you can display the weights. So, each of those three columns, the three columns correspond to 10, 15 and 20 percent so, accordingly this. So, these are the weights.

So, as you can observe very carefully that if you are risk averse at 10 percent so obviously, you put a large amount of money in the bonds that is more than half of your money is in bonds and then, if you switch from 10 to 15 percent of your risk tolerance level, then immediately the weight comes down from more than 50 percent or more than 0.5 to something like 20 percent of your total money is being invested in the; in the bond.

And finally, when you are setting at 20 percent, then all you have to do is then the optimized portfolio turns out that you just have to put the minimum 15 percent that you are required by the constraint to put in the bond.

So, as you see that as you move from left to right; that means, in this table that this means that as you are increasing your risk level, you see that your weights for the bonds is gradually decreasing and the weights for the equities you know that they have increased and of particular interest, observe that here that in the last case when you are targeting 20 percent risk, then the weights are increasing and actually hits the maximum limit of 35 percent in case of the emerging equities ah.

So, now, you can use this command estimate portfolio risk for each of those q weight. So, the qwgt is gives you the three portfolios at the three risk level. So, just as a check to make sure that things are going fine so, you can calculate what is the risk with this these different weights and the risk turns out to be 10, 15 and 20 percent as you had set earlier. So, these are some of the checks and balances that has to be accommodated for just to make sure that there is no error that unexpected error that has been creeping in ok.

So, now, that now, the next question is so, once you have all these things set up. So, what you do is now, we have talked about efficient frontier and we have talked about a specified return or a target amount of risk. So, what you want to do is that you want to shift from the current portfolio to a moderate portfolio. So, this means that we are now bringing into picture the amount of money the buying and selling of assets so, that is the reshuffling of portfolio to get a better result.

So, now you see that suppose that you want to shift. So, what you do is that you set the q weights so, you set the efficient FrontierByRisk and to be q and you set it to 0.15 so, that means, your turnover can be 15 percent. Now, you see that q buy will basically give you the buy end that you have to do and q sell is the selling that you have to do.

And interestingly, it turns out that if we average the q buying and q selling so; that means, the total proportion of wealth that is actually being involved in the in that transaction turns out that it is going to be 17 percent so; that means, the amount of money, amount of reshuffling that is happening or the readjustment of the portfolio results in a turnover of 17 percent which is higher than the permissible limit of 15 percent. So, clearly this is not going to work. So, what you want to do is that now you want to set the portfolio turnover so obviously, this command is not working.

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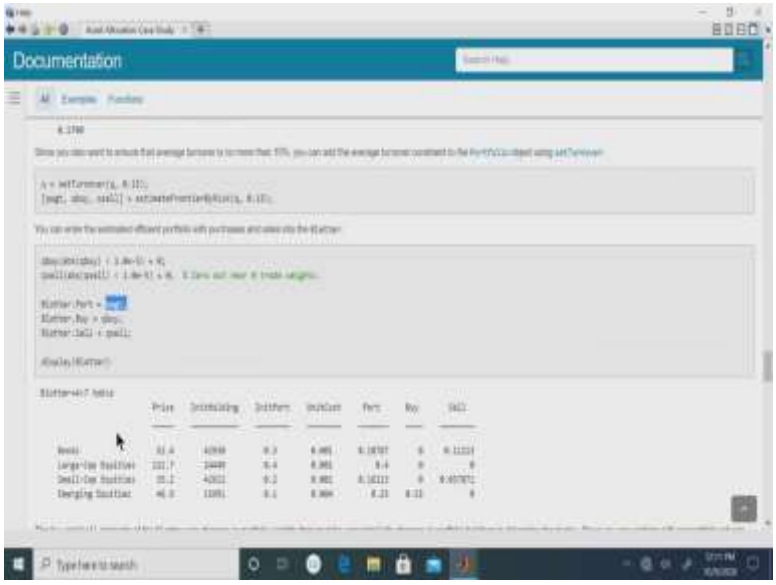

So, accordingly there is a set turnover in the financial toolbox which will ensure that you; you take the portfolio q and you basically you set the portfolio q such that the turnover is restricted to 0.1 5 percent and then you make an estimate of what is going to be the weights of the portfolio in terms of after having set that turnover at 15 percent and what is going to be the buy, the buying and the selling strategies that actually ensures that the turnover is restricted to 15 percent ah.

So, what you do is that so, here, now we go back to Blotter. So, we say that Blotter Port will basically will assign that q weight that is the weight of the efficient frontier q that is set equal to the Blotter Port.

So; that means, the portfolio now is changed from the original portfolio and the weights assigned to the portfolio now are going to be the weights which takes into consideration that there is a 15 percent cap on the turnover and the Blotter Buy and Blotter Sell will basically give you the number of units that you have to buy or sell.

So, now once you display the Blotters, remember that the original Blotter only had up to the unit cost. So, remember that we had the original Blotter table earlier which had bonds, large, small and emerging equities. So, we had the price, the initial holding, the Initial Portfolio was 30, 40, 20 and 10 percent and the UnitCost was this.

Now, what has happened is that now this Blotter Port what it does is that it now prints this portfolio. So, now, the portfolio has changed from 0 point this structure in the initial portfolio, the new portfolio now has the weights as given in this column.

So, for example, for bonds the Initial Portfolio had the weight of bonds that is as 0.3 and this is now changed to 0.18787. Similarly, the other ones have also changed. So, for example, large cap equities there is no change it remains as 0.4, small cap changes from 0.2 to 0.16213 and the emerging equities have changed from 0.1 to 0.25.

So, if you observe carefully that if you look at the Initial Portfolio and you look at the new portfolio so, this means that there is a reduction in the weight. So, this means that there is no buying, but there is only selling ah. In case of large cap equities, the weight remains unchanged as 0.4 so, the there is no buying or selling at all.

In case of the small cap equities, you move from 0.2 to 0.16213 so; that means, there is no buying because there is a reduction and instead there is selling. And in case of emerging equities, you have moved from 0.1 to 0.25 so that means, 0.25 minus 1 so, there is a change in the weight so that means, you have to buy and there is no selling.

So, basically as you move from this Initial Portfolio to a portfolio at your desired level that you have so, that at a set turnover of 15 percent it turns out that it will involve the buying in case of bonds and small cap equities and it involves no change in the status of the buying in case of

the bonds and small cap equities and no change in the status of large cap equities and there is a significant amount of buying involved in emerging equity. So, everything that you get by selling of bonds and small cap equities is then reinvested in emerging equities.

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Now, you have to take into account that you know this buying and selling will involve transaction cost. So, accordingly, what you have to do is that you have to take the Blotter into unit cost. So, what you do is that you take the Blotter into unit cost. So, what was the Blotter into unit cost? This was basically the entries in the UnitCost column, and you multiply this by Blotter buying and selling.

Remember that there is a cost involved for both buying and selling and that this buying and selling that you have here, the these are added and component wise they are multiplied with the UnitCost and these you multiply by your total wealth. So, what is this going to give you?

It is going to give you that it is the total wealth multiplied by the sum of the total cost so, this is going to be give you the total cost from the transaction that has happened that is the total transaction cost. So, this turns out to be 5.6248 into 10 raise to 3 that is 5625 dollars.

But one does not need to worry about that because you remember that you had kept sufficient cash namely 60000 dollars initially. So, this is 60000 dollars in addition to the 7.5 million that we had initially set up. So, this sufficient cash holding of 60000 dollars is more than enough to cover for this transaction cost because you see the transaction cost is 5625 which is obviously,

much much less than the 60000 which is the maximum amount of cash that is available to you for the transaction cost.

So, thus you know you are able to have this it is because of this amount of money that you are actually able to populate your Blotter with the new portfolio holdings now; that means, you are actually able to do this transaction to get a better portfolio because you had this money set aside.

So, now what you do is that now we can compute the number of shares to buy or sell on your Blotters. So, what we have done here is in terms of buy and sell, what we have identified here is nothing, but the weights. So, the weights is not enough for a practical point of view of course, you do not do the transaction in weights, but what you do is that you talk about the transactions in terms of the number of assets that you buy.

So, what you do is that the Blotter holding is given by the Blotter Portfolio. So, the Blotter Port is this column which is the new portfolio divided by the Blotter price into the wealth. So, basically you find out what is going to be the Blotter holding and the Blotter Buy Share so, this is going to give you the share that you have to number of shares that you have to buy and the Blotter Sell Share it will give you the number of shares that you have to sell.

So, once this strategy of buying and selling is specified in terms of number of weights, what this Blotter Buy Share and Blotter Sell Share does is essentially it gives you the exact units of the number of shares that you need to buy or sell in order to achieve your portfolio and so, accordingly, now that you now have a new component to the Blotter in terms of buying and selling; and selling that comes into the picture.

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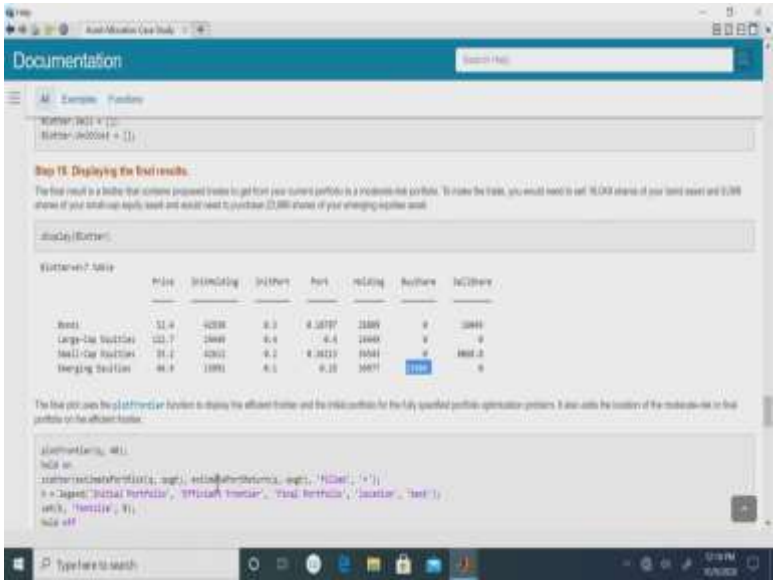

So, now the Blotter is a 4 by 7 table where of course, you know you have this price initial holding, Initial Portfolio that was there, this is your new portfolio which you have calculated. So, this has to be your new holding now.

So, the new holding now is given by this particular column and so, the new holdings so, now, you compare the Initial Holding with the new holding so; that means, the number of units of the bonds that you had which was 42938 now reduces to 26889 so, this means that there is a reduction in the share.

So, if you look very carefully that this 42938 minus 26889 the difference between these two ends up being the amount number of units of shares that you have to sell of course, there is no buying as before the large cap equities there is no change in the number of units.

And in the third case, you know this is the number of shares that you have sell, this is a truncation error that is why a 0.8 comes and of course, in the fourth case, you have a significant increase from 15991 to 39977 resulting from buying of 23986 number of shares. So, basically the sale from these two shares gives you an income and then, this is an expenditure that results from buying this large number of shares in emerging equities ok.

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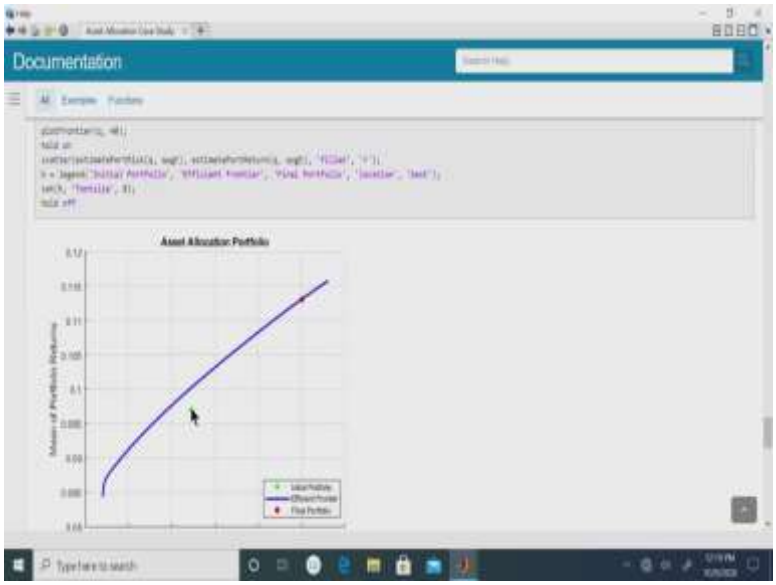

So, the final plot that you have here is remember that this is the final plot holder. So, this is the plot of the efficient frontier. So, we are reaching the closing stages of this discussion. So, the port display the efficient frontier with 40. So, what you does is that this final plot what it does is that it uses the plotFrontier function.

So, it is used to now we plot the efficient frontier and we have the Initial Portfolio which plots it plots the Initial Portfolio and also it plots the fully specified portfolio optimization problem.

So, this is the efficient frontier after all your constraints such as that all your constraints such as the transaction cost and the turnover rate these have been fully specified along with your specified level of return and risk. And so, for a fully specified optimization problem and so, what it does is that it gives you the optimization the efficient frontier, the green one is the Initial Portfolio and the red one is the final portfolio.

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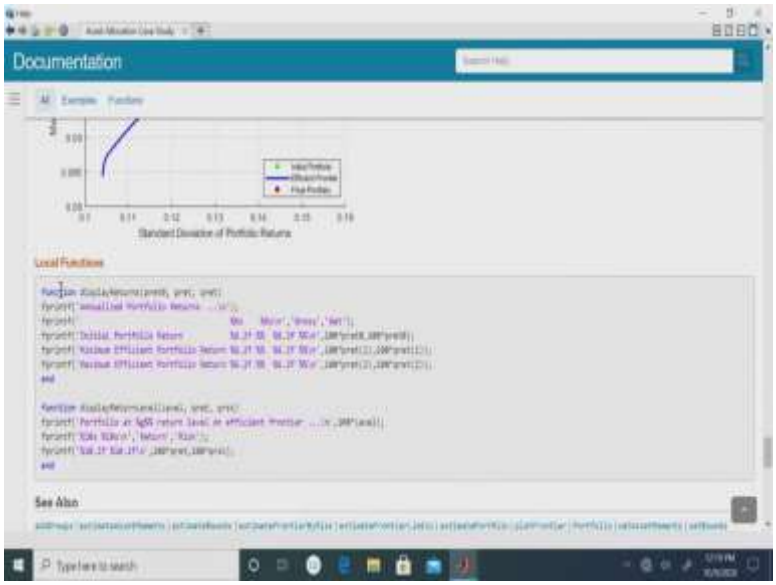

So, this is now this is now that we have displayed the final results and so, you can have some local functions that are specified such as this function of display returns and function of display return levels.

So, essentially you know this entire code is enough for you to actually create your own portfolio except that right at the beginning you have to separately calculate your using historical data, you have to calculate the AssetMean and AssetCovariance and you have to input it here, but after that the remaining work is actually taken care of by the financial toolbox.

So, this concludes this lecture. So, in this lecture, just to give a recap of whatever we have done we started off with a simple example of asset allocation for which we chose to invest in both equities and risk free assets namely bond and within equities we considered a variety of classes namely a large cap, small cap and emerging equities and what we did first was that we look at the historical data and we input the parameters that are required in the mean variance framework namely the expected return and the covariance matrix and this was simulated and then to obtain the efficient frontier.

Now, we started off with an efficient with a particular portfolio of our choice and then, we looked at an improvement over this portfolio to obtain a specific portfolio tailored to the interest or the requirements of an individual investor. So, several constraints were brought into the picture.

So, to begin with we had the constraints on the weights being equal to some of the weights being equal to 1 and also where the constraint that there was no negative words that means,

there was no short selling involved for equities and there was no borrowing or leverage in case of; in case of bonds and we then moved ahead and we set up a couple of other constraints.

One of the constraint was that we put a minimum level minimum amount of weight that has to be assigned to the bonds which consequently meant that there was an upper cap on the equities and within the equity structure, we had an upper cap on the highest risk group among those equities namely the emerging equities.

And then we talked about setting up a portfolio which was as a design to accommodate a specific return level that an investor might prefer and then, the other aspect of it was to include a specific risk level as given by the investor. And so, once this was done, we have to also take into account the other factors such as transaction cost and the transaction cost was specified in terms of basis points with higher basis points being applicable in case of the emerging equities.

And then finally, we had to bring into picture the constraint of turnover which means that we put a upper cap on the proportion of transaction or the extent to which we can do the transactions and once all of this was set up, we had the efficient frontier and the optimized portfolio which gave us that gave us what was the Initial Portfolio and what was the holdings that means, what was the specific number of units of each of those classes.

And after optimization having incorporated all the constraints as well as individual investor requirements we are able to get a new modified portfolio and the necessary transactions in terms of buying or selling of the individual assets that is necessary in order to attain this modified or a desired portfolio.

See this concludes the lecture for today and in the next lecture, we will continue our discussion on the usage of MATLAB and in particular, on the usage of the financial toolbox into other aspects of the portfolio optimization problem.

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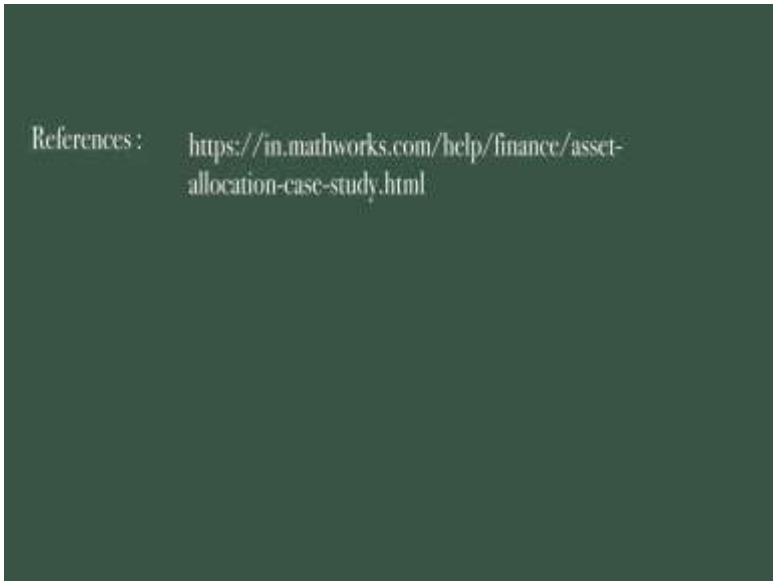

Thank you for watching.