Marketing Analytics
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Lecture 32
Marketing Mix Models and Advertising Models (Contd.)

Hello everybody, welcome to marketing analytics course. This is Dr. Swagato Chatterjee from VGSOM IIT, who is taking this course for you. And we are today in week 6 and we are discussing marketing mix model. So, in the last class, I discussed about the, the equation part of if there are multiple channels where you can give ads and multiple other things like price you can change or margin you can change for the retailer, etcetera, how that impact sales. So, that objective function finding out that objective function is important. And we have a data set and I will open a R file, which will actually deal with this kind of a problem.

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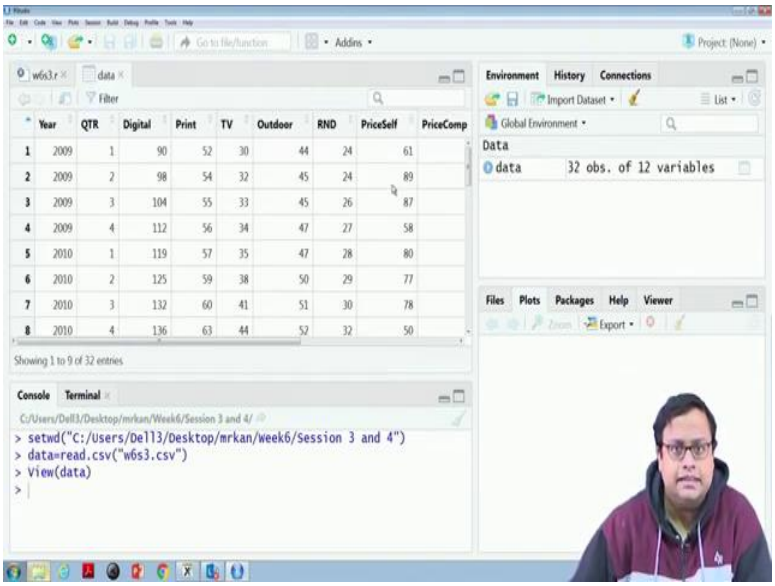

So, the data set I have already talked about. It is a quarterly data from 2006, 2009 to 2016 if I am not wrong, and then we will be dealing with that data set. So, to start with, I will first clean my console, clean my environment, everything is clean so that everybody are in the same page. And this week's session WSC3 dot R is the file that we will deal with.

So, first things first session set working directory to source file location and then read the data. The data looks like this, we have already discussed about what this data is, I have shown you in Excel. So, this is my data, the year, the quarter number, and this is first quarter, second quarter, third quarter, fourth quarter like that.

Then there are four channels where you can invest for promotion. For product you can invest on R&D, your price, your competitor's price, your margin, your competitor's margin and then the sales, so this is the data set that we have. So, now, the first thing is, this coding is difficult first of all, we will do step by step. The first thing is I will check the structure of the data, the structure of data looks fine, everything is integer so I can play with them and then I create a qtrn variable from 1 to 32 which is nothing but the quarter number so the timestamp basically.

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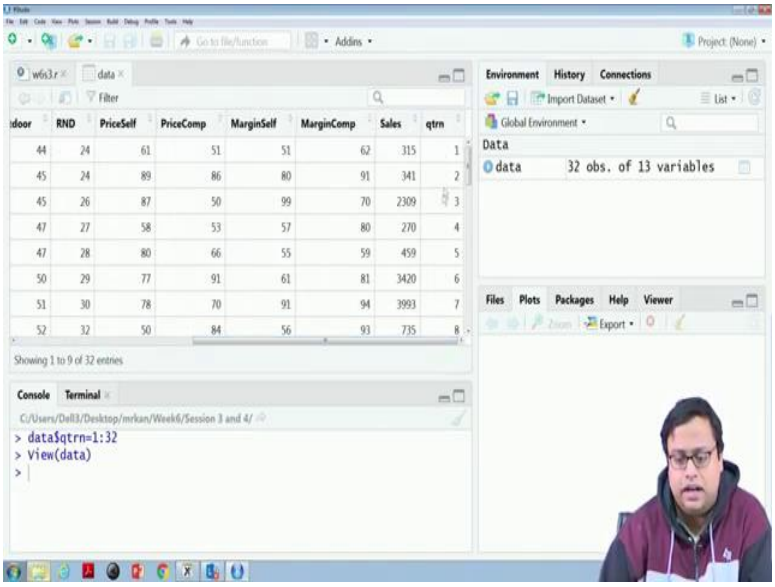

So, if I see, I have created this column right now, which starts from 1 and goes up to 32, the serial number column, this will be used in the trend analysis later. Now, if I try to plot my sales data, data dollars sales. I plot it using the plot function and type is equal L means it will give me a linear line plot, it looks like this.

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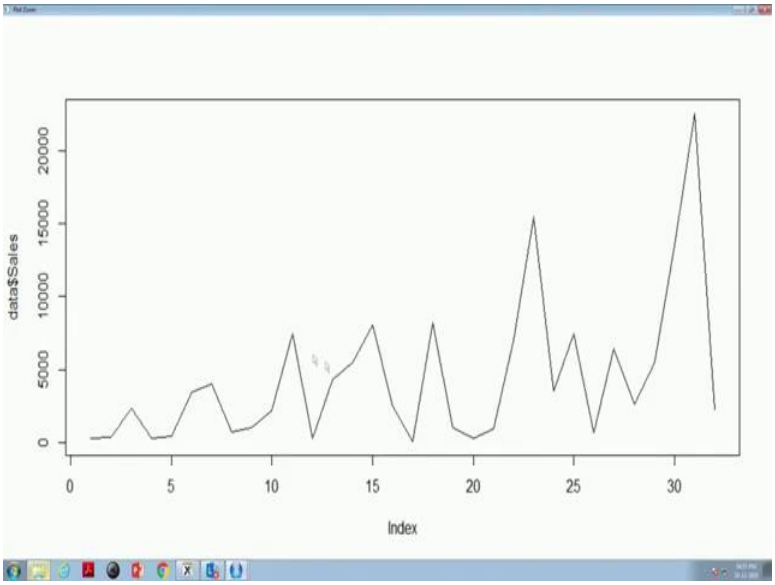

So, you will see that there are some amount of seasonal components existing and then the trend is more less is going up so it is a positive trend, some amount of seasonal component is there and then we will see that what other variables can explain it. Now, if you remember, in the Excel file we started with some initial stock. So, let us say that I have initiating digital in, print in, TV in, outdoor in, an R&D underscore in, in means initial.

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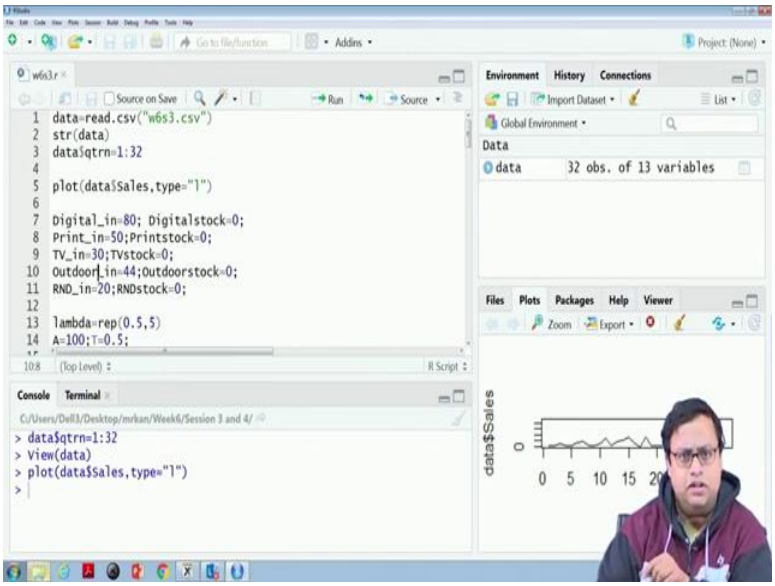

The values are given as 80, 50, 30, 44 and 20, some random values to start with. And the digital stock, this is what the variable I am creating, some variable I am creating where the digital stock will ultimately get calculated. So, digital stock, print stock, TV stock is the ad

stock for that particular channel. So, digital stock, print stock, TV stock, outdoor stock and R&D stock is initially 0 for everybody.

So, I am do you understand I have for 5 channels are there, 4 channels and 1 R&D. I told that each of them will work as that decay effect, it will first go up when you invest and then it will decay. Again you invest something, it will again go up, again decay, again you invest something, it will again go up again decay. So, that kind of model is applicable for the advertisement channels and for the R&D.

So, the initial stocks I have given by random, and the initial stock is 0 and initial expenditures are random. So, I create this and these values are getting saved here just like that, no other purpose

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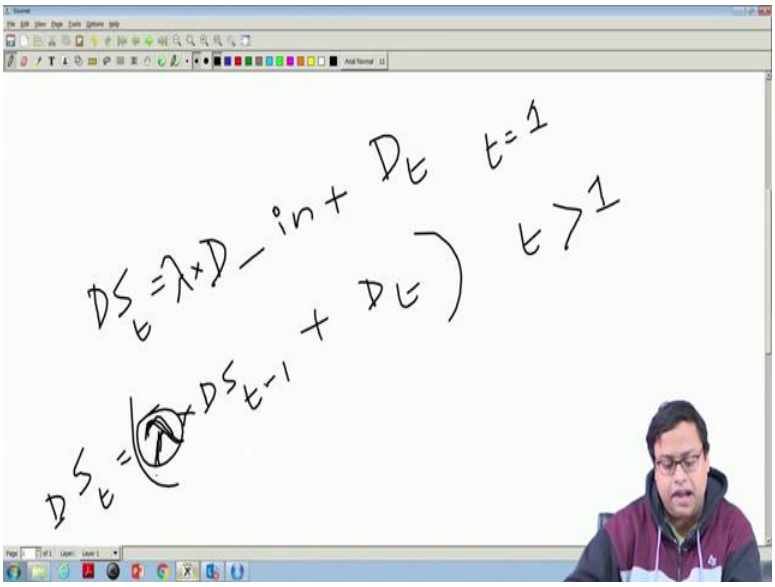

Now, each of them will have, if you remember the formula for what is the formula for digital stock DS? DS is, initially it is digital dot in so lambda into digital dot in plus so, digital expenditure at t, so this is digital stock at t, when t is equal to 1, and when t is greater than 1, it is DS of t is basically lambda into DS of t minus 1 plus Dt.

Now, this lambda the decay effect for a digital ad, and the decay effect for a print ad might be different. So, if I have 5 different kinds of this decay effect, then 5 different lambdas has to created. So, I am saying that initially all the lambdas are same, lambda is equal to repeat 0.5 five times, so all the lambdas are 0.5, 0.5, 0.5, 0.5 and 0.5 okay.

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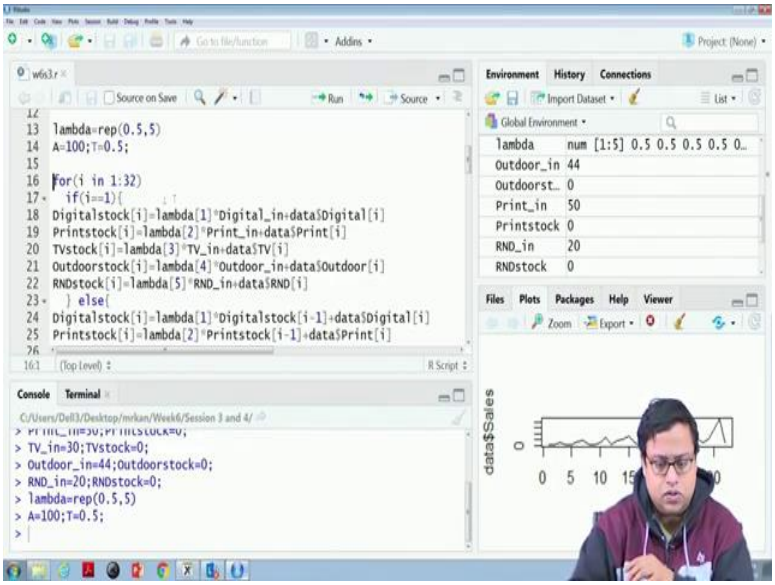

Now, the print component is 0.5, I am taking it positive because it is slowly increasing and the A is my the constant, the constant at the very first, so these are all initial files. Now, in the next part what I will do is, I will calculate I will calculate the, the digital stock, so carefully see what I have written in this code.

So, this particular line starts from here and goes up to here means from here to here it is one single code and writing this is not easy, you will stumble and I often times if you are finding it hard, I would not even ask that you write it, but in your mind it should be clear, crystal clear.

What I am doing? I am starting from i is equal to 1 to 32 so, I am starting from 1 going up to 32. i the indicator starts from first value goes up to 32 value. Now, if i is equal to 1, I double is equal to 1 means I am doing a comparison, if i is equal to 1, all the calculations will happen based on the digital in that means initial's expenditure, the values that have written at the top.

So, when at the first time period these values will be used 80, 50, 30, 44, 20 these values will be used when the time period is 1 but for all other case that will not be used. So, that is why the calculation will be different. So, here the stocks will be calculated using initial values, here the stocks will be calculated using last stock value, fair enough.

So, at t time period, the stock will be calculated based on the stock value at t minus 1 provided t is greater than 1. If t is 1 in the very first time period, it will be calculated based on the initial value, initial stock value, this is something that we are doing. So, digital stock, if i is equal to 1, digital stock at I is equal to lambda 1.

Lambda 1 means what? This lambda vector's first entry that means the lambda for digital stock, second entry is the lambda for TV stock, 3rd entry is the last sorry, 2nd entry is the lambda for print stock, 3rd entry is the lambda for TV stock, 4th entry is the lambda and for outdoor stock, 5th entry is lambda for R&D stock.

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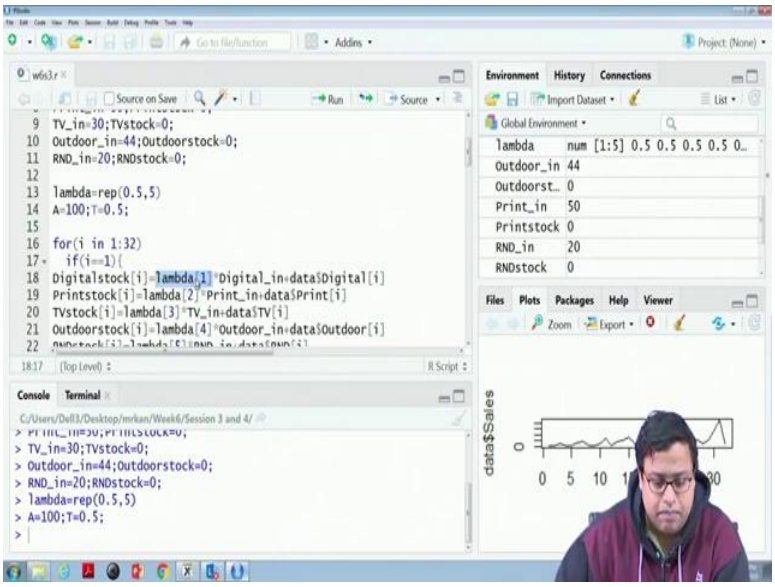

So, here lambda 1 means the lambda for digital stock, So, lambda 1 into digital in okay lambda 1 into digital in plus data of data dollar digital that means, in this data in this data dollar digital this column the 1st entry, the ith entry means i is equal to 1 that means the first entry.

So, the first entry is basically lambda means 0.5 into 80, 0.5 into 80 comes up to be 40 plus this first entry, first entry is 90, so 40 plus 90 is 130 that is the first. Now, if by chance i is greater than 1 ,if i is greater than 1, means else, if i is greater than 1, then this particular part will not work, then I will come to this part, then what, let us say 1 is going to be 2 then what?

The digital stock at second time period i is equal to 2 means second period is lambda 1 into digital stock at first time period i minus 1 that means 2 minus 1 that means first time period, so lambda in lambda 1 into digital stock at 1st time period plus the expenditure at that you do in the second time period where i is equal to 2.

Where i is equal going to 3, that means digital stock at 3, which is lambda 1 plus digital stock at 2 plus the expenditure at 3. Digital stock at 4 that is lambda 1 into digital stock at 3 plus expenditure in 4. So, that is how I go on calculating the digital stock from time period 1 to time period 32, and I do not do only for digital stock, I do it for print stock using the same formula, for TV stock, for outdoor stock and for R&D the exactly same formula.

So, if I just run this, if you understood that, if I just run this, based on the values that I have given 0.5, 80, 44, blah, blah, blah, I get started, I run it, and I gets certain digital stock. So, now, if I write Digital stock, see these are the values.

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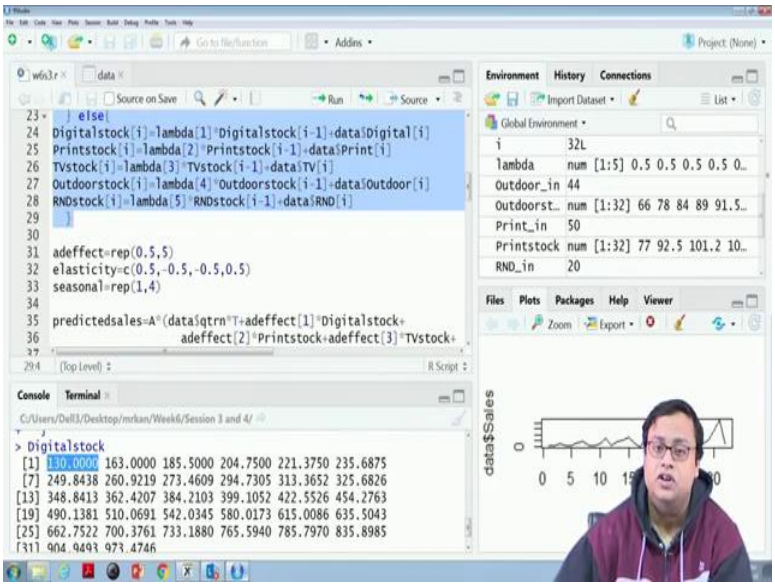

130 calculated, so next one is 130 into 0.5 plus, 130 into 0.5 is 65 plus 98 65 plus 98 is 163. Next one is 163 into 0.5 plus 104 comes up to be 185.5 and so on, so that is how the calculations are done. For like digital stock, I got it for all the five things. Now, these are the stocks will impact on my sales, fair enough. Now, if I have calculated the stock values, then if you remember, we have written the formula like this so this was the formula.

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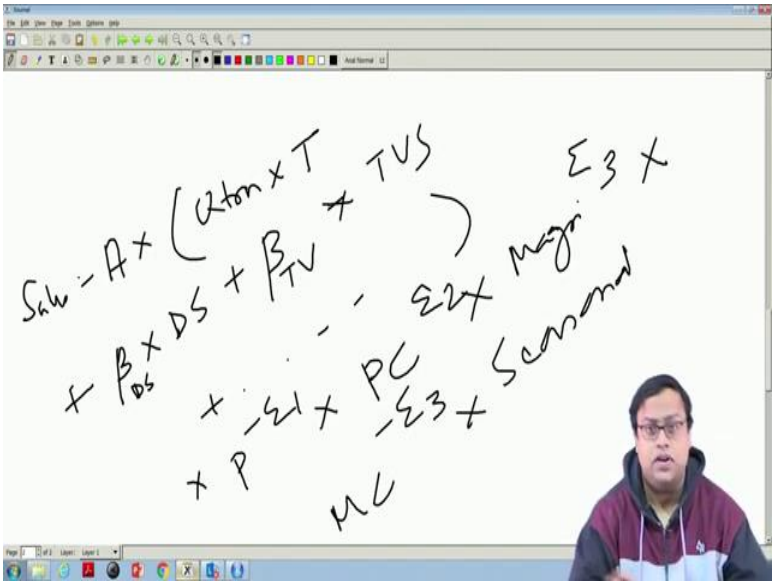

The formula was if you remember the sales formula was, sales is equal to A into Qtrn quarter number into the trend so in this case t plus beta 0 beta DS into digital stock beta TV into TV stock. So, for plus dot dot dot for all the stocks, five stocks into price to the power of minus elasticity into price of competitor to the power elasticity into margin to the power elasticity 1, 2, 3 into margin of competitor to the power minus elasticity into the seasonal component.

So, this was the more or less the formula and that is what we are doing it. So, carefully see what are the parameters? T, I have already done, A, I have already done so the here there will be five Betas. So, those five Betas we call it add effects. The five Betas is, I am again writing it the starting value as 0.5. Later we will find out the optimal, right now I am assuming that they are 0.5. Okay.

Then elasticity, there 4 elasticity, 1st elasticity is 0.5, then this is positive so 0.5 minus 0.5 minus 0.5 and then 0.5. So, for each of the case of this is I am running and seasonality is repeat 1 comma 4. Currently I am saying that for all the sessions the volume is 1 1 1 1. So, there is no seasonality later we will see that what it comes.

So, then, what is a predicted sales? predicted sales is A into, A multiplied by this whole things comes in one this one particular and you carefully see, the first is data dollar quarter number into T so Qtrn into t whatever I told here. That thing comes up to be here, data dollar quarter number into t plus ad effect 1 means ad effect.

I have five beta parameter each are 0.5, the 1st one is for again digital, the second one is for print, the third one is for TV, the fourth one is for outdoor, the fifth one is for R&D, that is

how TV effect into digital stock, ad effect 2 into print stock, ad effect 3 into TV stock, ad effect 4 into outdoor stock and ad effect 5 into R&D. If you want to bring in the interaction effects, you have to create more ad effects and then more interaction terms.

We are living it right now or we are assuming that it to be linear, if you want to be nonlinear effect you have to bring in non-linearity here. So, some logarithmic ,not logarithmic some exponential function or logistic function you can say S curve, logistic function you can use.

Now, this part is done. Then what, then I am writing price to the power minus elasticity, price of mine this is my price to the power minus elasticity, fair enough, multiplied by price of competitor to the power minus elasticity because I have taken competitor's elasticity as minus 0.5.

So, the competitors, so I can just change it, I can make it 0.5 and this is price to the power elasticity, fair enough. Then margin to the power elasticity so, my margin goes up, my sales will go up so margin to the power elasticity and then for margin of competitor to the power basically minus elasticity, so this is negative that means, the margin of my competitor goes up my margin drops, my sales drops. Okay, multiplied by the seasonal component.

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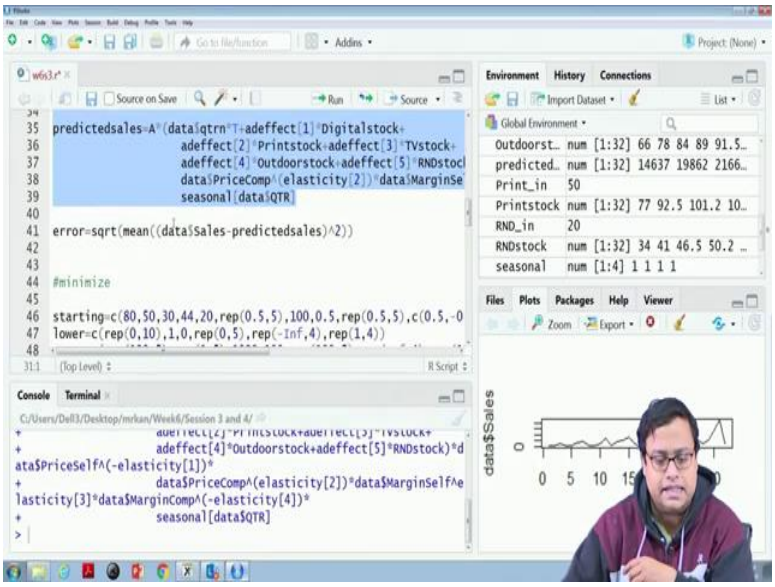

Seasonal within bracket data dollar QTR not QTRN. So, QTR variable of data changes, 1234 then it repeats again 1234 again repeats 1234. So, if the value is 1 corresponding seasonal components, first value will be taken. If the value is 2, then the second value is taken, currently all are 1, but when we do the optimization, it will change.

So, that is how I will get that. So, this is the predicted sales, I will run this I got some predicted sales, the error is nothing but the root mean squared error. So, mean of this is my square error. I am taking the mean of that, and then I am taking a square root of that. So, mean square root, root means square error RMSE is what I am calculating.

So, based on my current calculation, by error is around 53,466, RMSE root mean square error is something like that. So, now what I, what kind of problem I have? I have to change all the initial values that I have decided the 44, 80, 0.5 etc etc, so that I can minimize this error, this is my objective. So, first I did what I did is I wrote this all these codes properly.

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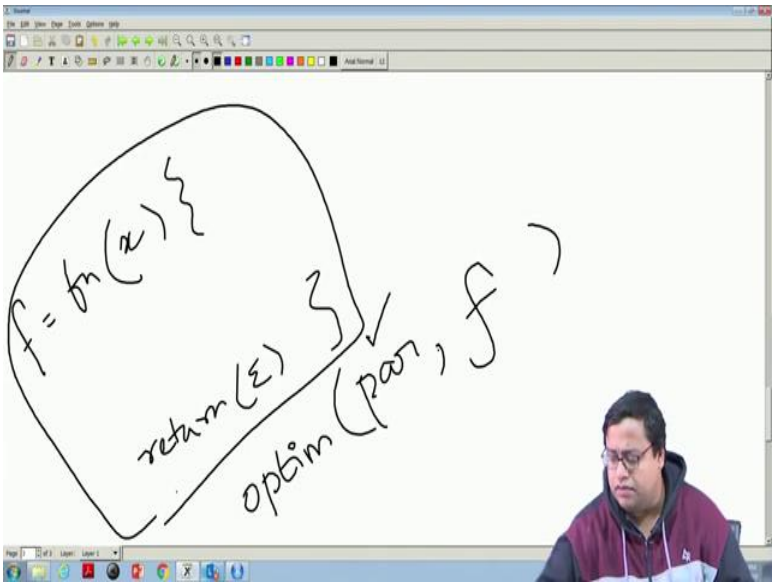

Now, for optimization in R what you have to write is, you have to write a function fn which will let us say function, let us say the name of the function is f, f is equal to function of x, where x is the input and the lots of stuff is done and ultimately the return will be the error. Now, optim is a function which is an inbuilt, where you have to give the parameter par the starting values and the function name f, what it will do?

It will minimize f by starting from this parameter values and give you the final result, which will actually give you the lowest possible parameter error value, okay. So, I will write a function now. If I can write a function which does the all the stuff that I have done till now that gives me the return the error, then I am done, I can use that function in this optim function, and I will be done.

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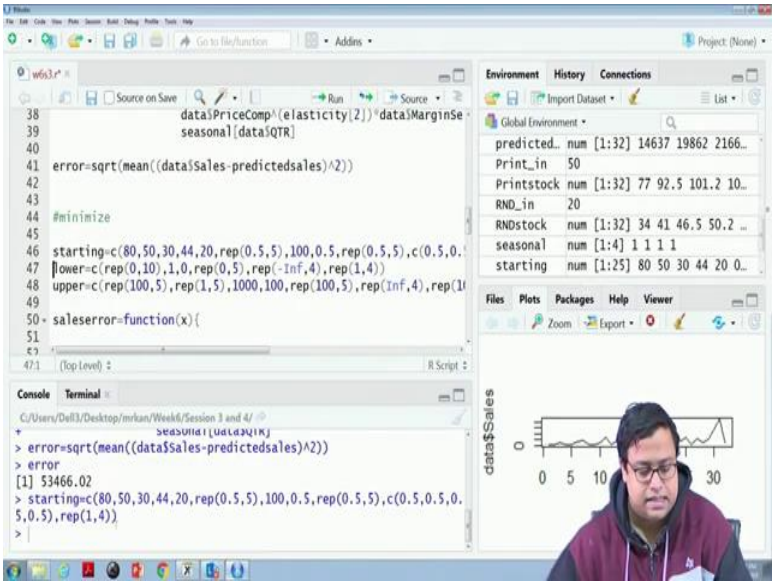

So, first what I do is that is why, whatever I wrote there before, I write as my starting value. My starting is, if you remember, there were five initial stocks, digital stock, print stock, TV stock, outdoor stock and R&D stock, so these are my first 5 values that is far you have to remember, that the first five values are the initial stock values.

Then, if you remember there are if there are five stocks then five lambdas also, those five lambdas are this okay. So, starting value has right now, up to this point starting value has 10 values and these 10 values are first 5 are initial stocks, the next five are the lambda values. Then come the A, this is the A, the constant, big constant. This is the print component 0.5, this repeat 0.5 comma 5 is the beta 0s beta tvs beta digital s, beta etc etc so 5 betas.

Then, these are my, these are my elasticity values and then these are my seasonal values repeat 1 to 4. So, if I run this and starting is basically then this 15 values and if you have to know which one is what, because the result will also come, the final optimized result will also come in a form of 25 values string, 25 values vector.

And if it is coming as a vector of 25 values, you have to know which value is actually corresponding to which parameter, there are lots of parameters, 25 parameters that we are estimating which parameter, which value is corresponding to which parameter, you have to know that. Now, what are the lower limit, the lower limit for these four guys, five guys, these are initial stocks, lower limit is 0. I am assuming that these guys are limit as 0, upper limit is 100.

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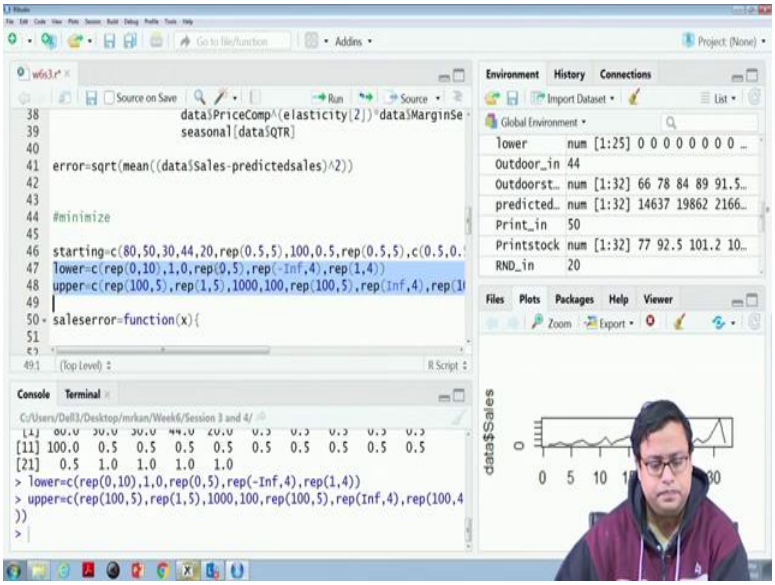

And for these guys these are lambda values, lambda value if you remember between 0 to 1, so lower limit is 0, upper limit is 1. So, that is why repeat 0 to 10 because all of these 10 guys have 0 as their lowest value all these 10 guys, so repeat 0 to 10 and the upper value is repeat 100 five times and repeat 1 five times, fair enough.

Now, what is the lowest value for this constant, the constant has to be positive. So, I have taken lowest value is 1, the highest value is 1000, then what is the trend component, 0.5 the lowest value is 0, the highest value is 100, this is something that I have taken. Then, what is the beta parameters? Beta parameter has to be positive so, the lowest value is repeat 05 and the highest value is 105, so 0 to 100 I am assuming the beta parameters.

What is the elasticity? Elasticity can be anything between minus infinite to plus infinite, so repeat infinite 4 times. And then what is the last one, this is a seasonal component, again they have to positive so 1 comma 4 repeat let us say 1 comma 4 to repeat 100 comma 4, so 1 to 100 in between something like that. So, this is something that I have taken as lower and upper value I have set up.

Then, I wrote whatever I wrote before I just copied and pasted here. So, whatever I wrote from in all these things from line number 7 to line number 41, whatever I wrote, I copied in my function. The only thing is now I have written sales error is a function of x, what is this x? This x is the value of the parameters, there are 25 values, starting value is, at the starting the x value is that starting column, whatever column that you have created named starting that is the starting value of this function when you try to optimize and then that changes.

So, whatever be the case, however, whatever changes happens, this x is actually a string of 25 values. So, when I run write the rest of the code, I have to put those values in right places, so I am writing function of x where digital in initial stock is the first entry of x, print is second entry of x, TV initial is third entry of x, outdoor entry is 4 entry of x, R&D entry is 5th entry of x.

So, right now previously say, I have hard coded, I hard coded it to be 80, 50, 30, 44, 20. Now, I am saying that whatever is the value of x, whatever is the value of x, the first entry of that is digital, second entry of that is print and so on. So, if it is the starting value, then the first entry is 80, 50, 44 so on, but if it changes, then whatever change happens that effects here as well so x 1 to x 5.

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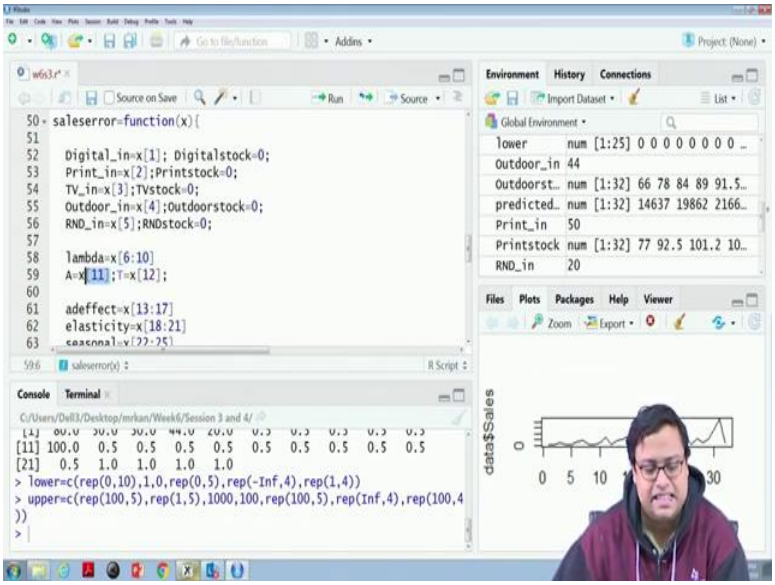

Similarly, lambda is x6 to x10, the A constant is 11th value, the trend component is 12 value, the ad effect component is 13, 14, 15, 16, 17 five values, elasticity component is 18 to 21 four values, and 22 to 25 four values is seasonal component. Now, using these values from x, the rest of the thing is just copy paste.

So, I again calculate the digital stock, I again calculate the predicted sales and I find out the return, I find out the error and I return the error Now, this is something that you have to be careful that previous calculations were happening outside the function, these calculations will have, are happening inside the functions so, in the local environment of the function, so, it will not affect the outside body.

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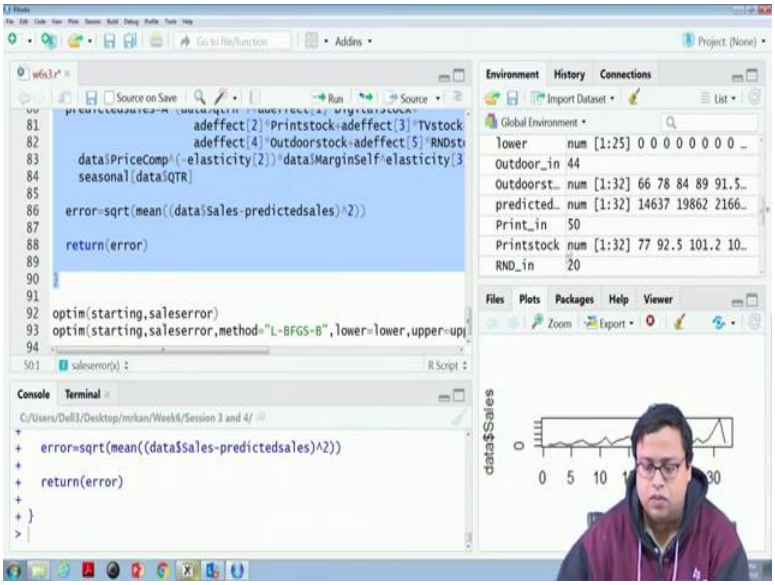

So, I have to select the whole function from line number 50 to line number 90 I have to select them and press run. Now, I have, if you see there is a salesforce function here okay. Now, what I do? Optim sales error, sorry, not salesforce, sales error, sale error is a function name and what is the starting value? My starting value is this starting this particular starting vector using that I optimise.

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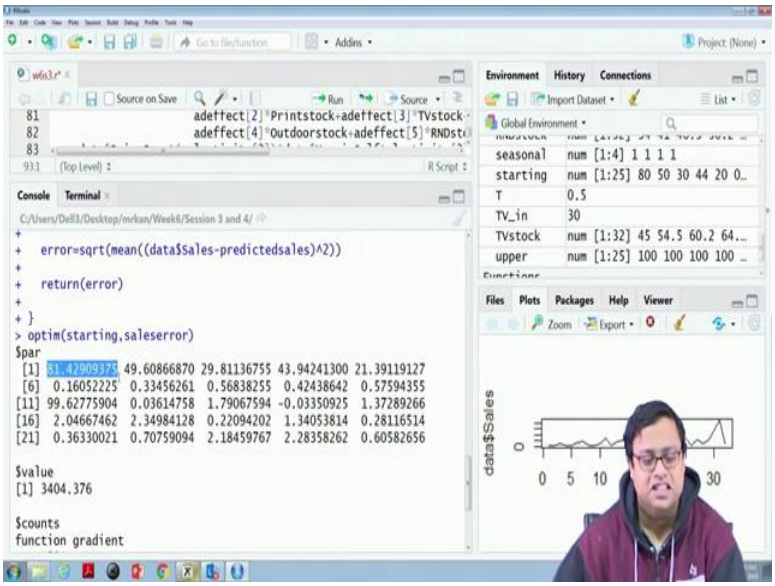

The moment I optimize, it has run and it has find out that this is the optimal set of values, this is my optimal digital stock, initial optimal print stock, optimal TV stock and so on. These values are my basically the beta values, lambda values, next five was the lambda, this is my A, this is my trend, these five values, this, this, this, this and this are my ad effect values.

Carefully see, this is negative this is coming negative, which should not be the case, then these five values, four values are what? These four values are the elasticity values and then so I am less elastic to my price, but very highly elastic, the cost elasticity for my competitors price 1.34 is very high, and same applies for margin so, with this data set and there is some seasonal component.

So, in the second and in the third session it goes up, in the first and fourth session it goes down. Now, in this case we did not have any upper limit or lower limit. To check, put the upper limit and lower limit, we have to write, method is equal to L-BFGS-B there is an optimization method which is bounded method and lower is equal to the lower column and upper is equal to the upper column that we have created, using that if I optimize, it is still giving me result, see previous one was 3404.

Now I have converse to a better result 2501, and some other results are coming. Still here, see for now in the previous one, these two are same, 2.18, 2.28, the seasonal component was almost same. Here, I am saying that the third session is much higher than the second session, and more or less, and then these are the values for, again, the parameters of lambda, and then these are my A and T, these are my beta parameters.

And here, all the beta parameters are coming positive because I have forced feed, I have said that it cannot be negative, it has to be positive, and so on, and the value has further reduced, so using this method, I am getting a little bit of better result, which is 5. So, all I am trying to say is now using these values, I can write down the function that I have written before.

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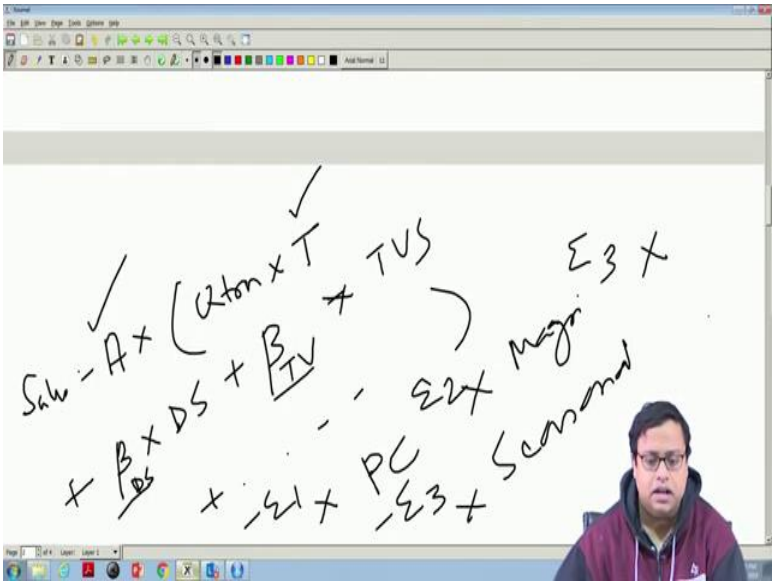

So, if I, if I want to write down the function, whatever I wrote before this function, I can actually write down their function. And if I can write down the function then I can optimize my sales by changing the values of my investment on my TV investment on my ad, reducing the price and etcetera etcetera so that I maximize my sales or maximize my profit at a later point of time.

So, that is how marketing mix models work, we will stop here. We have done quite a few of hard work and I would want to soak let it soak in this part this particular video probably is difficult and that is what we generally do in the market as well. This part is difficult. Let it soak in and then based on that try to play with some of the data that is available in various sources and try to play and create marketing mix models using this kind of a modelling approach. So, in the next slide, we will talk about media data. Thank you for being with me and I will meet you in the next video.