Intro To Regression

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This is something like a notebook. You can work with data and text at the same time. Things chunks are for code

```
print("I am in a chunk.")
```

```
## [1] "I am in a chunk."
```

By default they echo the code and then produce the result.

You can turn off the echo and just see the result.

```
## [1] "No Echo"
```

Assignment and Access

1. Lets start with a few R conventions. Lets start with scalars. '<-' is the assignment operator in R. '=' also works but '==' is used for comparisons.

```
1 + 1
```

```
## [1] 2
```

```
A <-  2 + 3
A + 2
```

```
## [1] 7
```

```
A <- A+2
B <- A + 4
A + B
```

```
## [1] 18
```

```
C = A + B
C
```

```
## [1] 18
```

```
A == B
```

```
## [1] FALSE
```

Note that when you save values to variables you can see them in the Environment tab.

Play with this in the chunk below and run to see what happens.

```
ThisIsAVariable <-10
this_is_a_variable <-23
```

2. R has many ways of representing values

```
A <- "Shale"
A
```

```
## [1] "Shale"
```

```
C <- c("Tom", "Dick", "Harry")
C
```

```
## [1] "Tom"   "Dick"  "Harry"
```

```
C[[1]]
```

```
## [1] "Tom"
```

```
C[1]
```

```
## [1] "Tom"
```

```
1:1000
```

```
##    [1]    1    2    3    4    5    6    7    8    9   10   11   12   13
##   [14]   14   15   16   17   18   19   20   21   22   23   24   25   26
##   [27]   27   28   29   30   31   32   33   34   35   36   37   38   39
##   [40]   40   41   42   43   44   45   46   47   48   49   50   51   52
##   [53]   53   54   55   56   57   58   59   60   61   62   63   64   65
##   [66]   66   67   68   69   70   71   72   73   74   75   76   77   78
##   [79]   79   80   81   82   83   84   85   86   87   88   89   90   91
##   [92]   92   93   94   95   96   97   98   99  100  101  102  103  104
##  [105]  105  106  107  108  109  110  111  112  113  114  115  116  117
##  [118]  118  119  120  121  122  123  124  125  126  127  128  129  130
##  [131]  131  132  133  134  135  136  137  138  139  140  141  142  143
##  [144]  144  145  146  147  148  149  150  151  152  153  154  155  156
##  [157]  157  158  159  160  161  162  163  164  165  166  167  168  169
##  [170]  170  171  172  173  174  175  176  177  178  179  180  181  182
##  [183]  183  184  185  186  187  188  189  190  191  192  193  194  195
##  [196]  196  197  198  199  200  201  202  203  204  205  206  207  208
##  [209]  209  210  211  212  213  214  215  216  217  218  219  220  221
##  [222]  222  223  224  225  226  227  228  229  230  231  232  233  234
##  [235]  235  236  237  238  239  240  241  242  243  244  245  246  247
##  [248]  248  249  250  251  252  253  254  255  256  257  258  259  260
##  [261]  261  262  263  264  265  266  267  268  269  270  271  272  273
##  [274]  274  275  276  277  278  279  280  281  282  283  284  285  286
##  [287]  287  288  289  290  291  292  293  294  295  296  297  298  299
##  [300]  300  301  302  303  304  305  306  307  308  309  310  311  312
##  [313]  313  314  315  316  317  318  319  320  321  322  323  324  325
##  [326]  326  327  328  329  330  331  332  333  334  335  336  337  338
##  [339]  339  340  341  342  343  344  345  346  347  348  349  350  351
##  [352]  352  353  354  355  356  357  358  359  360  361  362  363  364
##  [365]  365  366  367  368  369  370  371  372  373  374  375  376  377
##  [378]  378  379  380  381  382  383  384  385  386  387  388  389  390
##  [391]  391  392  393  394  395  396  397  398  399  400  401  402  403
##  [404]  404  405  406  407  408  409  410  411  412  413  414  415  416
##  [417]  417  418  419  420  421  422  423  424  425  426  427  428  429
##  [430]  430  431  432  433  434  435  436  437  438  439  440  441  442
##  [443]  443  444  445  446  447  448  449  450  451  452  453  454  455
##  [456]  456  457  458  459  460  461  462  463  464  465  466  467  468
##  [469]  469  470  471  472  473  474  475  476  477  478  479  480  481
##  [482]  482  483  484  485  486  487  488  489  490  491  492  493  494
##  [495]  495  496  497  498  499  500  501  502  503  504  505  506  507
##  [508]  508  509  510  511  512  513  514  515  516  517  518  519  520
##  [521]  521  522  523  524  525  526  527  528  529  530  531  532  533
##  [534]  534  535  536  537  538  539  540  541  542  543  544  545  546
##  [547]  547  548  549  550  551  552  553  554  555  556  557  558  559
##  [560]  560  561  562  563  564  565  566  567  568  569  570  571  572
##  [573]  573  574  575  576  577  578  579  580  581  582  583  584  585
```

```
##  [586]  586  587  588  589  590  591  592  593  594  595  596  597  598
##  [599]  599  600  601  602  603  604  605  606  607  608  609  610  611
##  [612]  612  613  614  615  616  617  618  619  620  621  622  623  624
##  [625]  625  626  627  628  629  630  631  632  633  634  635  636  637
##  [638]  638  639  640  641  642  643  644  645  646  647  648  649  650
##  [651]  651  652  653  654  655  656  657  658  659  660  661  662  663
##  [664]  664  665  666  667  668  669  670  671  672  673  674  675  676
##  [677]  677  678  679  680  681  682  683  684  685  686  687  688  689
##  [690]  690  691  692  693  694  695  696  697  698  699  700  701  702
##  [703]  703  704  705  706  707  708  709  710  711  712  713  714  715
##  [716]  716  717  718  719  720  721  722  723  724  725  726  727  728
##  [729]  729  730  731  732  733  734  735  736  737  738  739  740  741
##  [742]  742  743  744  745  746  747  748  749  750  751  752  753  754
##  [755]  755  756  757  758  759  760  761  762  763  764  765  766  767
##  [768]  768  769  770  771  772  773  774  775  776  777  778  779  780
##  [781]  781  782  783  784  785  786  787  788  789  790  791  792  793
##  [794]  794  795  796  797  798  799  800  801  802  803  804  805  806
##  [807]  807  808  809  810  811  812  813  814  815  816  817  818  819
##  [820]  820  821  822  823  824  825  826  827  828  829  830  831  832
##  [833]  833  834  835  836  837  838  839  840  841  842  843  844  845
##  [846]  846  847  848  849  850  851  852  853  854  855  856  857  858
##  [859]  859  860  861  862  863  864  865  866  867  868  869  870  871
##  [872]  872  873  874  875  876  877  878  879  880  881  882  883  884
##  [885]  885  886  887  888  889  890  891  892  893  894  895  896  897
##  [898]  898  899  900  901  902  903  904  905  906  907  908  909  910
##  [911]  911  912  913  914  915  916  917  918  919  920  921  922  923
##  [924]  924  925  926  927  928  929  930  931  932  933  934  935  936
##  [937]  937  938  939  940  941  942  943  944  945  946  947  948  949
##  [950]  950  951  952  953  954  955  956  957  958  959  960  961  962
##  [963]  963  964  965  966  967  968  969  970  971  972  973  974  975
##  [976]  976  977  978  979  980  981  982  983  984  985  986  987  988
##  [989]  989  990  991  992  993  994  995  996  997  998  999 1000
```

```
D <- 1:10
D
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

```
as.character(D)
```

```
##  [1] "1"  "2"  "3"  "4"  "5"  "6"  "7"  "8"  "9"  "10"
```

```
as.factor(D)
```

```
##  [1] 1  2  3  4  5  6  7  8  9  10
## Levels: 1 2 3 4 5 6 7 8 9 10
```

```
summary(D)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1.00    3.25    5.50    5.50    7.75   10.00
```

```
summary(as.character(D))
```

```
##    Length     Class      Mode
##        10 character character
```

```
summary(as.factor(D))
```

```
##  1  2  3  4  5  6  7  8  9 10
##  1  1  1  1  1  1  1  1  1  1
```

There are many others, "list" being the most important not shown.

3. There are also functions. Most, but not all, work on many things at once.

```
sqrt(D)
```

```
##  [1] 1.000000 1.414214 1.732051 2.000000 2.236068 2.449490 2.645751
##  [8] 2.828427 3.000000 3.162278
```

```
# sqrt(A)

sqrt(D[6])
```

```
## [1] 2.44949
```

```
sqrt(D[1:3])
```

```
## [1] 1.000000 1.414214 1.732051
```

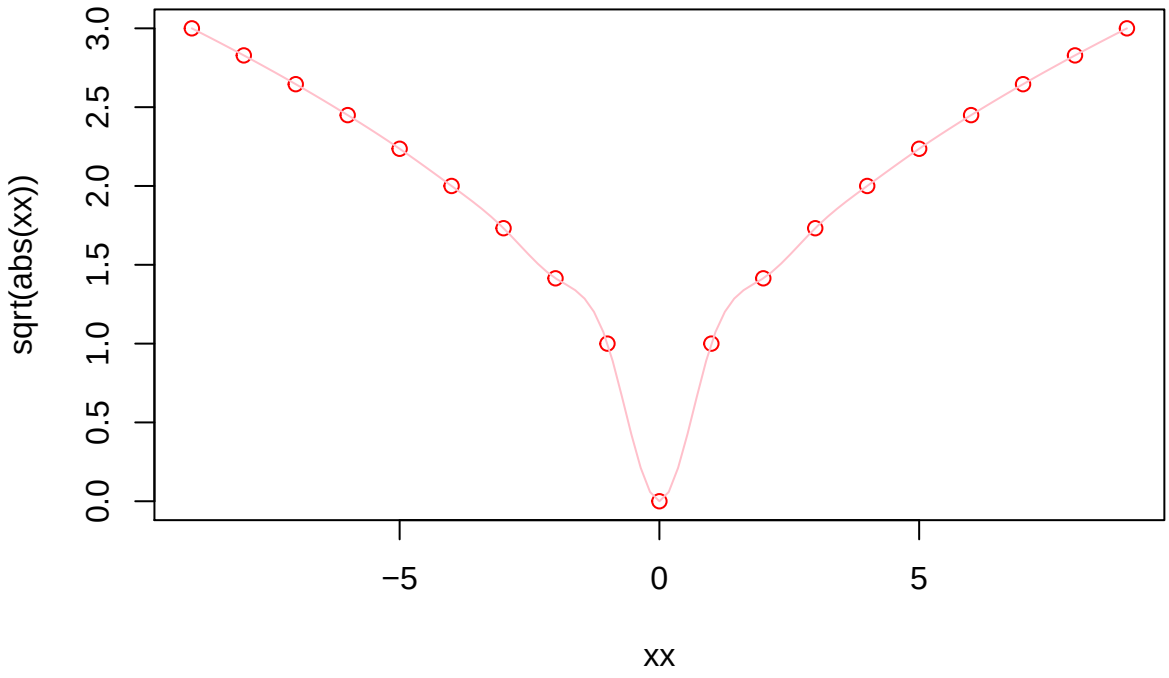
4. If you need help, use the help pane or ask for help. Everything has a help file and many functions come with examples of how to use.

```
help(sqrt)
```

```
## starting httpd help server ... done
```

```
example(sqrt)
```

```
##
## sqrt> require(stats) # for spline
##
## sqrt> require(graphics)
##
## sqrt> xx <- -9:9
##
## sqrt> plot(xx, sqrt(abs(xx)),  col = "red")
```




```
##
## sqrt> lines(spline(xx, sqrt(abs(xx)), n=101), col = "pink")
```

4. You can work with vectors and matrix but you will most frequently deal with dataframes, which is a matrix with extra attributes. Dataframes are objects that have variables inside them. You can access those variables with specific functions or with a '$'.

```
X <- runif(20, 2, 40)
MyData <- as.data.frame(X)
MyData$Y <-  100 - 2 * MyData$X + rnorm(20, mean = 0, sd = 1)

names(MyData)
```

```
## [1] "X" "Y"
```

```
names(MyData) <- c("Price","Quantity")
names(MyData)
```

```
## [1] "Price"    "Quantity"
```

```
summary(MyData)
```

```
##      Price           Quantity
##  Min.   : 2.365   Min.   :30.81
##  1st Qu.: 8.964   1st Qu.:42.22
##  Median :18.036   Median :63.24
##  Mean   :18.345   Mean   :63.38
##  3rd Qu.:28.680   3rd Qu.:81.46
##  Max.   :34.156   Max.   :96.15
```

5. You can get at columns and rows in other ways.

```
MyData[1:2]
```

```
##        Price Quantity
## 1   7.133680 85.99715
## 2  33.653215 34.64993
## 3  16.936706 64.72794
## 4  28.767068 42.70684
## 5  34.155720 30.80695
## 6  13.742116 73.44657
## 7  16.878220 68.35650
## 8  21.242790 57.53247
## 9   8.261871 83.66602
## 10  3.252648 93.63589
## 11 33.699309 33.02094
## 12 19.974595 61.64471
## 13 32.879849 33.16642
## 14 21.032628 58.56979
## 15  4.485552 91.28612
## 16  9.198394 80.71940
## 17 11.454320 75.11109
## 18  2.365383 96.14816
## 19 19.135119 61.75415
## 20 28.651570 40.74370
```

```
MyData[1]
```

```
##        Price
## 1   7.133680
## 2  33.653215
## 3  16.936706
## 4  28.767068
## 5  34.155720
## 6  13.742116
## 7  16.878220
## 8  21.242790
## 9   8.261871
## 10  3.252648
## 11 33.699309
## 12 19.974595
## 13 32.879849
## 14 21.032628
## 15  4.485552
## 16  9.198394
## 17 11.454320
## 18  2.365383
## 19 19.135119
## 20 28.651570
```

```
MyData[1:3,]
```

```
##      Price Quantity
## 1  7.13368 85.99715
## 2 33.65322 34.64993
## 3 16.93671 64.72794
```

```
MyData[1:3,"Price"]
```

```
## [1]  7.13368 33.65322 16.93671
```

```
MyData["Price"]
```

```
##        Price
## 1   7.133680
## 2  33.653215
## 3  16.936706
## 4  28.767068
## 5  34.155720
## 6  13.742116
## 7  16.878220
## 8  21.242790
## 9   8.261871
## 10  3.252648
## 11 33.699309
## 12 19.974595
## 13 32.879849
## 14 21.032628
## 15  4.485552
## 16  9.198394
## 17 11.454320
## 18  2.365383
## 19 19.135119
## 20 28.651570
```

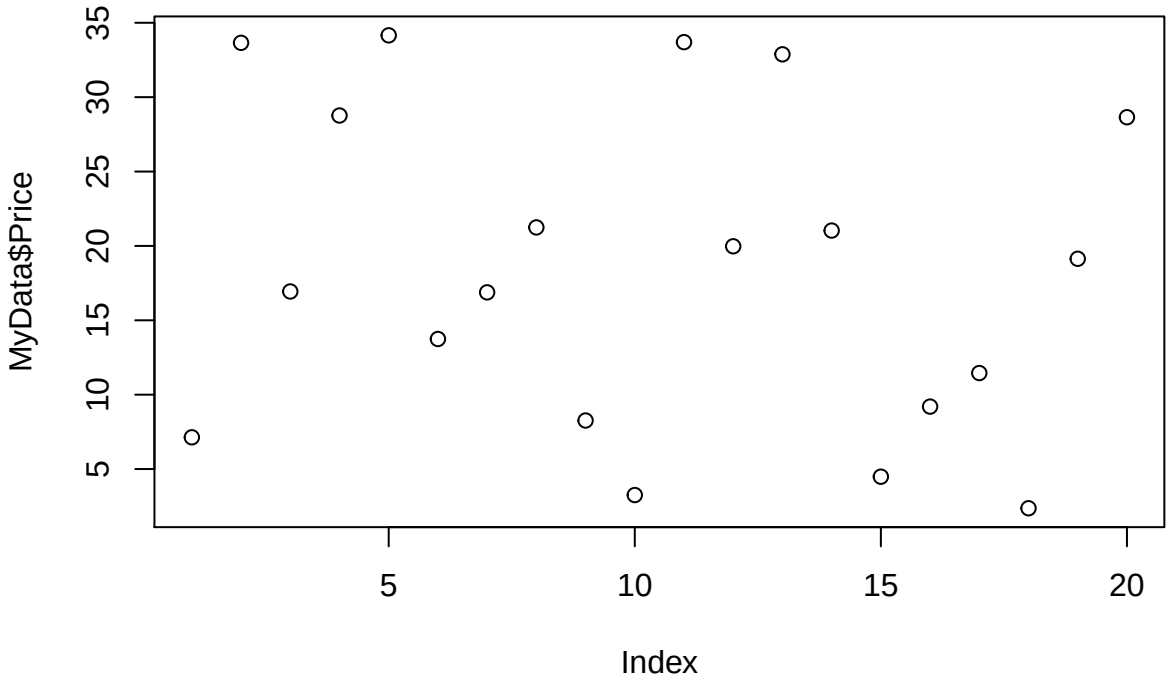
```
MyData[c(1,5,8),]
```

```
##      Price Quantity
## 1  7.13368 85.99715
## 5 34.15572 30.80695
## 8 21.24279 57.53247
```

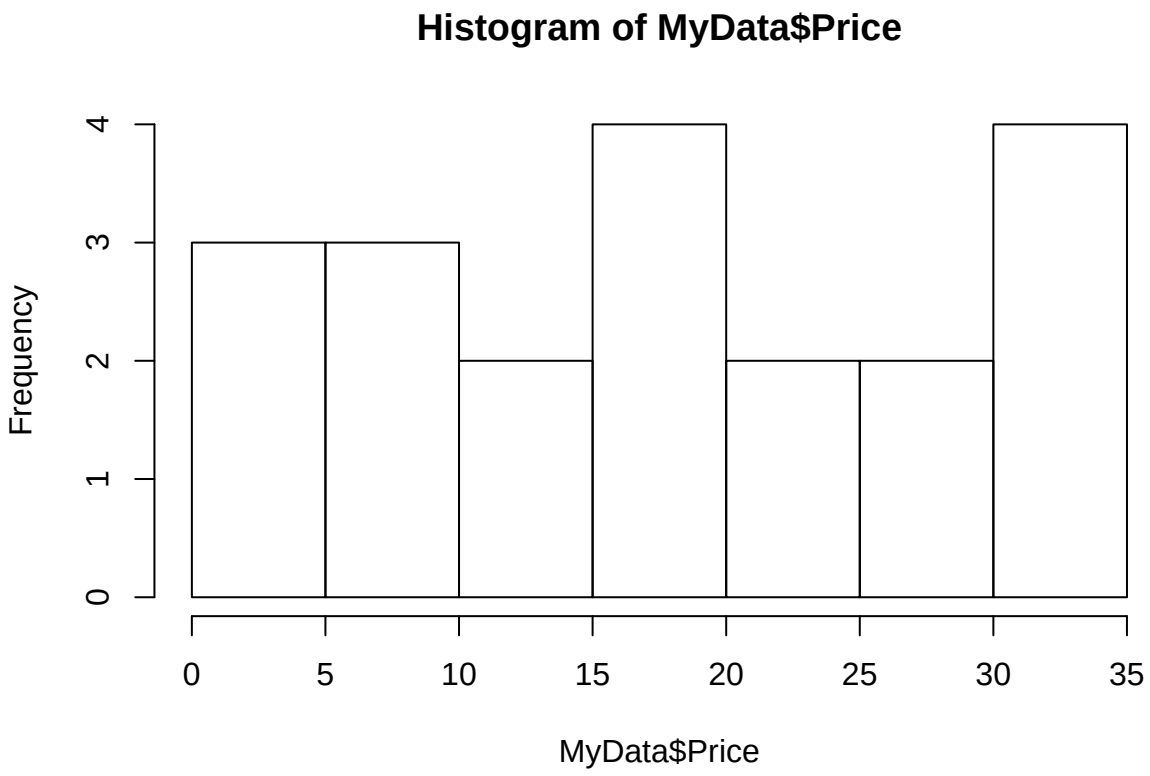
Pictures

Now lets make pictures.

```
plot(MyData$Price)
```

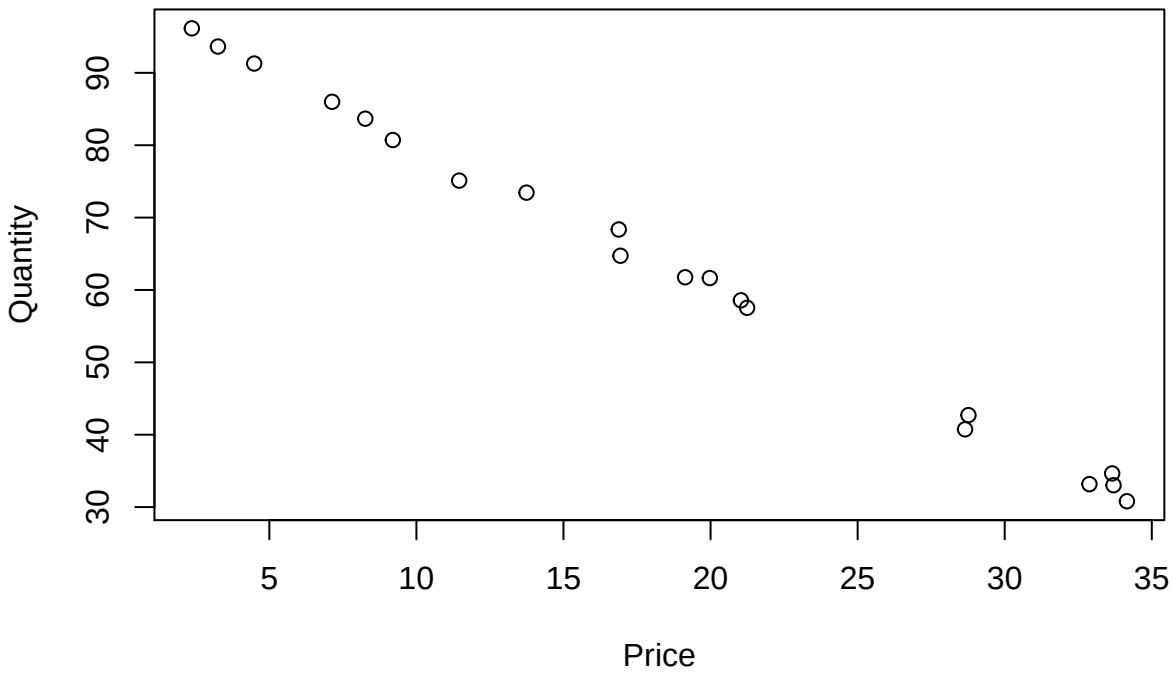


If you don't want to see the code and just the result, make sure to add echo=false to the chunk. Here is a Histogram without the code.



Show the relationship between two variables with "plot" or more than two with "pairs".

```
plot(Quantity ~ Price, data= MyData)
```



Regression with Pictures

5. A regression line can be thought of as just putting a line through a cloud of data in a well defined way. Remember the data we created? Here is what the regression gives you. You may want to make some notes on how to write formulas for regression in this file.

```
FirstRegression<- lm(Quantity ~ Price, data=MyData)

summary(FirstRegression)
```

```
##
## Call:
## lm(formula = Quantity ~ Price, data = MyData)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.10044 -0.89349  0.06973  0.60832  2.02863
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 100.19590    0.53401  187.63   <2e-16 ***
## Price        -2.00661    0.02524  -79.51   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 1.19 on 18 degrees of freedom
## Multiple R-squared:  0.9972, Adjusted R-squared:  0.997
## F-statistic:  6322 on 1 and 18 DF,  p-value: < 2.2e-16
```

Note that the estimates are the parameter, or very close to the parameters we used to create the data. Note also that the residual standard errors are the same as what we used to create the data. Nice when you know what is true.

Some other things you should note:

- ADD *NOTES* TO THIS LIST
- MORE NOTES FOR YOU TO ADD

You should probably make a lot of notes in this document so you can remember what we are talking about. Just add things. By the way, you can do equations too, $\frac{1}{2}x$ or even

$$\lim_{x \to +\infty} \frac{3x^2 + 7x^3}{x^2 + 5x^4} = 3$$

If you take 400 level math classes, your homework will be in latex like this.

Regression can also show you things that are not true. You always have to assume a functional form and if you get that functional form wrong you get garbage. Sometimes the garbage makes some kind of sense and sometimes it leads you to believe that you have to make some kind of statistical fix. Students that have taken econometrics will be aware of autocorrelation, heterskedasticity and endogenaity as common problems. Having the wrong functional form will often present as one of these problems.

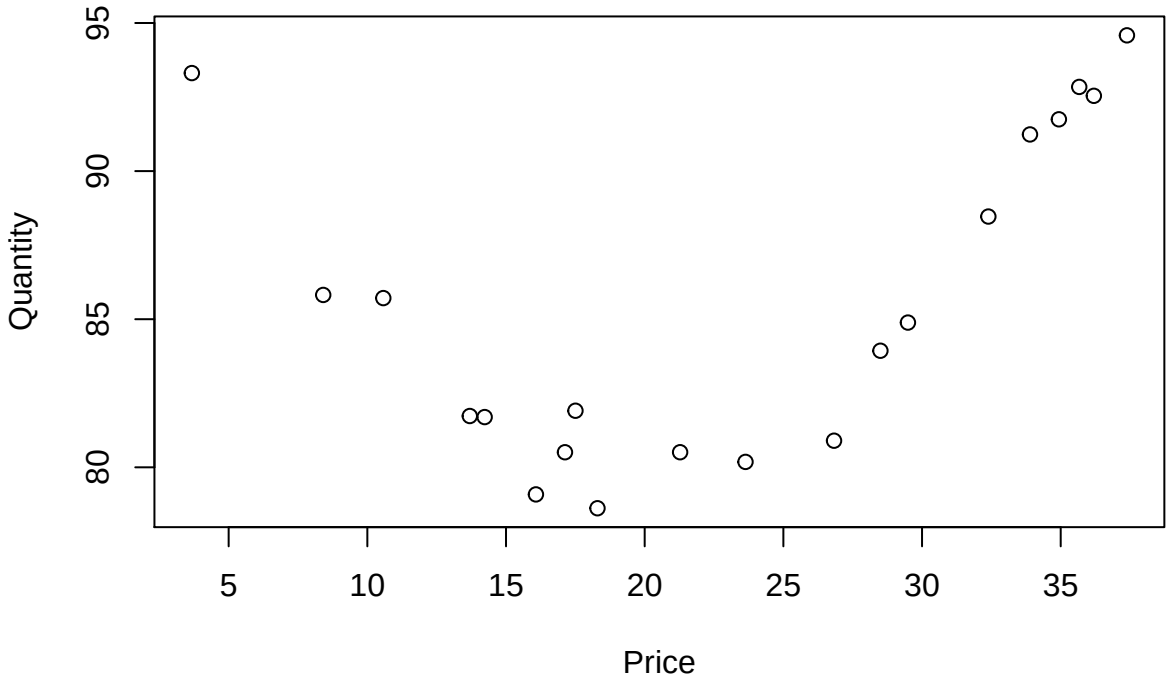
Lets wake new data and show how getting the regression model wrong can cause problems.

```
MyData2 <- data.frame(Price = runif(20, 2, 40))
MyData2$Quantity <-  100 - 2 * MyData2$Price + .05 * MyData2$Price^2 + rnorm(20, mean =0, sd = 1)

summary(MyData2)
```

```
##      Price           Quantity
##  Min.   : 3.672   Min.   :78.62
##  1st Qu.:15.617   1st Qu.:80.80
##  Median :22.456   Median :84.41
##  Mean   :22.989   Mean   :85.51
##  3rd Qu.:32.766   3rd Qu.:91.37
##  Max.   :37.388   Max.   :94.58
```

Not a line

```
plot(Quantity ~ Price, data = MyData2)
```



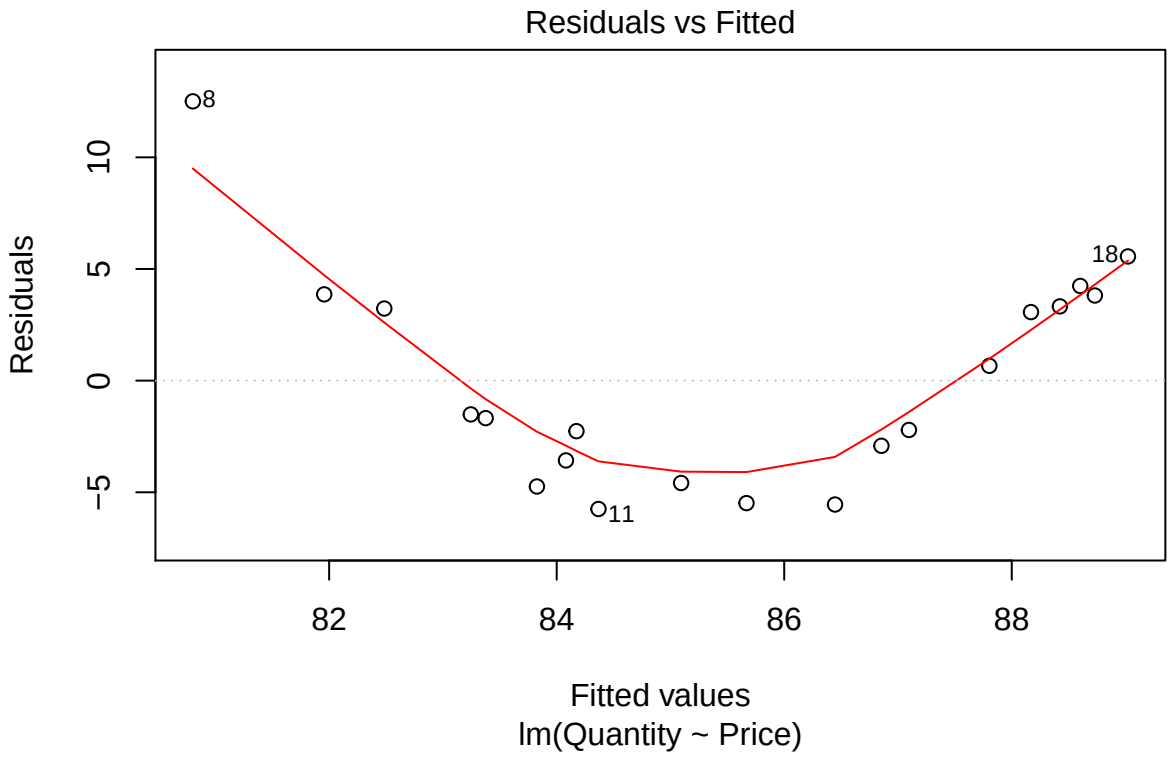
Give me a line anyway.

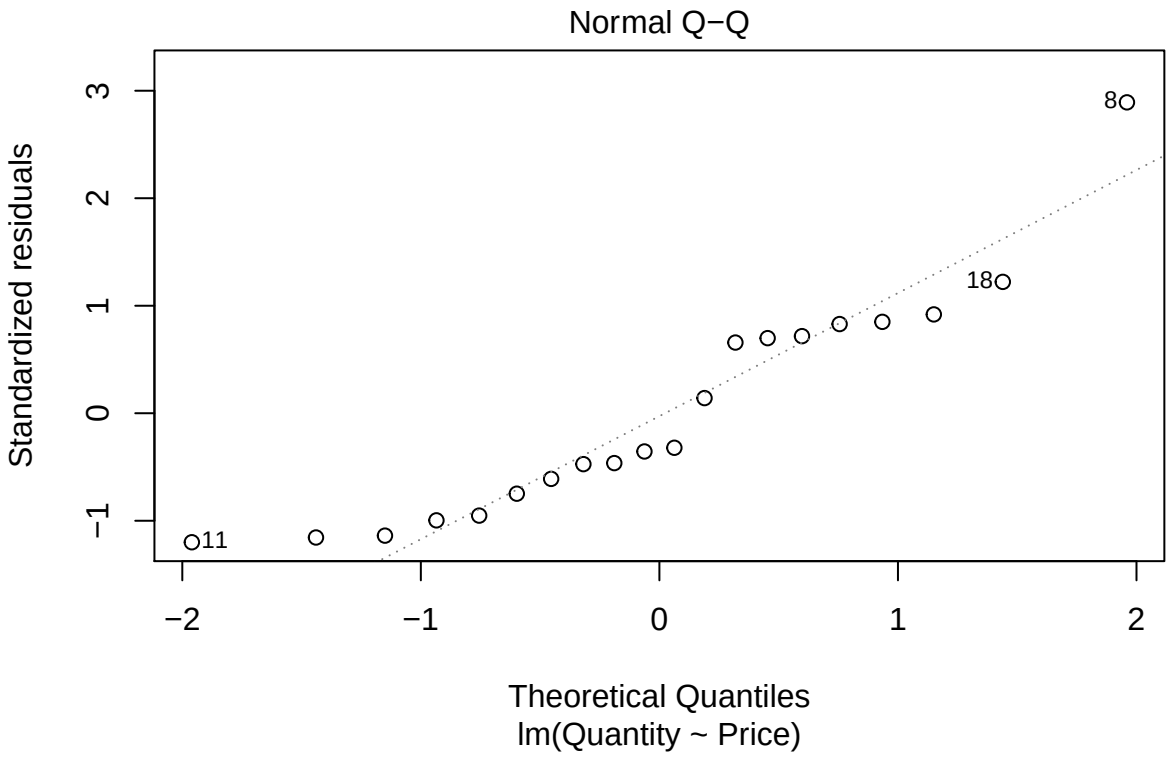
```
NotALine<- lm(Quantity ~ Price, data=MyData2)

summary(NotALine)
```

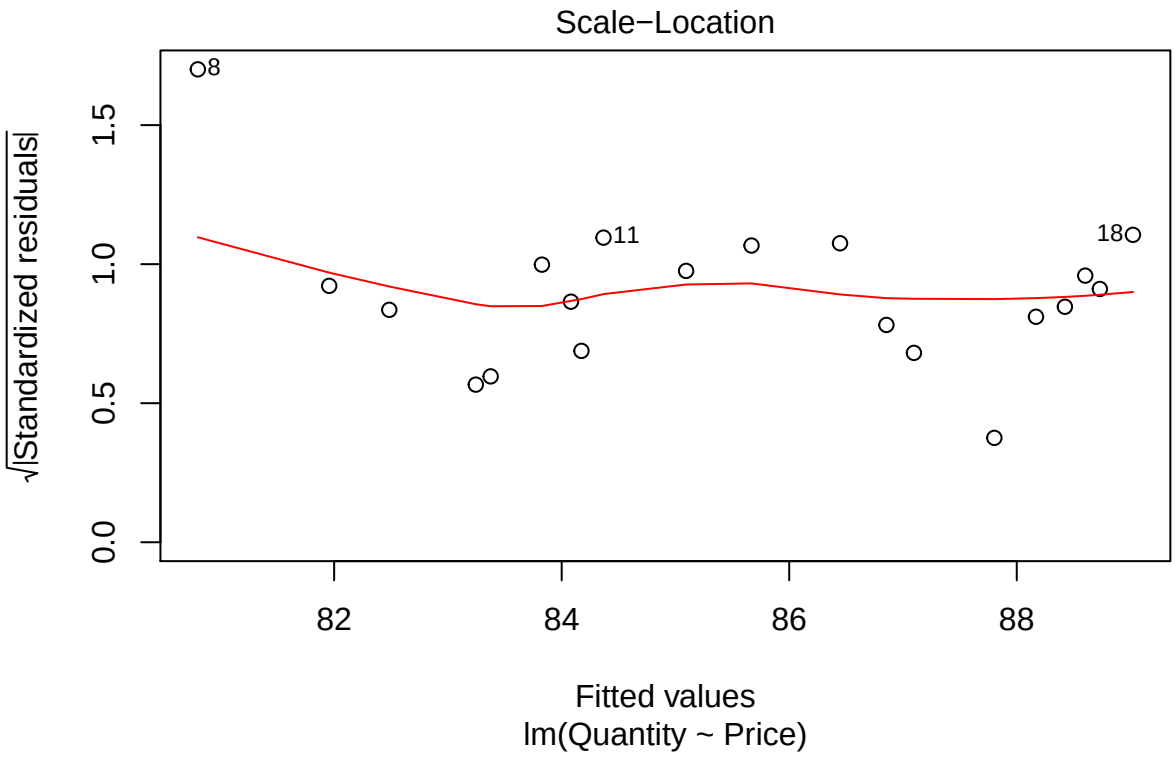
```
##
## Call:
## lm(formula = Quantity ~ Price, data = MyData2)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -5.749 -3.826 -1.596  3.446 12.507
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  79.9065     2.7596  28.955   <2e-16 ***
## Price         0.2438     0.1100   2.217   0.0398 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.944 on 18 degrees of freedom
## Multiple R-squared:  0.2144, Adjusted R-squared:  0.1708
## F-statistic: 4.913 on 1 and 18 DF,  p-value: 0.03978
```

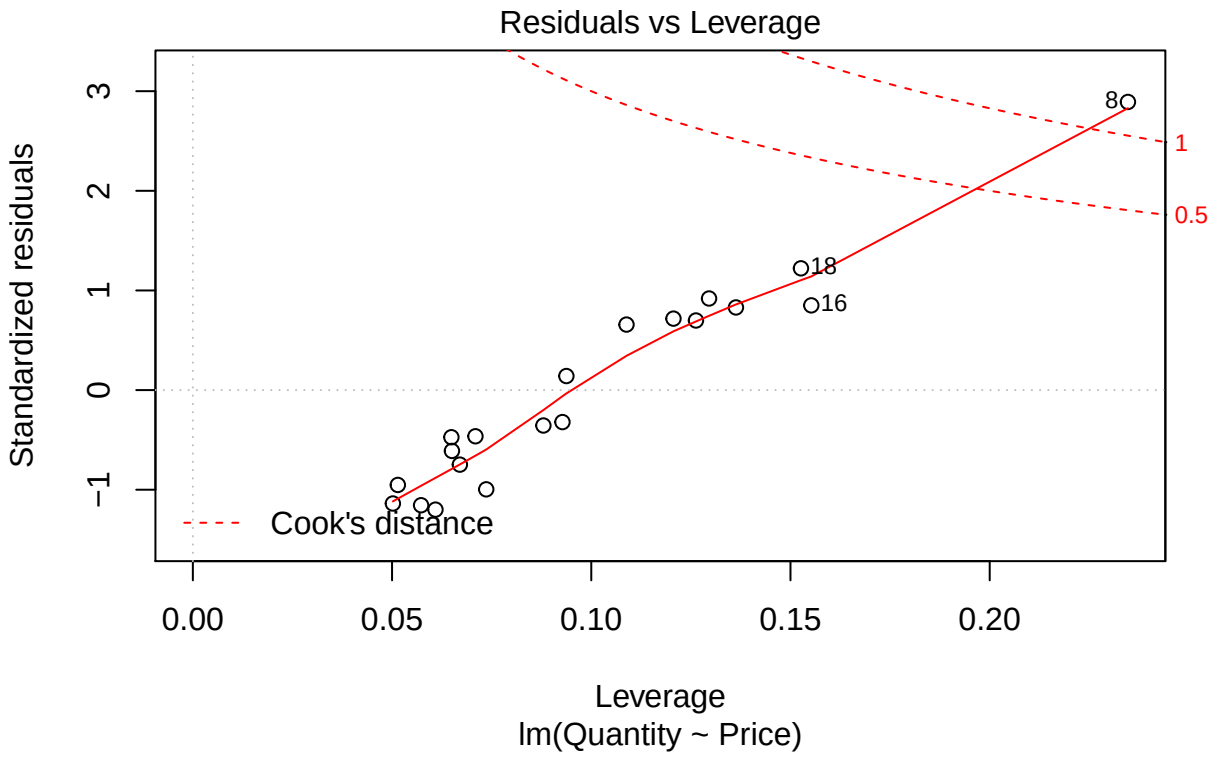
How to tell you were wrong thinking it was a line. Make a pictures

```r
plot(NotALine)
```



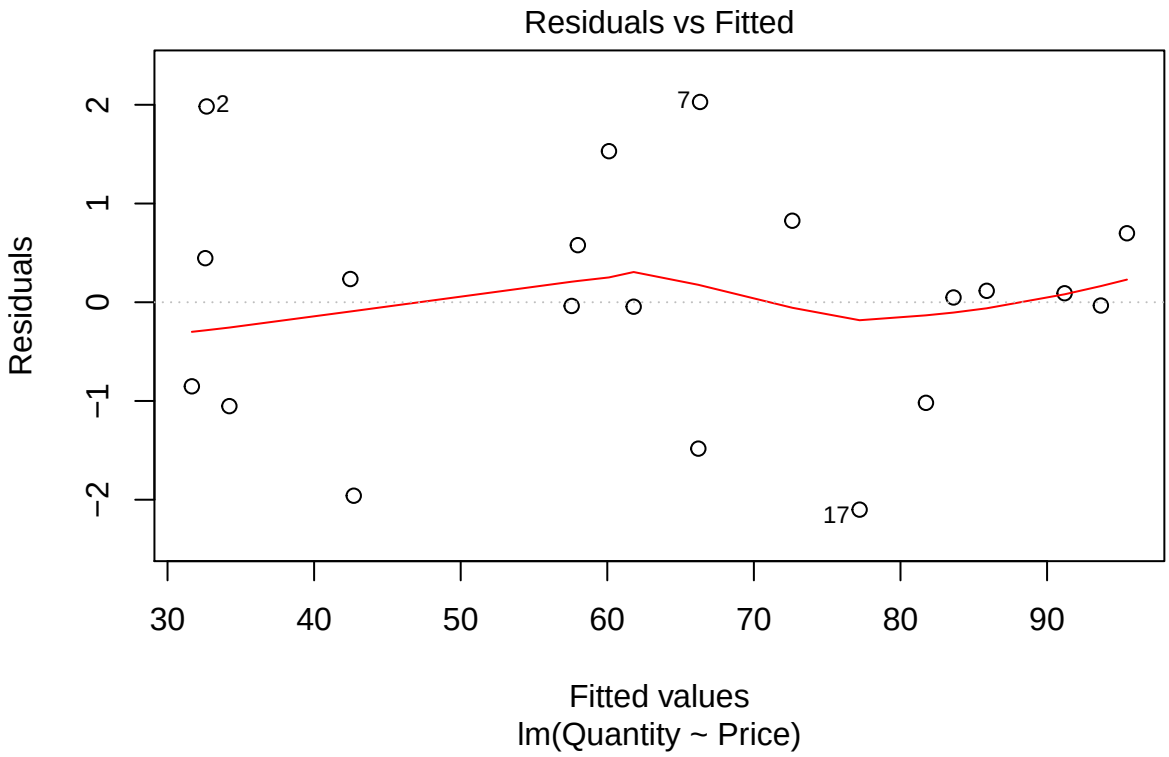

Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(Quantity ~ Price)
8
18
11
−2
−1
0
1
2
−1
0
1
2
3

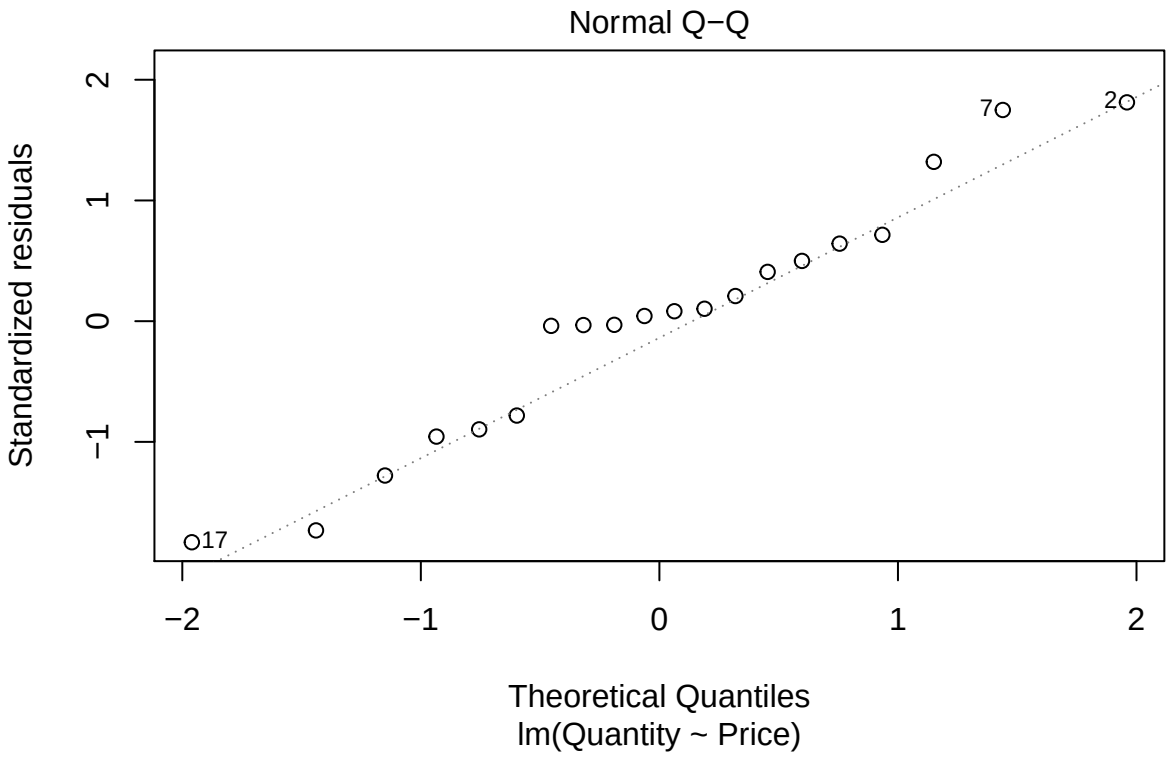

Scale−Location
√|Standardized residuals|
0.0
0.5
1.0
1.5
8
11
18
82
84
86
88
Fitted values
lm(Quantity ~ Price)

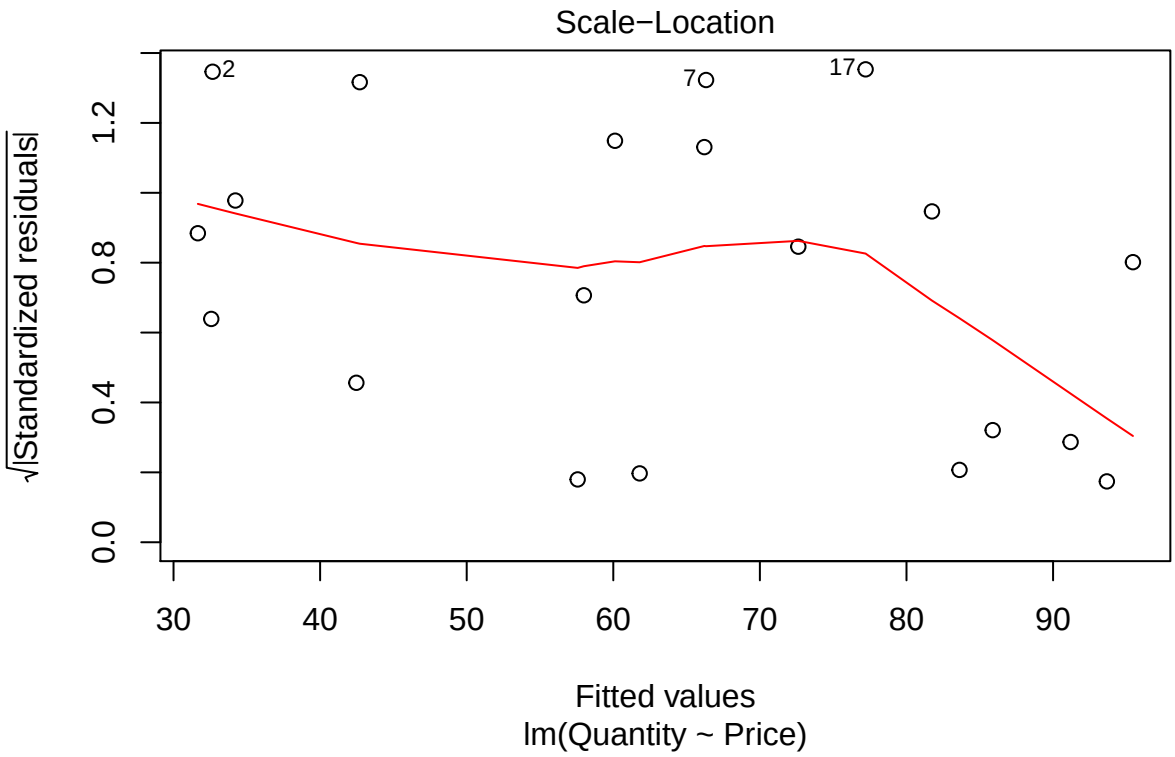


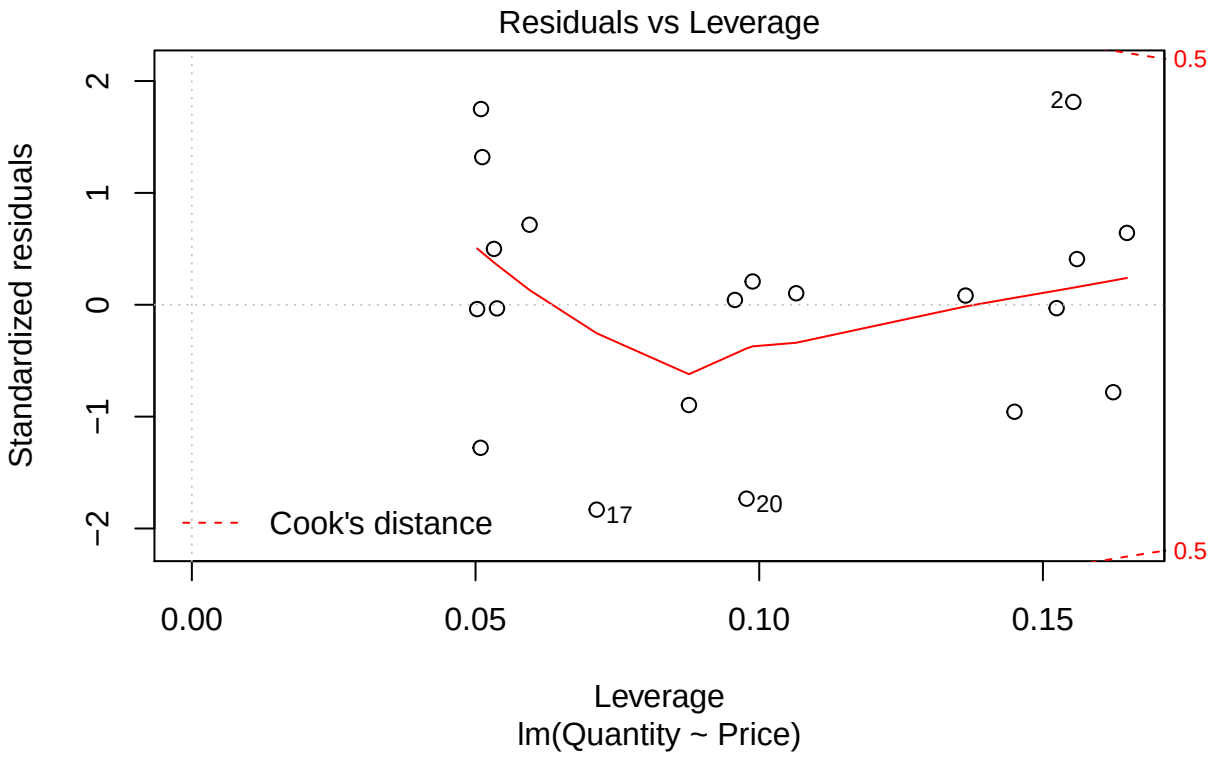
Compare with when it was a line and you estimated a line

```
plot(FirstRegression)
```


Residuals vs Fitted
Residuals
Fitted values
lm(Quantity ~ Price)
2
7
17
2
1
0
−1
−2
30
40
50
60
70
80
90

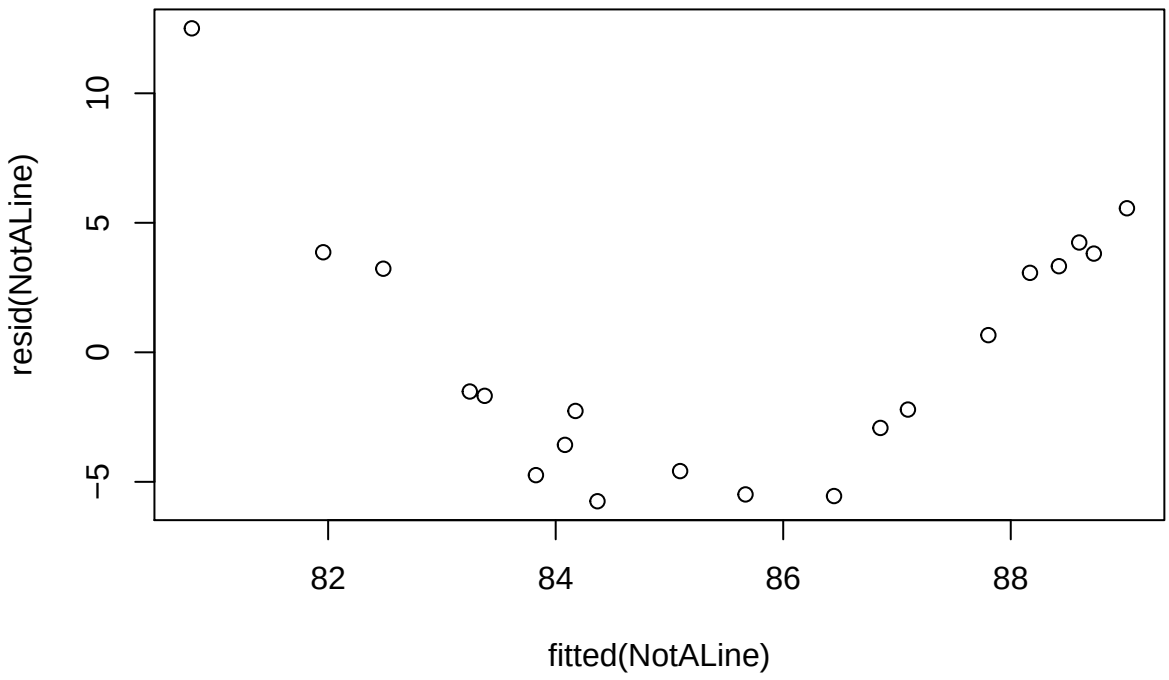

Normal Q−Q
Standardized residuals
Theoretical Quantiles
lm(Quantity ~ Price)
17
7
2
−2
−1
0
1
2


Scale−Location
√|Standardized residuals|
0.0
0.4
0.8
1.2
2
7
17
30
40
50
60
70
80
90
Fitted values
lm(Quantity ~ Price)



You can make these by hand too. Here are two accessor functions.

```
plot(resid(NotALine)~fitted(NotALine))
```



Dummy Variables

Not every variable is real valued, some are true false or categorical like night and day. R deals with categorical variables, called factors, very well and has fewer of the problems you see in other languages.

Lets make new fake data with dummy variables. I will reuse the first artificial dataset that was truly linear.

```
MyData$Time <- as.factor(ifelse(runif(20) < .5, "Day", "Night"))

MyData$Quantity[MyData$Time == "Day"] <- MyData$Quantity[MyData$Time == "Day"] + 12
```

I just made it so that if it is Day the quantity is 12 higher.

```
WTime <- lm(Quantity ~ Price + Time, data=MyData)

summary(WTime)
```

```
##
## Call:
## lm(formula = Quantity ~ Price + Time, data = MyData)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.2816 -0.5447  0.1296  0.5854  1.7162
##
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 111.96260    0.52931  211.52  < 2e-16 ***
## Price        -2.01764    0.02501  -80.66  < 2e-16 ***
## TimeNight   -11.12888    0.52758  -21.09 1.25e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.137 on 17 degrees of freedom
## Multiple R-squared:  0.998,  Adjusted R-squared:  0.9978
## F-statistic:  4231 on 2 and 17 DF,  p-value: < 2.2e-16
```

See something odd. Interpreting this can be tricky. Best take some notes.

You can also make it so that the reaction to price is different depending on if it is night or day.

```
WTimeInteract <- lm(Quantity ~ Price*Time, data=MyData)

summary(WTimeInteract)
```

```
##
## Call:
## lm(formula = Quantity ~ Price * Time, data = MyData)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.16963 -0.62535  0.09932  0.60599  1.90283
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)     111.76468    0.65321 171.101  < 2e-16 ***
## Price            -2.00489    0.03478 -57.639  < 2e-16 ***
## TimeNight       -10.61482    1.09391  -9.704 4.17e-08 ***
## Price:TimeNight  -0.02768    0.05127  -0.540    0.597
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.161 on 16 degrees of freedom
## Multiple R-squared:  0.998,  Adjusted R-squared:  0.9977
## F-statistic:  2703 on 3 and 16 DF,  p-value: < 2.2e-16
```

You will need a lot of notes on this. Interpreting interactive effects is tricky.

Useful facts

You can get elasticites directly out of a regression model if both quantity and price are logged. In every other case you have to calculate elasticities by hand and they are different at every point.

```
ElastForm <- lm(log(Quantity) ~ log(Price) + Time, data=MyData)

summary(ElastForm)
```

```
##
## Call:
## lm(formula = log(Quantity) ~ log(Price) + Time, data = MyData)
##
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -0.25916 -0.15725  0.06056  0.14053  0.21103
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  5.29041    0.13225  40.004  < 2e-16 ***
## log(Price)  -0.37942    0.04882  -7.771 5.41e-07 ***
## TimeNight   -0.20447    0.07643  -2.675    0.016 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1662 on 17 degrees of freedom
## Multiple R-squared:  0.8278, Adjusted R-squared:  0.8075
## F-statistic: 40.86 on 2 and 17 DF,  p-value: 3.208e-07
```

I did it, but is it right?

If only the right hand side variable is logged, you interpret the parameter as the effect of a percent change.

```
PercentForm <- lm(Quantity ~ log(Price) + Time, data=MyData)

summary(PercentForm)
```

```
##
## Call:
## lm(formula = Quantity ~ log(Price) + Time, data = MyData)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -12.332  -7.017   3.762   5.551   9.574
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  143.493      6.172  23.247 2.53e-14 ***
## log(Price)   -25.291      2.279 -11.098 3.29e-09 ***
## TimeNight    -13.239      3.567  -3.711  0.00173 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.755 on 17 degrees of freedom
## Multiple R-squared:  0.9067, Adjusted R-squared:  0.8957
## F-statistic: 82.61 on 2 and 17 DF,  p-value: 1.753e-09
```

Common statistical problems

This is the basics. You now know enough to be insanely overconfident. Don't destroy the world.

Beyond getting the specification wrong, which you usually support with several similar models that show similar results, there are common statistical problems that you learn about in econometrics

- Autocorrelation, which makes your regression look better than it actually is.
- Heteroskadasticity, which makes it worse.
- Endogenaity, which biases your parameters in unknown directions.
- Errors in variables (RHS), which bias parameters towards zero.
- ...

Don't get cocky.

What we are going to do next is read in some real data that looks like either supply or demand but will be neither. Why, because supply and demand determine price and quantity simultaneously, that means that something either price or quantity is endogenous. At this point, you are at about 1910 as far as standard econometric practice.

Real Data

- I will walk you through a few steps on reading in the data. The biggest hurdle to doing stats on the data is reading it in. There is actually an R library for working with EIA data directly, EIAdata, but we will use the more general tools to read files.
- Download into R data on coal prices and quantities. Again, the assignment operator in R is the "<-" symbol.

```
Coal <- read.csv("https://www.eia.gov/totalenergy/data/browser/csv.cfm?tbl=T06.01")
```

There are many ways of loading data into R (http://www.r-tutor.com/r-introduction/data-frame/data-import). Some work some of the time. In most cases Comma Separated Values (CSV) is the safest format to work with.

- Take a look at the summary of the data

```
summary(Coal)
```

```
##       MSN           YYYYMM                  Value       Column_Order
##  CLEXPUS: 603   Min.   :194913   Not Available: 244   Min.   :1.00
##  CLIMPUS: 603   1st Qu.:198210   2              :   3   1st Qu.:2.75
##  CLLUPUS: 603   Median :199405   3              :   3   Median :4.50
##  CLNIPUS: 603   Mean   :199348   -4657          :   2   Mean   :4.50
##  CLPRPUS: 603   3rd Qu.:200513   114            :   2   3rd Qu.:6.25
##  CLSCPUS: 603   Max.   :201707   129            :   2   Max.   :8.00
##  (Other):1206                    (Other)        :4568
##                            Description                     Unit
##  Coal Consumption                : 603   Thousand Short Tons:4824
##  Coal Exports                    : 603
##  Coal Imports                    : 603
##  Coal Losses and Unaccounted for: 603
##  Coal Net Imports                : 603
##  Coal Production                 : 603
##  (Other)                         :1206
```

You will notice that for some variables they give counts, e.g., MSN, and for others you get numerical summaries, e.g., Column_Order. The difference has to do with the data types (http://www.statmethods.net/input/datatypes.html).

- Since we are trying to make a simple supply model, i.e., trying to explain coal production, lets select just the production part of the data set and also get only the annual production values. This is a little primer on changing data types and taking part of data.
- Load the dplyr package. This is the normal way to load libraries of functions that you need.

```
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

- Select only the Coal Production Figures and save it as CoalProduction. There is a cheat sheet for dplyr built into R. Look under the help menu.

```
CoalProduction <- Coal %>% filter(MSN == "CLPRPUS")
```

- Note that you have monthly data but that the annual data is shown as month 13. Grab all of the observations with month not equal to 13.

```
library(stringr)

CoalProduction <- CoalProduction %>% filter(str_sub(as.character(YYYYMM),5 ) != "13")
```

- At this point you will have noticed that we don't need all the columns so lets keep just the ones we need and then give the two columns we saved new names.

```
CoalProduction <- CoalProduction %>% select(YYYYMM, Value)

names(CoalProduction) <- c("RawMonth", "ProductionKShortTon")
summary(CoalProduction)
```

```
##     RawMonth      ProductionKShortTon
##  Min.   :197301   100000.27 :  1
##  1st Qu.:198403   100427.638:  1
##  Median :199504   100627.455:  1
##  Mean   :199486   100653.897:  1
##  3rd Qu.:200606   101144.833:  1
##  Max.   :201707   101490.13 :  1
##                   (Other)   :529
```

- Notice that the ProductionKShortTon variable shows a count rather than a numerical summary. This means that R thinks it is a factor rather than a number. Lets fix that. It requires to first convert the factor, which is an integer, to the real value as a character and then convert that to numeric.

```
CoalProduction$ProductionKShortTon <- as.numeric(as.character(CoalProduction$ProductionKShortTon))
```

Play around with this doing one function at a time to see what each does and what each does alone.

- Next lets create a column for the year and make it a numeric value.

```
CoalProduction <- CoalProduction  %>% mutate(Year = as.numeric(str_sub(as.character(RawMonth),0,4 ))) %>



summary(CoalProduction)
```

```
##     RawMonth      ProductionKShortTon      Year          Month
##  Min.   :197301   Min.   : 23664      Min.   :1973   Min.   : 1.000
##  1st Qu.:198403   1st Qu.: 69716      1st Qu.:1984   1st Qu.: 3.000
##  Median :199504   Median : 82470      Median :1995   Median : 6.000
##  Mean   :199486   Mean   : 79110      Mean   :1995   Mean   : 6.467
##  3rd Qu.:200606   3rd Qu.: 90540      3rd Qu.:2006   3rd Qu.: 9.000
##  Max.   :201707   Max.   :104390      Max.   :2017   Max.   :12.000
```

- Now grab some price data. We are going to use Quandl (https://www.quandl.com/), which has a bunch of data on energy and a lot of other things (https://www.quandl.com/collections/markets/coal). Make sure you have the Quandl library installed. If you don't install.packages("Quandl") should do it.

```
library(Quandl)
```

```
## Loading required package: xts
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
##
## Attaching package: 'xts'
```

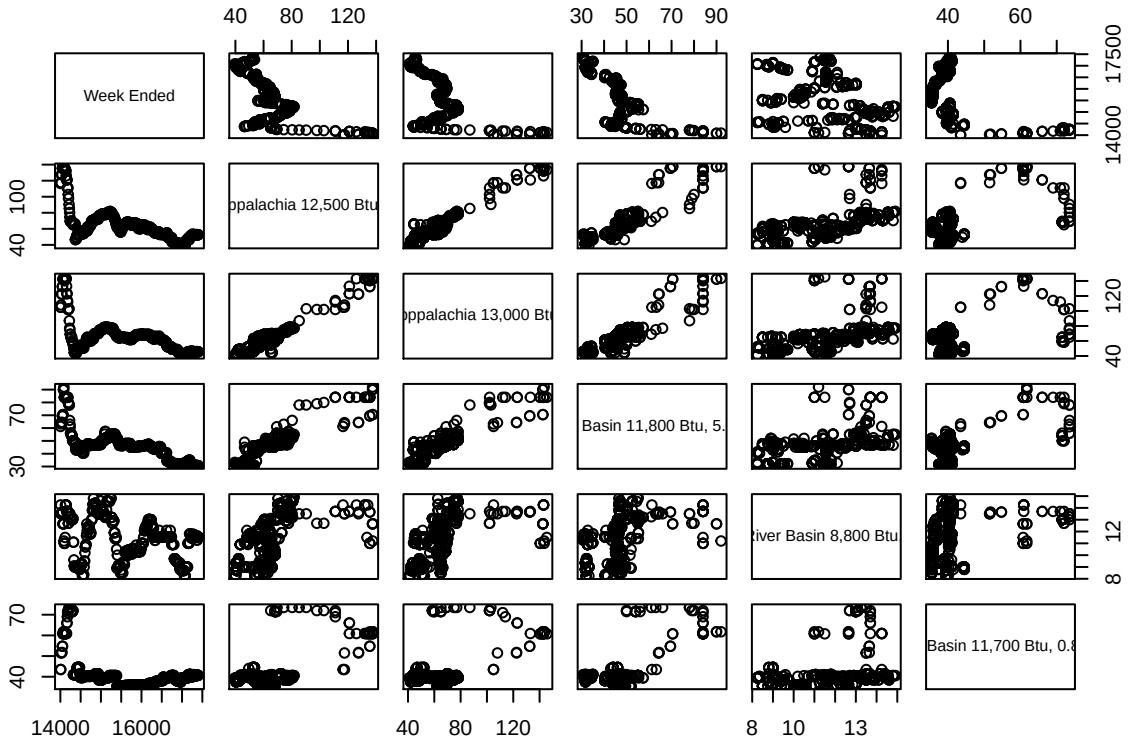
```
## The following objects are masked from 'package:dplyr':
##
##     first, last
```

```
Prices <- Quandl("EIA/COAL")

summary(Prices)
```

```
##    Week Ended         Central Appalachia 12,500 Btu, 1.2 SO2
##  Min.   :2008-05-06   Min.   : 39.55
##  1st Qu.:2010-09-11   1st Qu.: 52.75
##  Median :2012-12-25   Median : 60.90
##  Mean   :2013-01-01   Mean   : 64.07
##  3rd Qu.:2015-04-27   3rd Qu.: 69.30
##  Max.   :2017-08-25   Max.   :137.50
##  Northern Apppalachia 13,000 Btu, <3.0 SO2
##  Min.   : 40.75
##  1st Qu.: 51.90
##  Median : 64.10
##  Mean   : 64.62
##  3rd Qu.: 68.65
##  Max.   :145.50
##  Illinois Basin 11,800 Btu, 5.0 SO2 Powder River Basin 8,800 Btu, 0.8 SO2
##  Min.   :30.70                      Min.   : 8.25
##  1st Qu.:40.45                      1st Qu.:10.04
##  Median :46.00                      Median :11.55
##  Mean   :45.87                      Mean   :11.38
##  3rd Qu.:47.90                      3rd Qu.:12.90
##  Max.   :92.00                      Max.   :14.90
##  Uinta Basin 11,700 Btu, 0.8 SO2
##  Min.   :35.50
##  1st Qu.:36.59
##  Median :39.45
##  Mean   :41.04
##  3rd Qu.:40.55
##  Max.   :73.50
```

- Lets make a picture

```
library(ggplot2)
plot(Prices)
```



- Story time on the picture. What do you see? What stories come to mind?
- As before we will convert the year to a numeric value.

```
library(lubridate)
```

```
##
## Attaching package: 'lubridate'
```

```
## The following object is masked from 'package:base':
##
##     date
```

```
# Prices$Year <- as.numeric(str_sub(Prices$Year,0,4))

Prices <- Prices %>% mutate(Month = month(`Week Ended`) )  %>% mutate(Year = year (`Week Ended`))
```

- Now we are going to get monthly averages

```
Prices <- Prices %>% group_by(Month, Year) %>% summarise_all(mean)
```

For illustrative purposes lets let stick with one price and then merge the price and volume data.

```
Prices <- Prices %>% select(Year, Month,Price = `Central Appalachia 12,500 Btu, 1.2 SO2` )
```

- Merge the two data frames

```
summary(CoalProduction)
```

```
##     RawMonth      ProductionKShortTon      Year          Month
##  Min.   :197301   Min.   : 23664      Min.   :1973   Min.   : 1.000
##  1st Qu.:198403   1st Qu.: 69716      1st Qu.:1984   1st Qu.: 3.000
##  Median :199504   Median : 82470      Median :1995   Median : 6.000
##  Mean   :199486   Mean   : 79110      Mean   :1995   Mean   : 6.467
##  3rd Qu.:200606   3rd Qu.: 90540      3rd Qu.:2006   3rd Qu.: 9.000
##  Max.   :201707   Max.   :104390      Max.   :2017   Max.   :12.000
```

```
summary(Prices)
```

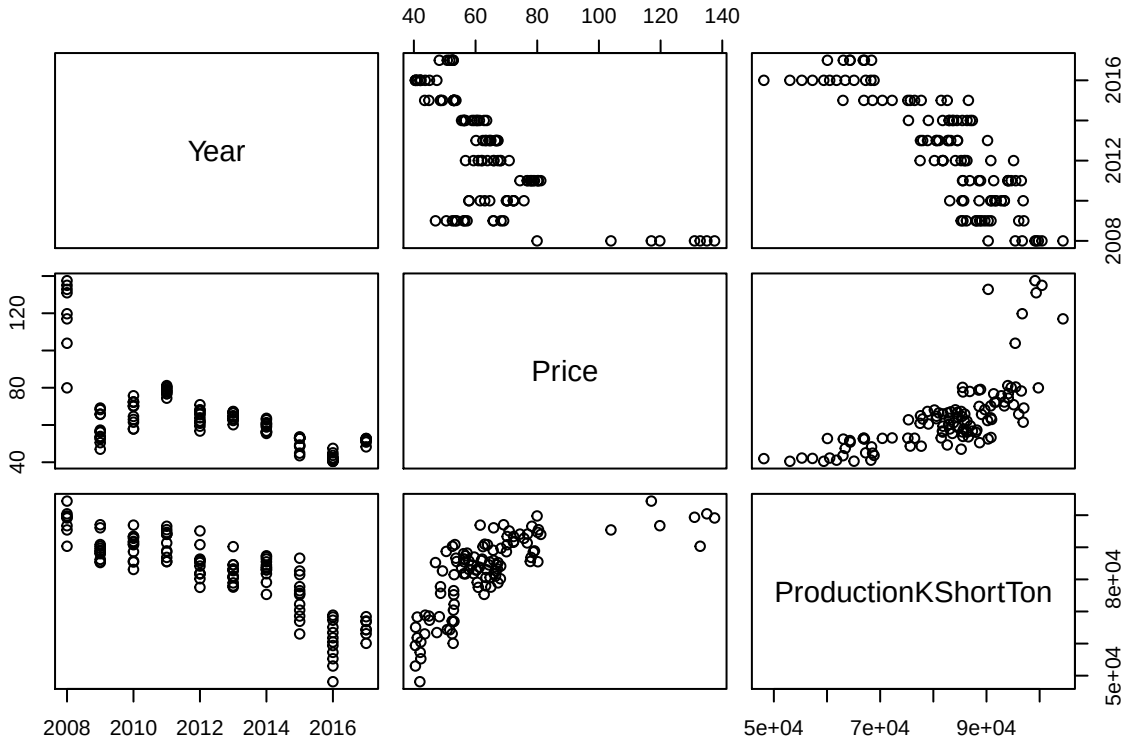
```
##       Year          Month          Price
##  Min.   :2008   Min.   : 1.0   Min.   : 40.50
##  1st Qu.:2010   1st Qu.: 4.0   1st Qu.: 52.81
##  Median :2012   Median : 6.5   Median : 61.37
##  Mean   :2012   Mean   : 6.5   Mean   : 64.17
##  3rd Qu.:2015   3rd Qu.: 9.0   3rd Qu.: 69.33
##  Max.   :2017   Max.   :12.0   Max.   :137.50
```

```
CoalMarket <- inner_join(Prices, CoalProduction, by =c("Year","Month"))

summary(CoalMarket)
```

```
##       Year          Month            Price           RawMonth
##  Min.   :2008   Min.   : 1.000   Min.   : 40.50   Min.   :200805
##  1st Qu.:2010   1st Qu.: 4.000   1st Qu.: 52.87   1st Qu.:201009
##  Median :2012   Median : 6.000   Median : 61.50   Median :201212
##  Mean   :2012   Mean   : 6.486   Mean   : 64.28   Mean   :201252
##  3rd Qu.:2015   3rd Qu.: 9.000   3rd Qu.: 69.55   3rd Qu.:201504
##  Max.   :2017   Max.   :12.000   Max.   :137.50   Max.   :201707
##  ProductionKShortTon
##  Min.   : 48115
##  1st Qu.: 76995
##  Median : 84568
##  Mean   : 82171
##  3rd Qu.: 90313
##  Max.   :104390
```

Lets look at the data.

```
pairs(~ Year+ Price + ProductionKShortTon, data = CoalMarket)
```


Year
Price
ProductionKShortTon
40
60
80
100
120
140
2008
2012
2016
40
80
120
2008
2010
2012
2014
2016
5e+04
8e+04
5e+04
7e+04
9e+04