Interaction

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2018/11/27

## Interaction Overview

## Interaction R Part A

### import data

IceCreamExcel <- read\_excel('IceCreamExcel.xlsx')  
head(IceCreamExcel)

## # A tibble: 6 x 5  
## id cons income price temp  
## <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 10 0.264 82 0.280 25  
## 2 39 0.256 79 0.277 24  
## 3 9 0.269 77 0.270 33  
## 4 38 0.269 76 0.265 32  
## 5 23 0.282 93 0.279 32  
## 6 52 0.284 94 0.277 32

str(IceCreamExcel)

## Classes 'tbl\_df', 'tbl' and 'data.frame': 58 obs. of 5 variables:  
## $ id : num 10 39 9 38 23 52 11 40 8 37 ...  
## $ cons : num 0.264 0.256 0.269 0.269 0.282 0.284 0.288 0.286 0.288 0.289 ...  
## $ income: num 82 79 77 76 93 94 81 82 79 78 ...  
## $ price : num 0.28 0.277 0.27 0.265 0.279 0.277 0.282 0.282 0.267 0.267 ...  
## $ temp : num 25 24 33 32 32 32 28 28 47 48 ...

summary(IceCreamExcel)

## id cons income price   
## Min. : 1.00 Min. :0.2560 Min. :76.00 Min. :0.2540   
## 1st Qu.:15.25 1st Qu.:0.3103 1st Qu.:79.25 1st Qu.:0.2700   
## Median :29.50 Median :0.3465 Median :83.00 Median :0.2770   
## Mean :29.50 Mean :0.3534 Mean :84.40 Mean :0.2764   
## 3rd Qu.:43.75 3rd Qu.:0.3860 3rd Qu.:87.75 3rd Qu.:0.2820   
## Max. :58.00 Max. :0.4720 Max. :96.00 Max. :0.2920   
## temp   
## Min. :24.00   
## 1st Qu.:33.00   
## Median :47.50   
## Mean :48.55   
## 3rd Qu.:63.75   
## Max. :73.00

### exclude variable x(id)

ICD <- subset(IceCreamExcel, select = -c(id))  
str(ICD)

## Classes 'tbl\_df', 'tbl' and 'data.frame': 58 obs. of 4 variables:  
## $ cons : num 0.264 0.256 0.269 0.269 0.282 0.284 0.288 0.286 0.288 0.289 ...  
## $ income: num 82 79 77 76 93 94 81 82 79 78 ...  
## $ price : num 0.28 0.277 0.27 0.265 0.279 0.277 0.282 0.282 0.267 0.267 ...  
## $ temp : num 25 24 33 32 32 32 28 28 47 48 ...

summary(ICD)

## cons income price temp   
## Min. :0.2560 Min. :76.00 Min. :0.2540 Min. :24.00   
## 1st Qu.:0.3103 1st Qu.:79.25 1st Qu.:0.2700 1st Qu.:33.00   
## Median :0.3465 Median :83.00 Median :0.2770 Median :47.50   
## Mean :0.3534 Mean :84.40 Mean :0.2764 Mean :48.55   
## 3rd Qu.:0.3860 3rd Qu.:87.75 3rd Qu.:0.2820 3rd Qu.:63.75   
## Max. :0.4720 Max. :96.00 Max. :0.2920 Max. :73.00

### run correlations

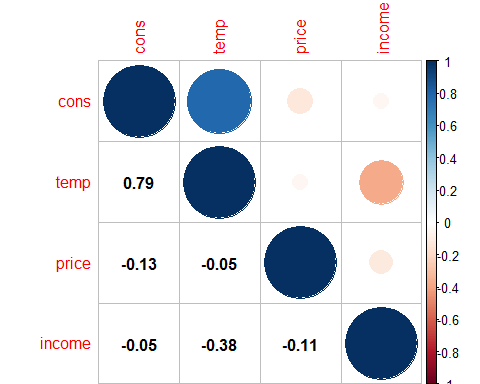
cor(ICD)

## cons income price temp  
## cons 1.00000000 -0.04683888 -0.12709010 0.78761058  
## income -0.04683888 1.00000000 -0.11173850 -0.37693836  
## price -0.12709010 -0.11173850 1.00000000 -0.04729122  
## temp 0.78761058 -0.37693836 -0.04729122 1.00000000

The correlation matrix show us that,the correlation in variable *temp* and *cons* is about **0.788**,which mean these two variable have strong correlationship.And the other variables are almost independent.

### corr visualization

corr <- cor(ICD)  
# corrplot::corrplot(corr = corr)  
corrplot::corrplot(corr = corr, order = "AOE", tl.pos = "tp")  
corrplot::corrplot(corr = corr,   
 add = TRUE, type = "lower", method = "number", order = "AOE",   
 col = "black", diag = FALSE, tl.pos = "n", cl.pos = "n")

 The correlations plot only is an another method for explanation of correlation matrix,what it tells us is the same.

### use Hmisc

library(Hmisc)  
rcorr(as.matrix(ICD))

## cons income price temp  
## cons 1.00 -0.05 -0.13 0.79  
## income -0.05 1.00 -0.11 -0.38  
## price -0.13 -0.11 1.00 -0.05  
## temp 0.79 -0.38 -0.05 1.00  
##   
## n= 58   
##   
##   
## P  
## cons income price temp   
## cons 0.7270 0.3418 0.0000  
## income 0.7270 0.4037 0.0035  
## price 0.3418 0.4037 0.7245  
## temp 0.0000 0.0035 0.7245

The **rcoor** is not only provided correlation matrix,it also provide test in correlation across variable.And only *p-value* in test of *temp* and *cons* is smaller than 0.05,that is ,*temp* is correlated with *cons*

## Interaction R Part B

### create some new var, run correlations

ICD <- ICD %>% mutate(  
 Income\_by\_price = income \* price,  
 Income\_by\_temp = income \* temp ,  
 Price\_by\_temp = price \* temp  
) %>% mutate(  
 income\_mc = scale(income, center = TRUE),  
 price\_mc = scale(price, center = TRUE),  
 temp\_mc = scale(temp, center = TRUE)  
)  
  
summary(ICD)

## cons income price temp   
## Min. :0.2560 Min. :76.00 Min. :0.2540 Min. :24.00   
## 1st Qu.:0.3103 1st Qu.:79.25 1st Qu.:0.2700 1st Qu.:33.00   
## Median :0.3465 Median :83.00 Median :0.2770 Median :47.50   
## Mean :0.3534 Mean :84.40 Mean :0.2764 Mean :48.55   
## 3rd Qu.:0.3860 3rd Qu.:87.75 3rd Qu.:0.2820 3rd Qu.:63.75   
## Max. :0.4720 Max. :96.00 Max. :0.2920 Max. :73.00   
## Income\_by\_price Income\_by\_temp Price\_by\_temp income\_mc.V1   
## Min. :20.14 Min. :1896 Min. : 6.648 Min. :-1.3880139   
## 1st Qu.:22.31 1st Qu.:2984 1st Qu.: 8.876 1st Qu.:-0.8507642   
## Median :23.27 Median :3834 Median :12.848 Median :-0.2308606   
## Mean :23.32 Mean :4062 Mean :13.414 Mean : 0.0000000   
## 3rd Qu.:24.63 3rd Qu.:5157 3rd Qu.:17.485 3rd Qu.: 0.5543505   
## Max. :26.79 Max. :5915 Max. :20.586 Max. : 1.9181383   
## price\_mc.V1 temp\_mc.V1   
## Min. :-2.7027504 Min. :-1.5277786   
## 1st Qu.:-0.7734024 1st Qu.:-0.9677362   
## Median : 0.0706873 Median :-0.0654456   
## Mean : 0.0000000 Mean : 0.0000000   
## 3rd Qu.: 0.6736085 3rd Qu.: 0.9457422   
## Max. : 1.8794510 Max. : 1.5213414

rcorr(as.matrix(ICD))

## cons income price temp Income\_by\_price Income\_by\_temp  
## cons 1.00 -0.05 -0.13 0.79 -0.11 0.82  
## income -0.05 1.00 -0.11 -0.38 0.91 -0.19  
## price -0.13 -0.11 1.00 -0.05 0.31 -0.08  
## temp 0.79 -0.38 -0.05 1.00 -0.39 0.98  
## Income\_by\_price -0.11 0.91 0.31 -0.39 1.00 -0.23  
## Income\_by\_temp 0.82 -0.19 -0.08 0.98 -0.23 1.00  
## Price\_by\_temp 0.78 -0.39 0.04 1.00 -0.36 0.97  
## income\_mc -0.05 1.00 -0.11 -0.38 0.91 -0.19  
## price\_mc -0.13 -0.11 1.00 -0.05 0.31 -0.08  
## temp\_mc 0.79 -0.38 -0.05 1.00 -0.39 0.98  
## Price\_by\_temp income\_mc price\_mc temp\_mc  
## cons 0.78 -0.05 -0.13 0.79  
## income -0.39 1.00 -0.11 -0.38  
## price 0.04 -0.11 1.00 -0.05  
## temp 1.00 -0.38 -0.05 1.00  
## Income\_by\_price -0.36 0.91 0.31 -0.39  
## Income\_by\_temp 0.97 -0.19 -0.08 0.98  
## Price\_by\_temp 1.00 -0.39 0.04 1.00  
## income\_mc -0.39 1.00 -0.11 -0.38  
## price\_mc 0.04 -0.11 1.00 -0.05  
## temp\_mc 1.00 -0.38 -0.05 1.00  
##   
## n= 58   
##   
##   
## P  
## cons income price temp Income\_by\_price Income\_by\_temp  
## cons 0.7270 0.3418 0.0000 0.4067 0.0000   
## income 0.7270 0.4037 0.0035 0.0000 0.1529   
## price 0.3418 0.4037 0.7245 0.0188 0.5261   
## temp 0.0000 0.0035 0.7245 0.0025 0.0000   
## Income\_by\_price 0.4067 0.0000 0.0188 0.0025 0.0865   
## Income\_by\_temp 0.0000 0.1529 0.5261 0.0000 0.0865   
## Price\_by\_temp 0.0000 0.0025 0.7590 0.0000 0.0049 0.0000   
## income\_mc 0.7270 0.0000 0.4037 0.0035 0.0000 0.1529   
## price\_mc 0.3418 0.4037 0.0000 0.7245 0.0188 0.5261   
## temp\_mc 0.0000 0.0035 0.7245 0.0000 0.0025 0.0000   
## Price\_by\_temp income\_mc price\_mc temp\_mc  
## cons 0.0000 0.7270 0.3418 0.0000   
## income 0.0025 0.0000 0.4037 0.0035   
## price 0.7590 0.4037 0.0000 0.7245   
## temp 0.0000 0.0035 0.7245 0.0000   
## Income\_by\_price 0.0049 0.0000 0.0188 0.0025   
## Income\_by\_temp 0.0000 0.1529 0.5261 0.0000   
## Price\_by\_temp 0.0025 0.7590 0.0000   
## income\_mc 0.0025 0.4037 0.0035   
## price\_mc 0.7590 0.4037 0.7245   
## temp\_mc 0.0000 0.0035 0.7245

### create two\_way interaction terms and view corr

ICD <- ICD %>% mutate(  
 Income\_by\_price = income\_mc \* price\_mc,  
 Income\_by\_temp = income\_mc \* temp\_mc ,  
 Price\_by\_temp = price\_mc \* temp\_mc  
)  
  
summary(ICD)

## cons income price temp   
## Min. :0.2560 Min. :76.00 Min. :0.2540 Min. :24.00   
## 1st Qu.:0.3103 1st Qu.:79.25 1st Qu.:0.2700 1st Qu.:33.00   
## Median :0.3465 Median :83.00 Median :0.2770 Median :47.50   
## Mean :0.3534 Mean :84.40 Mean :0.2764 Mean :48.55   
## 3rd Qu.:0.3860 3rd Qu.:87.75 3rd Qu.:0.2820 3rd Qu.:63.75   
## Max. :0.4720 Max. :96.00 Max. :0.2920 Max. :73.00   
## Income\_by\_price.V1 Income\_by\_temp.V1 Price\_by\_temp.V1   
## Min. :-5.184249 Min. :-2.2416441 Min. :-1.8871213   
## 1st Qu.:-0.366100 1st Qu.:-1.0429021 1st Qu.:-0.6270359   
## Median :-0.063060 Median :-0.2647573 Median : 0.0446646   
## Mean :-0.109812 Mean :-0.3704394 Mean :-0.0464759   
## 3rd Qu.: 0.625419 3rd Qu.: 0.1130087 3rd Qu.: 0.5054885   
## Max. : 1.910356 Max. : 1.4296031 Max. : 1.4175626   
## income\_mc.V1 price\_mc.V1 temp\_mc.V1   
## Min. :-1.3880139 Min. :-2.7027504 Min. :-1.5277786   
## 1st Qu.:-0.8507642 1st Qu.:-0.7734024 1st Qu.:-0.9677362   
## Median :-0.2308606 Median : 0.0706873 Median :-0.0654456   
## Mean : 0.0000000 Mean : 0.0000000 Mean : 0.0000000   
## 3rd Qu.: 0.5543505 3rd Qu.: 0.6736085 3rd Qu.: 0.9457422   
## Max. : 1.9181383 Max. : 1.8794510 Max. : 1.5213414

rcorr(as.matrix(ICD))

## cons income price temp Income\_by\_price Income\_by\_temp  
## cons 1.00 -0.05 -0.13 0.79 -0.39 -0.21  
## income -0.05 1.00 -0.11 -0.38 -0.49 -0.26  
## price -0.13 -0.11 1.00 -0.05 0.26 -0.12  
## temp 0.79 -0.38 -0.05 1.00 -0.09 -0.12  
## Income\_by\_price -0.39 -0.49 0.26 -0.09 1.00 -0.09  
## Income\_by\_temp -0.21 -0.26 -0.12 -0.12 -0.09 1.00  
## Price\_by\_temp 0.22 -0.13 -0.09 0.12 -0.31 0.07  
## income\_mc -0.05 1.00 -0.11 -0.38 -0.49 -0.26  
## price\_mc -0.13 -0.11 1.00 -0.05 0.26 -0.12  
## temp\_mc 0.79 -0.38 -0.05 1.00 -0.09 -0.12  
## Price\_by\_temp income\_mc price\_mc temp\_mc  
## cons 0.22 -0.05 -0.13 0.79  
## income -0.13 1.00 -0.11 -0.38  
## price -0.09 -0.11 1.00 -0.05  
## temp 0.12 -0.38 -0.05 1.00  
## Income\_by\_price -0.31 -0.49 0.26 -0.09  
## Income\_by\_temp 0.07 -0.26 -0.12 -0.12  
## Price\_by\_temp 1.00 -0.13 -0.09 0.12  
## income\_mc -0.13 1.00 -0.11 -0.38  
## price\_mc -0.09 -0.11 1.00 -0.05  
## temp\_mc 0.12 -0.38 -0.05 1.00  
##   
## n= 58   
##   
##   
## P  
## cons income price temp Income\_by\_price Income\_by\_temp  
## cons 0.7270 0.3418 0.0000 0.0023 0.1100   
## income 0.7270 0.4037 0.0035 0.0000 0.0530   
## price 0.3418 0.4037 0.7245 0.0510 0.3822   
## temp 0.0000 0.0035 0.7245 0.5115 0.3597   
## Income\_by\_price 0.0023 0.0000 0.0510 0.5115 0.5042   
## Income\_by\_temp 0.1100 0.0530 0.3822 0.3597 0.5042   
## Price\_by\_temp 0.1024 0.3219 0.5146 0.3738 0.0172 0.6167   
## income\_mc 0.7270 0.0000 0.4037 0.0035 0.0000 0.0530   
## price\_mc 0.3418 0.4037 0.0000 0.7245 0.0510 0.3822   
## temp\_mc 0.0000 0.0035 0.7245 0.0000 0.5115 0.3597   
## Price\_by\_temp income\_mc price\_mc temp\_mc  
## cons 0.1024 0.7270 0.3418 0.0000   
## income 0.3219 0.0000 0.4037 0.0035   
## price 0.5146 0.4037 0.0000 0.7245   
## temp 0.3738 0.0035 0.7245 0.0000   
## Income\_by\_price 0.0172 0.0000 0.0510 0.5115   
## Income\_by\_temp 0.6167 0.0530 0.3822 0.3597   
## Price\_by\_temp 0.3219 0.5146 0.3738   
## income\_mc 0.3219 0.4037 0.0035   
## price\_mc 0.5146 0.4037 0.7245   
## temp\_mc 0.3738 0.0035 0.7245

This step add variable interaction term in raw data.

## Interaction R Part C

### testing linear model w/no interactions

model <- lm(cons ~ income + price + temp, data = ICD)  
summary(model)

##   
## Call:  
## lm(formula = cons ~ income + price + temp, data = ICD)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.059146 -0.018587 0.007452 0.018436 0.071937   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 0.0819503 0.1662346 0.493 0.62403   
## income 0.0026093 0.0007533 3.464 0.00105 \*\*   
## price -0.3575747 0.5095112 -0.702 0.48582   
## temp 0.0030912 0.0002821 10.958 2.43e-15 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.03155 on 54 degrees of freedom  
## Multiple R-squared: 0.696, Adjusted R-squared: 0.6791   
## F-statistic: 41.21 on 3 and 54 DF, p-value: 5.46e-14

library(car)  
  
vif(model)

## income price temp   
## 1.188929 1.022290 1.176717

According to the result of this model,and the function **Vif** ,which compute each variable's **Variance Inflation Factors**;and vif value in each variable is smaller than 10,which mean that collinearity in model does not exist.And the *R.Square* in thsis model is about **0.68**.

### testing linear model w/no interactions without pequod, note use of mean center predictoros

model1 <- lm(cons ~ income + price + temp + Income\_by\_temp +   
 Income\_by\_price + Price\_by\_temp, data = ICD)  
summary(model1)

##   
## Call:  
## lm(formula = cons ~ income + price + temp + Income\_by\_temp +   
## Income\_by\_price + Price\_by\_temp, data = ICD)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.055437 -0.014994 -0.001467 0.014653 0.075777   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 0.1940702 0.1684847 1.152 0.2548   
## income 0.0007633 0.0010230 0.746 0.4590   
## price -0.1412090 0.4870840 -0.290 0.7731   
## temp 0.0026738 0.0003001 8.910 5.66e-12 \*\*\*  
## Income\_by\_temp -0.0079020 0.0050423 -1.567 0.1233   
## Income\_by\_price -0.0127447 0.0048355 -2.636 0.0111 \*   
## Price\_by\_temp 0.0040494 0.0055626 0.728 0.4700   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.02927 on 51 degrees of freedom  
## Multiple R-squared: 0.7529, Adjusted R-squared: 0.7239   
## F-statistic: 25.9 on 6 and 51 DF, p-value: 6.96e-14

vif(model1)

## income price temp Income\_by\_temp   
## 2.548701 1.085771 1.547520 1.358149   
## Income\_by\_price Price\_by\_temp   
## 2.206110 1.288576

This new model add interaction term.Accordding to the summary of the new model,we can know that all predictors'**Variance Inflation Factors** in this model ara still smaller than 10,which mean that collinearity in new model does not exist too,but in **R.Square** is about **0.72**,that is to said this model perform better than origin model.

### testing linear model w/no interactions using pequod

library(pequod)  
  
modelpe <- lmres(cons ~ income + price + temp, data = ICD)  
summary(modelpe)

## Formula:  
## cons ~ income + price + temp  
## <environment: 0x00000000131e4ae8>  
##   
## Models  
## R R^2 Adj. R^2 F df1 df2 p.value   
## Model 0.834 0.696 0.679 41.206 3.000 54 5.5e-14 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residuals  
## Min. 1st Qu. Median Mean 3rd Qu. Max.   
## -0.0591 -0.0186 0.0075 0.0000 0.0184 0.0719   
##   
## Coefficients  
## Estimate StdErr t.value beta p.value   
## (Intercept) 0.08195 0.16623 0.49298 0.62403   
## income 0.00261 0.00075 3.46405 0.2834 0.00105 \*\*   
## price -0.35757 0.50951 -0.70180 -0.0532 0.48582   
## temp 0.00309 0.00028 10.95810 0.8919 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Collinearity  
## VIF Tolerance  
## income 1.1889 0.8411  
## price 1.0223 0.9782  
## temp 1.1767 0.8498

modelpe1 <- lmres(cons ~ income \* price + income \* temp + price \* temp,   
 centered = c("income", "price", "temp"), data = ICD)  
summary(modelpe1)

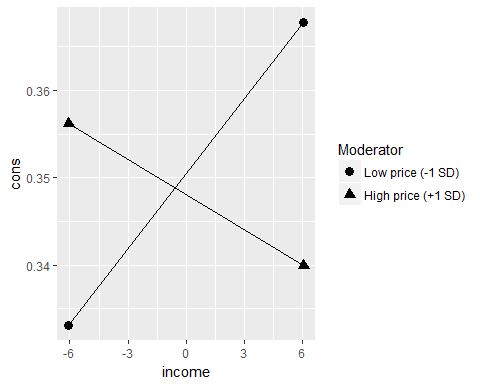
## Formula:  
## cons ~ income + price + temp + income.XX.price + income.XX.temp +   
## price.XX.temp  
## <environment: 0x000000000b225020>  
##   
## Models  
## R R^2 Adj. R^2 F df1 df2 p.value   
## Model 0.868 0.753 0.724 25.904 6.000 51 7e-14 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residuals  
## Min. 1st Qu. Median Mean 3rd Qu. Max.   
## -0.0554 -0.0150 -0.0015 0.0000 0.0147 0.0758   
##   
## Coefficients  
## Estimate StdErr t.value beta p.value   
## (Intercept) 0.34928 0.00442 78.94223 <2e-16 \*\*\*  
## income 0.00076 0.00102 0.74609 0.0829 0.4590   
## price -0.14121 0.48708 -0.28991 -0.0210 0.7731   
## temp 0.00267 0.00030 8.91026 0.7715 <2e-16 \*\*\*  
## income.XX.price -0.25405 0.09639 -2.63563 -0.2725 0.0111 \*   
## income.XX.temp -0.00008 0.00005 -1.56715 -0.1271 0.1233   
## price.XX.temp 0.03038 0.04174 0.72796 0.0575 0.4700   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Collinearity  
## VIF Tolerance  
## income 2.5487 0.3924  
## price 1.0858 0.9210  
## temp 1.5475 0.6462  
## income.XX.price 2.2061 0.4533  
## income.XX.temp 1.3581 0.7363  
## price.XX.temp 1.2886 0.7761

In model that lack of interactions,the coefficient of *income* and *temp* is significant,and these two variables both has positive effect on response *cons*;But in the model that add interactions,the coefficient of *itercept*,*temp* and *iteraction of income and price* are significant.The coefficient result change,but the latter model perform better based on *R.Square*.However,the coefficient of interaction is greater than other,and is is negative,that is ,the interaction has a more greater effect on response.And the comparion between the two model,interaction term should add in linear model.

## Interaction R Part D

### Simple slope test and plot for income by price interatcion

S\_slopes <- simpleSlope(modelpe1, pred = "income", mod1 = "price")  
PLotIncome\_by\_proce <- PlotSlope(S\_slopes)  
PLotIncome\_by\_proce



summary(S\_slopes)

##   
## \*\* Estimated points of cons \*\*  
##   
## Low income (-1 SD) High income (+1 SD)  
## Low price (-1 SD) 0.3331 0.3678  
## High price (+1 SD) 0.3562 0.3400  
##   
##   
##   
## \*\* Simple Slopes analysis ( df= 51 ) \*\*  
##   
## simple slope standard error t-value p.value   
## Low price (-1 SD) 0.0029 0.0008 3.79 0.0004 \*\*\*  
## High price (+1 SD) -0.0013 0.0017 -0.80 0.4257   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
##   
##   
## \*\* Bauer & Curran 95% CI \*\*  
##   
## lower CI upper CI  
## price -0.0034 0.0348

The result show us that,the slope is significant when price is low,and is not sigificant when price is high.And the *cons* change whether is positive or not is effect signifivantly by price

## Interaction R Part E

### creating and testing:

testing three-way interactions without pequod, note use of maen center predictors

ICD <- ICD %>% mutate(threeway = income\_mc \* price\_mc \* temp\_mc)  
model2 <- lm(cons ~ income + price + temp + Income\_by\_temp +   
 Income\_by\_price + Price\_by\_temp + threeway, data = ICD)  
summary(model2)

##   
## Call:  
## lm(formula = cons ~ income + price + temp + Income\_by\_temp +   
## Income\_by\_price + Price\_by\_temp + threeway, data = ICD)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.053020 -0.010476 -0.000138 0.015241 0.069999   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 0.4371217 0.1794095 2.436 0.018436 \*   
## income -0.0003607 0.0010364 -0.348 0.729238   
## price -0.6627874 0.4916374 -1.348 0.183695   
## temp 0.0025004 0.0002876 8.694 1.43e-11 \*\*\*  
## Income\_by\_temp -0.0141126 0.0052022 -2.713 0.009125 \*\*   
## Income\_by\_price -0.0175438 0.0048328 -3.630 0.000666 \*\*\*  
## Price\_by\_temp 0.0014251 0.0052917 0.269 0.788793   
## threeway -0.0141151 0.0049541 -2.849 0.006349 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.02742 on 50 degrees of freedom  
## Multiple R-squared: 0.7874, Adjusted R-squared: 0.7577   
## F-statistic: 26.46 on 7 and 50 DF, p-value: 9.665e-15

vif(model2)

## income price temp Income\_by\_temp   
## 2.980614 1.260545 1.620030 1.647387   
## Income\_by\_price Price\_by\_temp threeway   
## 2.511157 1.328835 1.431312

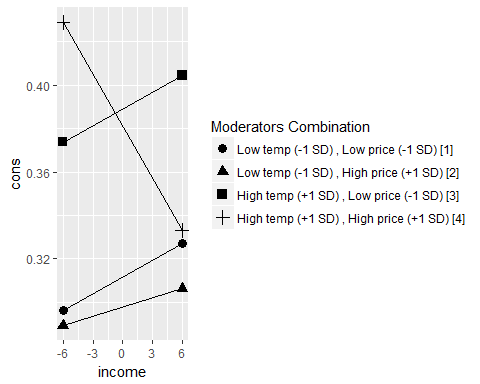
modelpe2 <- lmres(cons ~ income \* price \* temp,   
 centered = c("income", "price", "temp"), data = ICD)  
summary(modelpe2)

## Formula:  
## cons ~ income + price + temp + income.XX.price + income.XX.temp +   
## price.XX.temp + income.XX.price.XX.temp  
## <environment: 0x0000000014b34db8>  
##   
## Models  
## R R^2 Adj. R^2 F df1 df2 p.value   
## Model 0.887 0.787 0.758 26.461 7.000 50 9.7e-15 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residuals  
## Min. 1st Qu. Median Mean 3rd Qu. Max.   
## -0.0530 -0.0105 -0.0001 0.0000 0.0152 0.0700   
##   
## Coefficients  
## Estimate StdErr t.value beta p.value   
## (Intercept) 0.34487 0.00442 77.96730 < 2e-16 \*\*\*  
## income -0.00036 0.00104 -0.34808 -0.0392 0.72924   
## price -0.66279 0.49164 -1.34812 -0.0987 0.18369   
## temp 0.00250 0.00029 8.69365 0.7215 < 2e-16 \*\*\*  
## income.XX.price -0.34971 0.09633 -3.63015 -0.3751 0.00067 \*\*\*  
## income.XX.temp -0.00015 0.00005 -2.71283 -0.2270 0.00913 \*\*   
## price.XX.temp 0.01069 0.03971 0.26932 0.0202 0.78879   
## income.XX.price.XX.temp -0.01751 0.00615 -2.84915 -0.2222 0.00635 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Collinearity  
## VIF Tolerance  
## income 2.9806 0.3355  
## price 1.2605 0.7933  
## temp 1.6200 0.6173  
## income.XX.price 2.5112 0.3982  
## income.XX.temp 1.6474 0.6070  
## price.XX.temp 1.3288 0.7525  
## income.XX.price.XX.temp 1.4313 0.6987

According to the models show us that,the result is the model with threeway interaction perform better based on *R.Square*,The *R.Square* is about 0.75.And other resultr is simliar with the model with twoway interaction.However,in this time,the coefficinet of interaction of income\_price,income\_temp,income\_price\_temp are sigificant,and the effect of them are all negative on response.

### Simple slope test and plot for the three-way interatcion

S\_slopes\_3way <- simpleSlope(modelpe2, pred = "income", mod1 = "temp", mod2 = "price")  
Plot\_threeway <- PlotSlope(S\_slopes\_3way)  
Plot\_threeway



summary(S\_slopes\_3way)

##   
## \*\* Estimated points of cons \*\*  
##   
## Low income (-1 SD)  
## Low temp (-1 SD) , Low price (-1 SD) [1] 0.2963  
## Low temp (-1 SD) , High price (+1 SD) [2] 0.2893  
## High temp (+1 SD) , Low price (-1 SD) [3] 0.3738  
## High temp (+1 SD) , High price (+1 SD) [4] 0.4289  
## High income (+1 SD)  
## Low temp (-1 SD) , Low price (-1 SD) [1] 0.3270  
## Low temp (-1 SD) , High price (+1 SD) [2] 0.3063  
## High temp (+1 SD) , Low price (-1 SD) [3] 0.4045  
## High temp (+1 SD) , High price (+1 SD) [4] 0.3330  
##   
##   
##   
## \*\* Simple Slopes analysis ( df= 50 ) \*\*  
##   
## simple slope standard error  
## Low temp (-1 SD) , Low price (-1 SD) [1] 0.0025 0.0011  
## Low temp (-1 SD) , High price (+1 SD) [2] 0.0014 0.0015  
## High temp (+1 SD) , Low price (-1 SD) [3] 0.0025 0.0012  
## High temp (+1 SD) , High price (+1 SD) [4] -0.0079 0.0028  
## t-value p.value   
## Low temp (-1 SD) , Low price (-1 SD) [1] 2.37 0.0214 \*   
## Low temp (-1 SD) , High price (+1 SD) [2] 0.95 0.3449   
## High temp (+1 SD) , Low price (-1 SD) [3] 2.05 0.0452 \*   
## High temp (+1 SD) , High price (+1 SD) [4] -2.87 0.0061 \*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
##   
##   
## \*\* Slope Difference Test (( df= 50 ); Dawson & Richter, 2006) \*\*  
## t-value  
## High temp (+1 SD) , High price (+1 SD) [4] vs. High temp (+1 SD) , Low price (-1 SD) [3] -3.9393  
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , High price (+1 SD) [2] -3.2992  
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , Low price (-1 SD) [1] -3.6964  
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , Low price (-1 SD) [1] 0.0003  
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , High price (+1 SD) [2] 0.6544  
## Low temp (-1 SD) , High price (+1 SD) [2] vs. Low temp (-1 SD) , Low price (-1 SD) [1] -0.4266  
## p.value  
## High temp (+1 SD) , High price (+1 SD) [4] vs. High temp (+1 SD) , Low price (-1 SD) [3] 0.0003  
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , High price (+1 SD) [2] 0.0018  
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , Low price (-1 SD) [1] 0.0005  
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , Low price (-1 SD) [1] 0.9998  
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , High price (+1 SD) [2] 0.5159  
## Low temp (-1 SD) , High price (+1 SD) [2] vs. Low temp (-1 SD) , Low price (-1 SD) [1] 0.6715  
## Bonferroni.p  
## High temp (+1 SD) , High price (+1 SD) [4] vs. High temp (+1 SD) , Low price (-1 SD) [3] 0.0015  
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , High price (+1 SD) [2] 0.0108  
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , Low price (-1 SD) [1] 0.0033  
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , Low price (-1 SD) [1] 1.0000  
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , High price (+1 SD) [2] 1.0000  
## Low temp (-1 SD) , High price (+1 SD) [2] vs. Low temp (-1 SD) , Low price (-1 SD) [1] 1.0000  
##   
## High temp (+1 SD) , High price (+1 SD) [4] vs. High temp (+1 SD) , Low price (-1 SD) [3] \*\*  
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , High price (+1 SD) [2] \*   
## High temp (+1 SD) , High price (+1 SD) [4] vs. Low temp (-1 SD) , Low price (-1 SD) [1] \*\*  
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , Low price (-1 SD) [1]   
## High temp (+1 SD) , Low price (-1 SD) [3] vs. Low temp (-1 SD) , High price (+1 SD) [2]   
## Low temp (-1 SD) , High price (+1 SD) [2] vs. Low temp (-1 SD) , Low price (-1 SD) [1]   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

According to the result of this test,the slope change sinifcant when temp,price change,which indicates that the *cons* is mianly effect by *income* and *temp*

In conclusion,*price* and *temp* are the main effective factor on response *cons*,and their interaction ,treeway interaction still have effect on *cons*,but inetractions' effect is less.