AN INTRODUCTION TO R PROGRAMMING

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Introduction

R language is the GNU arm of S language, which has taken the computational world by storm in the last decade. Starting as a compendium of statistical tools, this language has grown up into a canopy lording over a research analysis environment thereby subsuming many hitherto complicated manoeuvres onto the realms of syntactical simplicity. As this an exponentially expanding field of development with ever exploding information downpour, it would be a near impossible task to frame it onto a short simple foundational discourse. However in the subsequent sections we would try to view the potential and the extent of practicality we would unravel the hidden features of the software through a GUI envelop also apart from the regular console and syntax based one. To get its power more understandable we would visualize its forays into the field of analytics using medium scale examples from marine fisheries data.

R is "GNU S" — A language and environment for data manipulation, calculation and graphical display.

- R is similar to the award-winning S system, which was developed at Bell Laboratories by John Chambers et al.
- a suite of operators for calculations on arrays, in particular matrices,
- a large, coherent, integrated collection of intermediate tools for interactive data analysis,
- graphical facilities for data analysis and display either directly at the computer or on hardcopy
- a well developed programming language which includes conditionals, loops, user defined recursive functions and input and output facilities.

The core of R is an interpreted computer language.

- It allows branching and looping as well as modular programming using functions.
- Most of the user-visible functions in R are written in R, calling upon a smaller set of internal primitives.

It is possible for the user to interface to procedures written in C, C++ or FORTRAN languages for efficiency, and also to write additional primitives

R, S and S-plus- a brief time line

- S: an interactive environment for data analysis developed at Bell Laboratories since 1976
    - 1988 - S2: RA Becker, JM Chambers, A Wilks
    - 1992 - S3: JM Chambers, TJ Hastie
    - 1998 - S4: JM Chambers
- Exclusively licensed by *AT&T/Lucent* to *Insightful Corporation*, Seattle WA. Product name: "S-plus".
- Implementation languages C, Fortran.
- See:http://cm.bell-labs.com/cm/ms/departments/sia/S/history.html
- R: initially written by Ross Ihaka and Robert Gentleman at Dep. of Statistics of U of Auckland, New Zealand during 1990s.
- Since 1997: international "R-core" team of ca. 15 people with access to common CVS archive.

What R does and does not

o data handling and storage: numeric, textual	o is not a database, but connects to DBMSs
o matrix algebra	o has no graphical user interfaces, but connects to Java, TclTk
o hash tables and regular expressions	o language interpreter can be very slow, but allows to call own C/C++ code
o high-level data analytic and statistical functions	o no spreadsheet view of data, but connects to Excel/MsOffice
o classes (Object Oriented "OO")	o no professional / commercial support
o graphics	
o programming language: loops, branching, subroutines	

R and statistics

- Packaging: a crucial infrastructure to efficiently produce, load and keep consistent software libraries from (many) different sources / authors, which are updated at a best possible refresh rate
- Statistics: most packages deal with statistics and data analysis and there are many conduit and value addition libraries which augment the statistical inference

- State of the art: many statistical researchers provide their methods as R packages

Statistical Analysis

Data Analysis and Presentation happen to be the core strength of R software environment and the ease with which this is performed makes the environment as the ultimate winner. Faster computational routines and amenability of access and modification to interim steps and results makes the programming environment a winner.

- The R distribution contains functionality for large number of statistical procedures.
  - linear and generalized linear models
  - nonlinear regression models
  - time series analysis
  - classical parametric and nonparametric tests
  - clustering
  - smoothing
- R also has a large set of functions which provide a flexible graphical environment for creating various kinds of data presentations.

References

- **For R**,
  - The basic reference is The New S Language: A Programming Environment for Data Analysis and Graphics by Richard A. Becker, John M. Chambers and Allan R. Wilks (the "Blue Book") .
  - The new features of the 1991 release of S (S version 3) are covered in Statistical Models in S edited by John M. Chambers and Trevor J. Hastie (the "White Book").
  - Classical and modern statistical techniques have been implemented.
    - Some of these are built into the base R environment.
    - Many are supplied as packages. There are about 8 packages supplied with R (called "standard" packages) and many more are available through the cran family of Internet sites (via http://cran.r-project.org).
- All the R functions have been documented in the form of help pages in an "output independent" form which can be used to create versions for HTML, LATEX, text etc.
  - The document "An Introduction to R" provides a more user-friendly starting point.

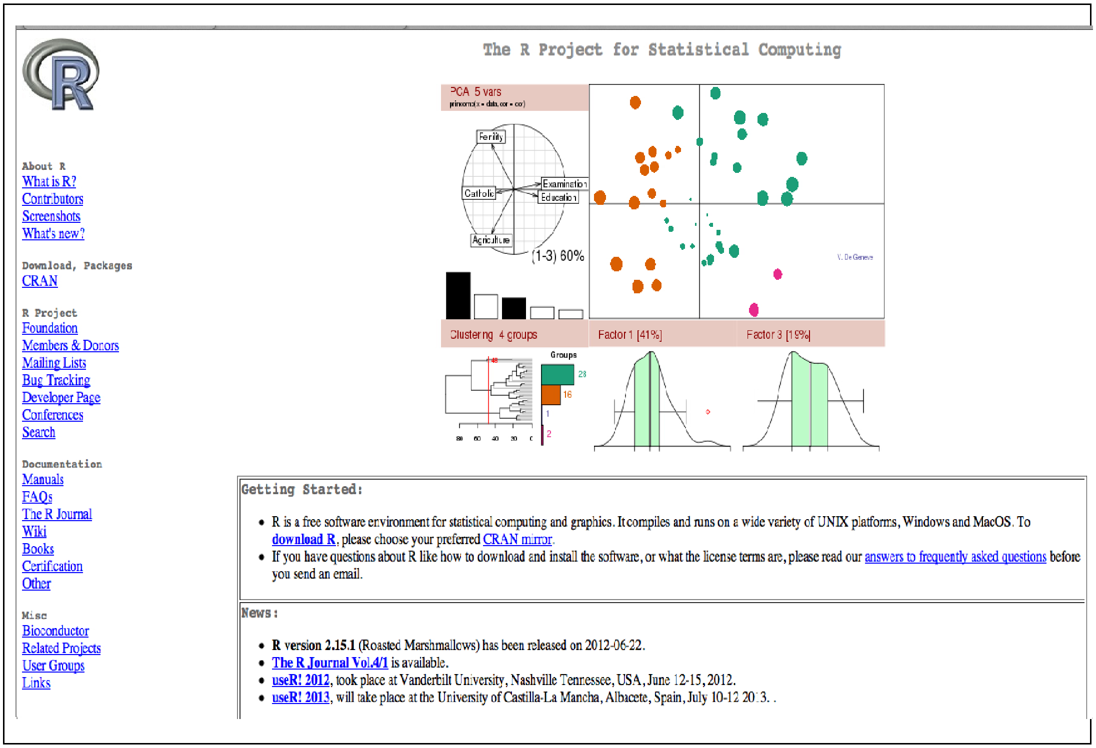
– An "R Language Definition" manual

– More specialized manuals on data import/export and extending R.

R installations

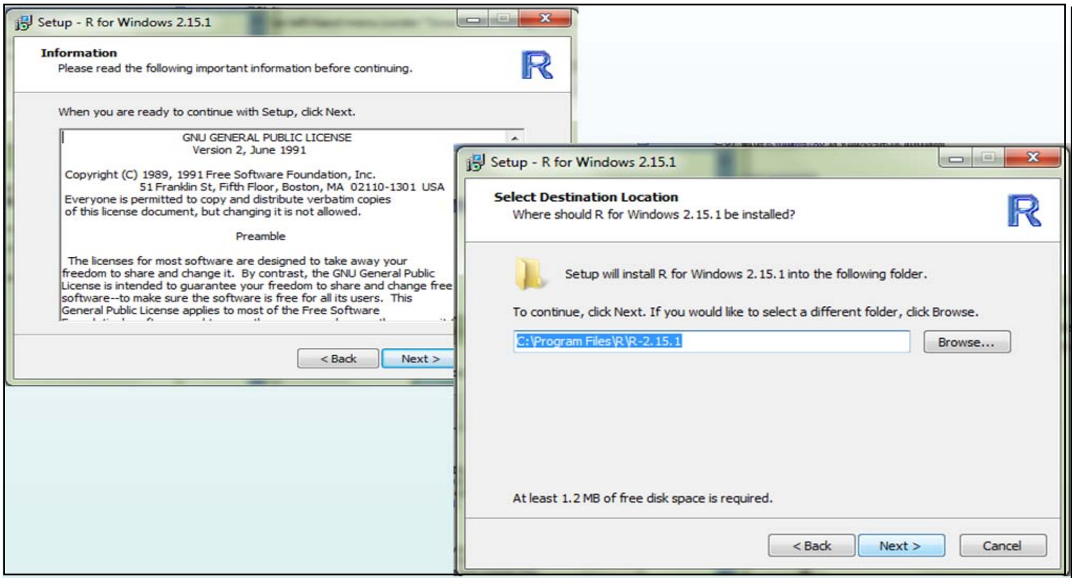
Getting Started

To install R on your MAC or PC the starting point has to behttp://www.r-project.org/.



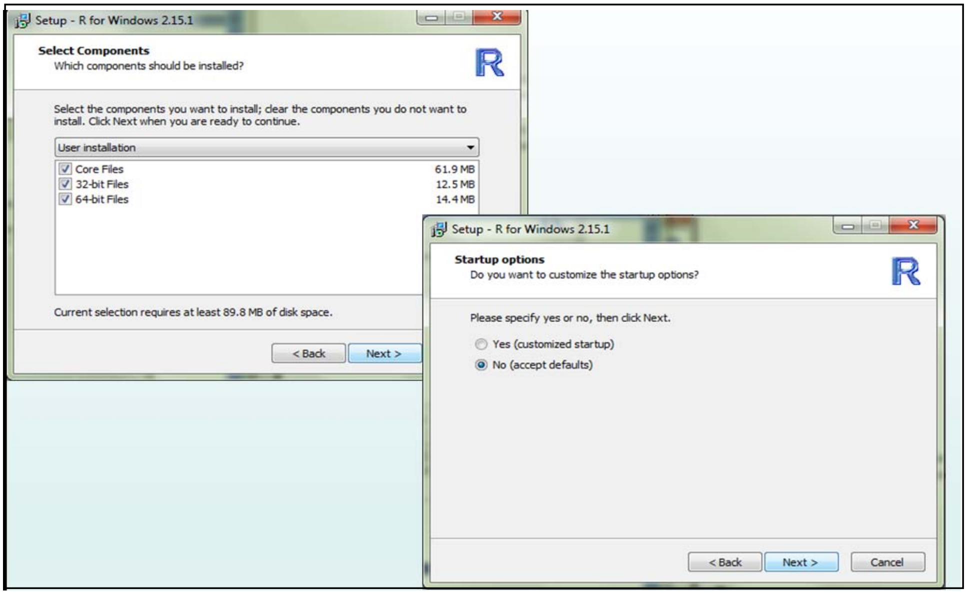
Depending on the choice of operating system the installer/ zip file with checksum may be downloaded and verified.

An effort to download R for Windows would have the following sequence of interactions with the portal, whose snapshots are given below:

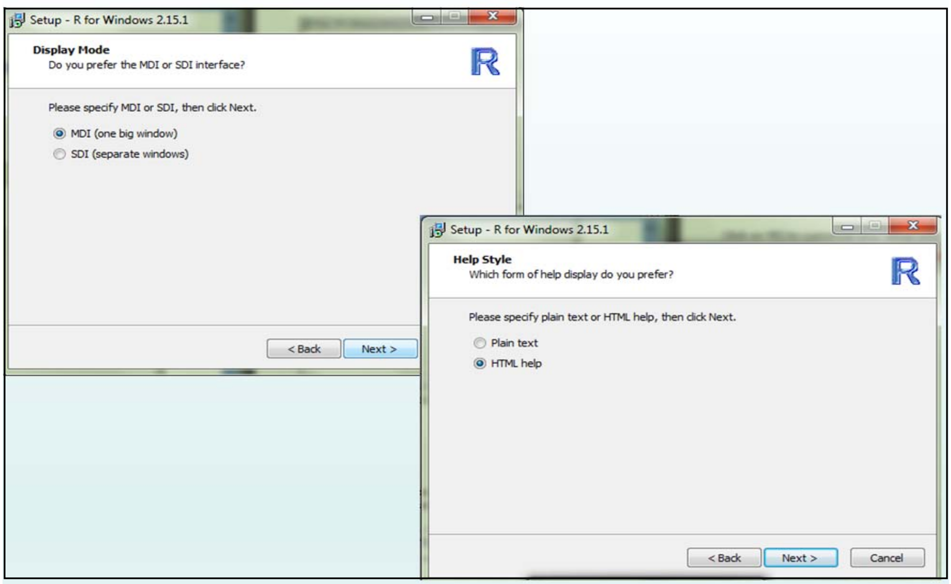

Setup - R for Windows 2.15.1
Information
Please read the following important information before continuing.
When you are ready to continue with Setup, click Next.
GNU GENERAL PUBLIC LICENSE
Version 2, June 1991
Copyright (C) 1989, 1991 Free Software Foundation, Inc.
51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA
Everyone is permitted to copy and distribute verbatim copies
of this license document, but changing it is not allowed.
Preamble
The licenses for most software are designed to take away your
freedom to share and change it. By contrast, the GNU General Public
License is intended to guarantee your freedom to share and change free
software--to make sure the software is free for all its users. This
General Public License applies to most of the Free Software
< Back
Next >
Setup - R for Windows 2.15.1
Select Destination Location
Where should R for Windows 2.15.1 be installed?
Setup will install R for Windows 2.15.1 into the following folder.
To continue, click Next. If you would like to select a different folder, click Browse.
C:\Program Files\R\R-2.15.1
Browse...
At least 1.2 MB of free disk space is required.
< Back
Next >
Cancel


The Comprehensive R Archive Network
Download and Install R
Precompiled binary distributions of the base system and contributed packages, Windows and Mac users most likely want one of these versions of R:
Download R for Linux
Download R for MacOS X
Download R for Windows
R is part of many Linux distributions, you should check with your Linux package management system in addition to the link above.
Source Code for all Platforms
Questions About R
R-2.15.1 for Windows (32/64 bit)
Download R 2.15.1 for Windows
Installation and other instructions
New features in this version
Frequently asked questions
Other builds
Last change: 2012-06-22, by Duncan Murdoch

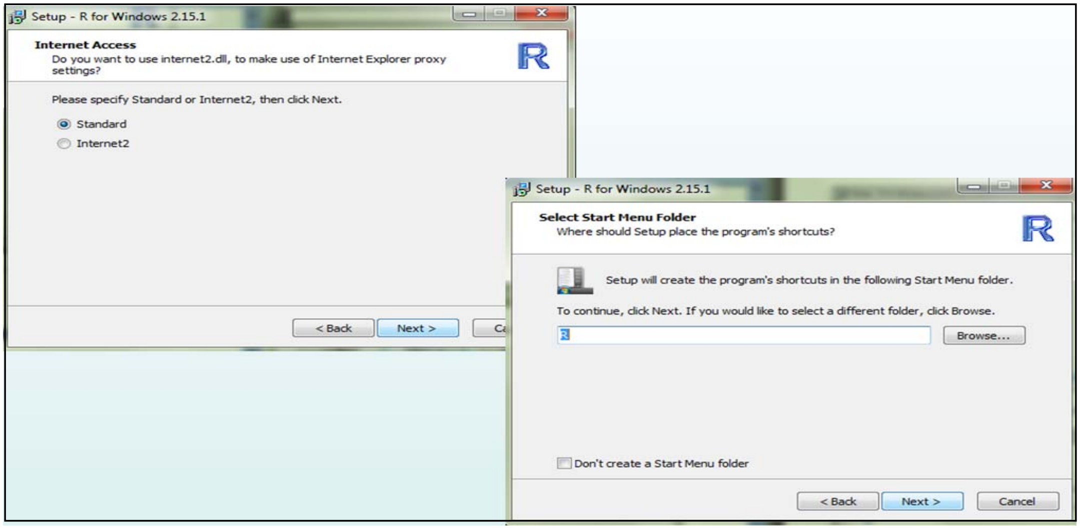
It's always a good idea to download all the files.

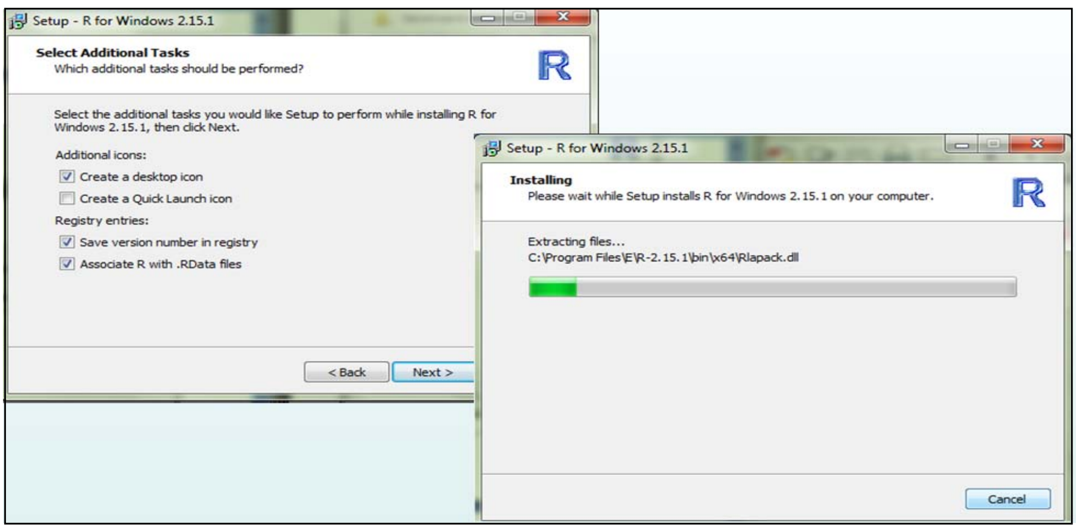


MDI is when the windows will be contained within one large window.



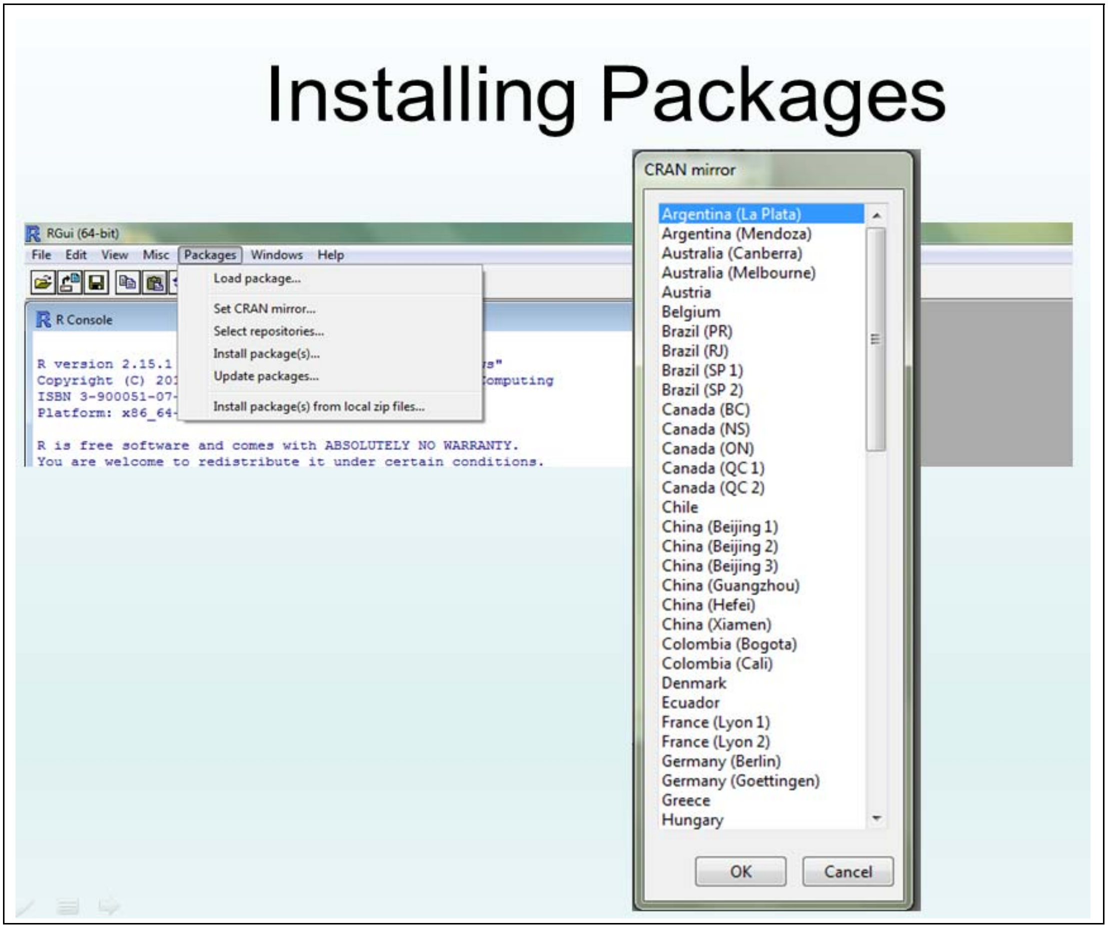
This is similar to how Excel is setup. SDI is a single document interface where every item will get its own window. This is similar to how SPSS is set up where it has separate data editor, viewer, and syntax windows. Once you choose which your prefer click next.Choosing either html or plain text and clicking is the next step.The installation may take awhile





To install packages on Windows, clicking on packages and install packages will be the next step.

Scrolling down to country nearest and choosing a "mirror" that is close is the next step

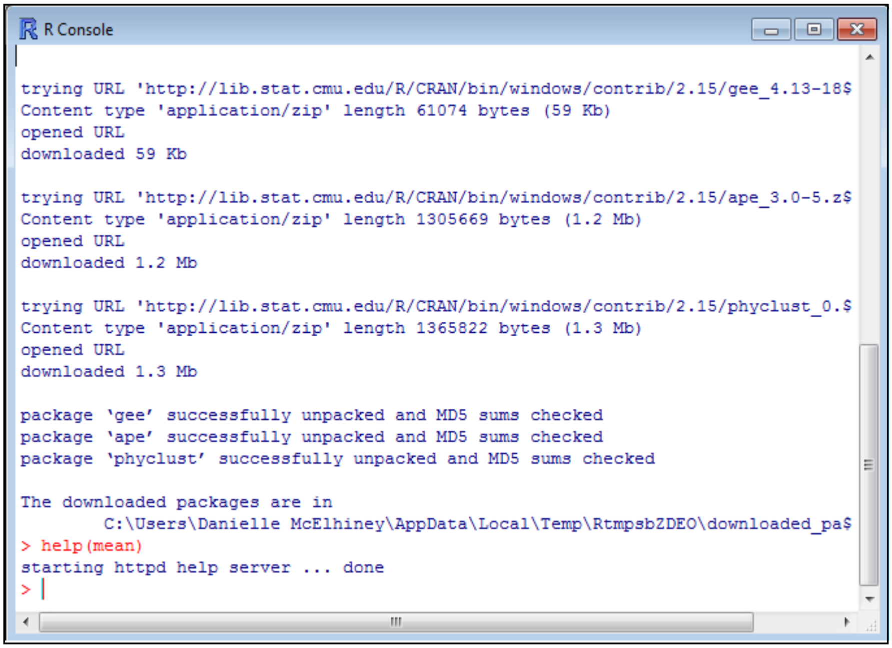


Scrolling down list until the requisite package is the next step, keeping in mind that R lists things in alphabetical order and by uppercase than lowercase. Once a package is clicked to load, R will install not only the package but all of the packages needed to run the package, including the dependencies.

To actually use the package, one has to go back to the package tab and click on load package.

Using Help Command

?solve translates on to giving details of help information about "solve" function whilst help.search or ?? allows searching for help in various ways

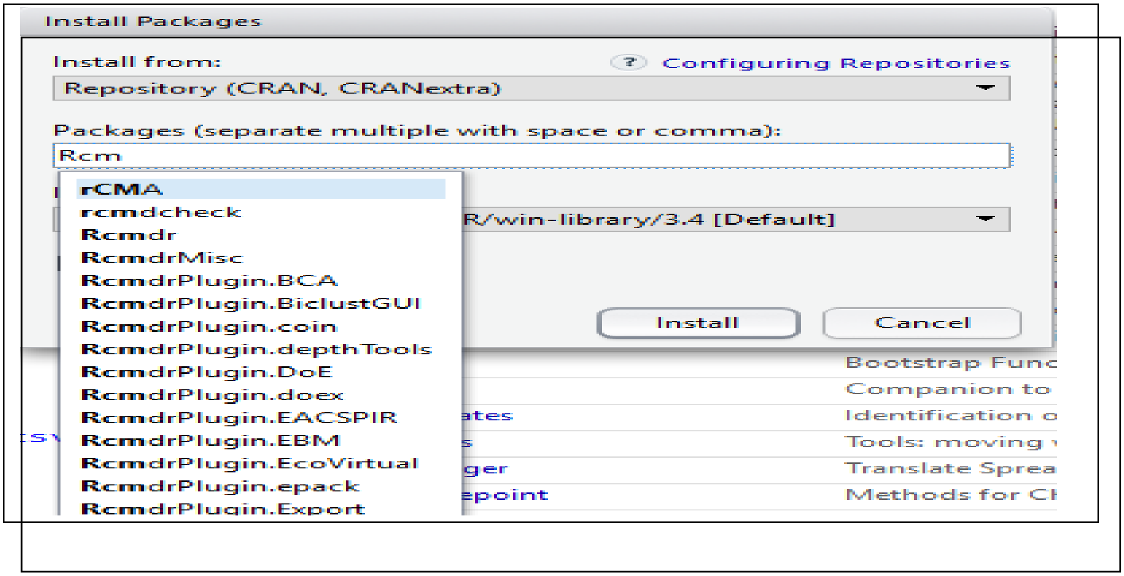


Rcommander – A graphical interaction "skin" for R

R provides a powerful and comprehensive system for analysing data and when used in conjunction with the R-commander (a graphical user interface, commonly known as Rcmdr) it also provides one that is easy and intuitive to use. Basically, R provides the engine that carries out the analyses and Rcmdr provides a convenient way for users to input commands. The Rcmdr program enables analysts to access a selection of commonly-used R commands using a simple interface that should be familiar to most computer users. It also serves the important role of helping users to implement R commands and develop their knowledge and expertise in using the command line --- an important skill for those wishing to exploit the full power of the program.(http://www.rcommander.com/)

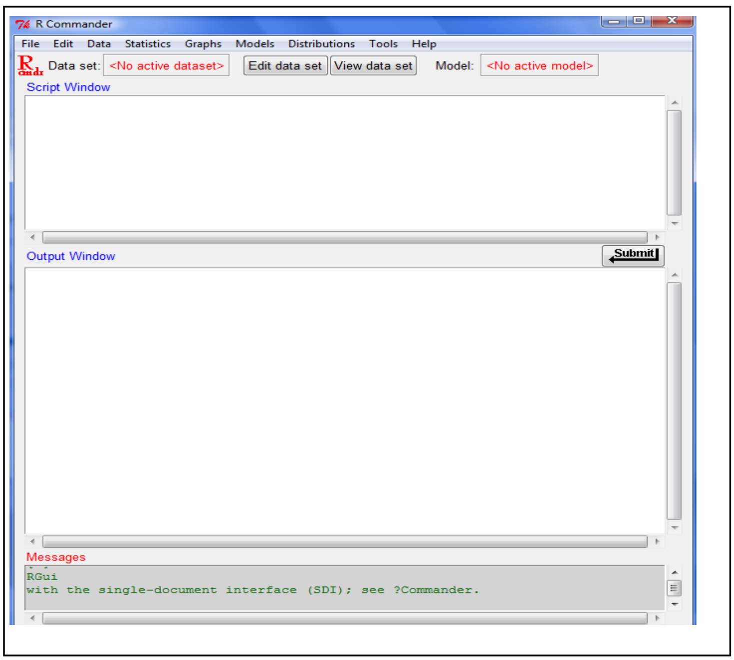
a) Loading R Commander

– Packages -> Install Packages -> Cran Mirror Selection -> Rcmdr



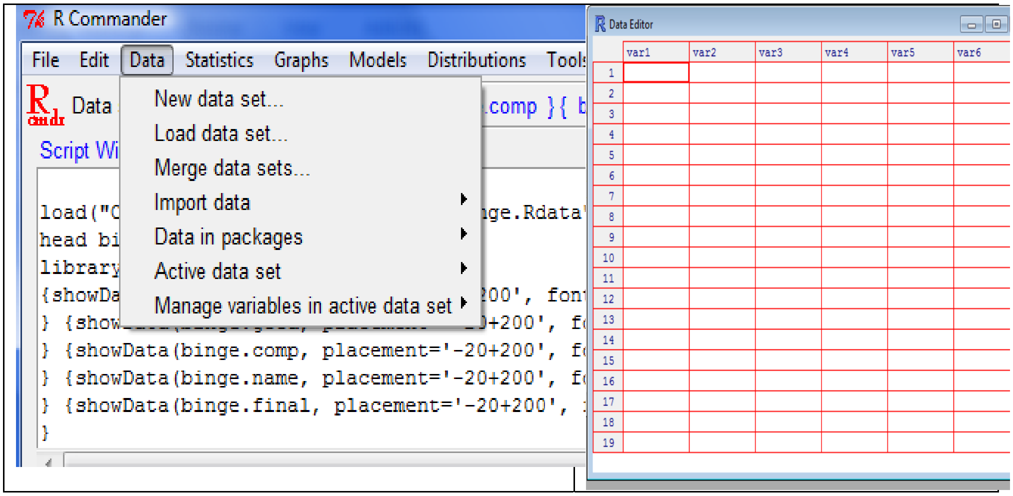
b) Opening R Commander

Open R -> Packages -> Load Packages -> Rcmdr



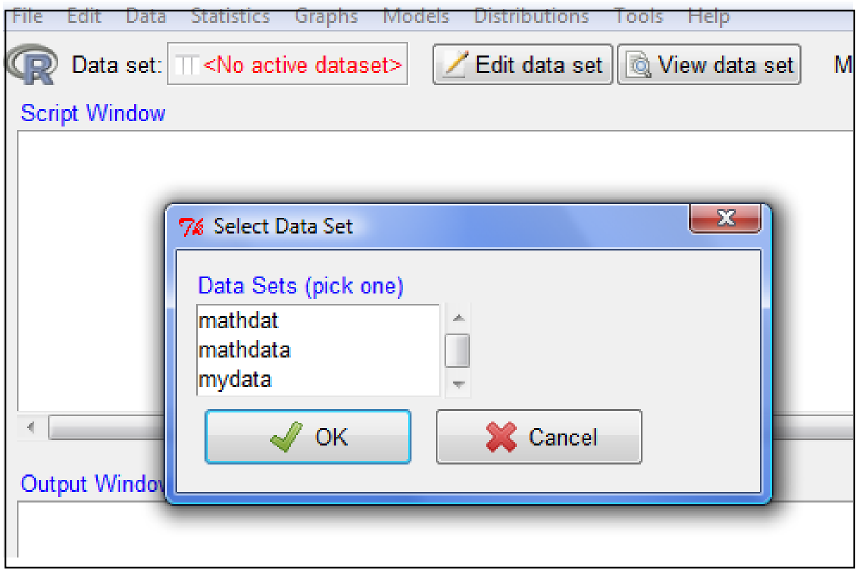
c) Loading Data

Data->Load data

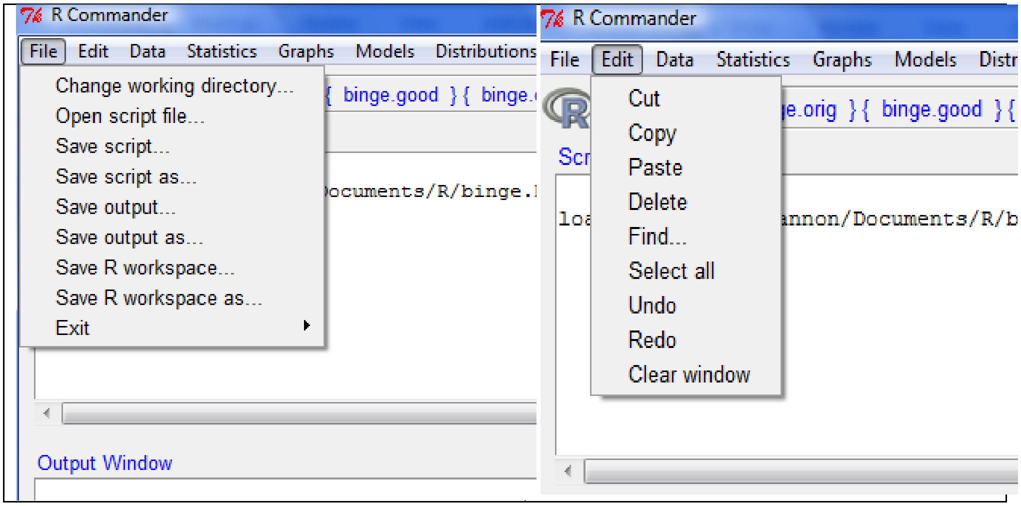


d) Active Data selection

Data ->Active data set -> Select active data set



e) Menu driven File edit options

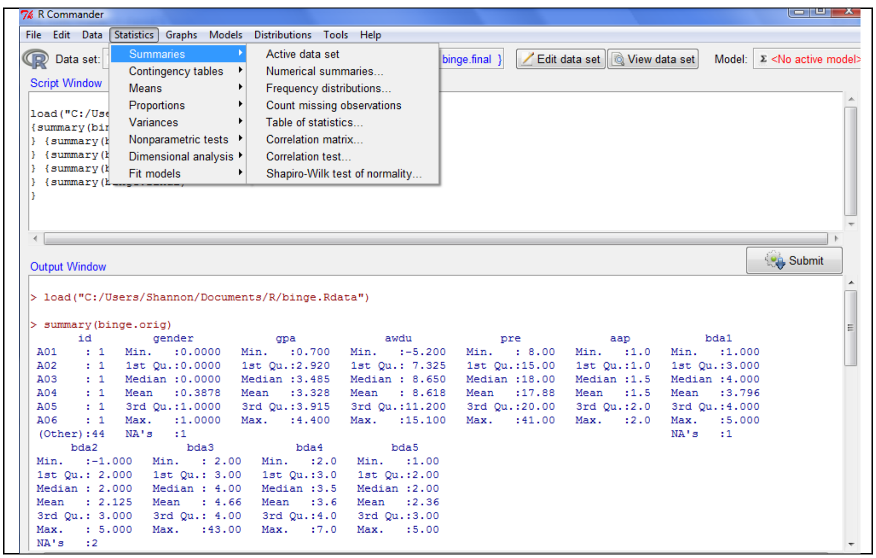


Script will save it as an R file .R and Output will save it as a text file. .txt

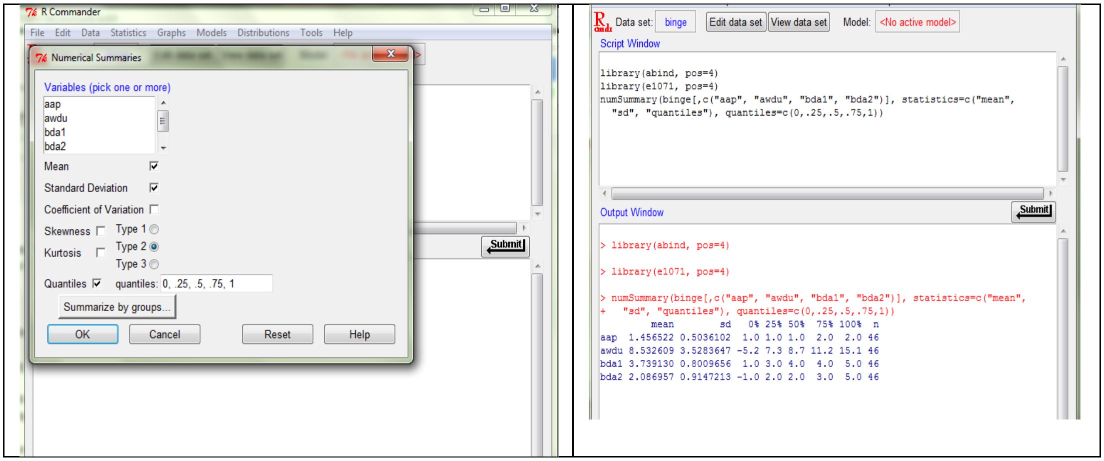
f) Summary of the data

Statistics -> Summaries

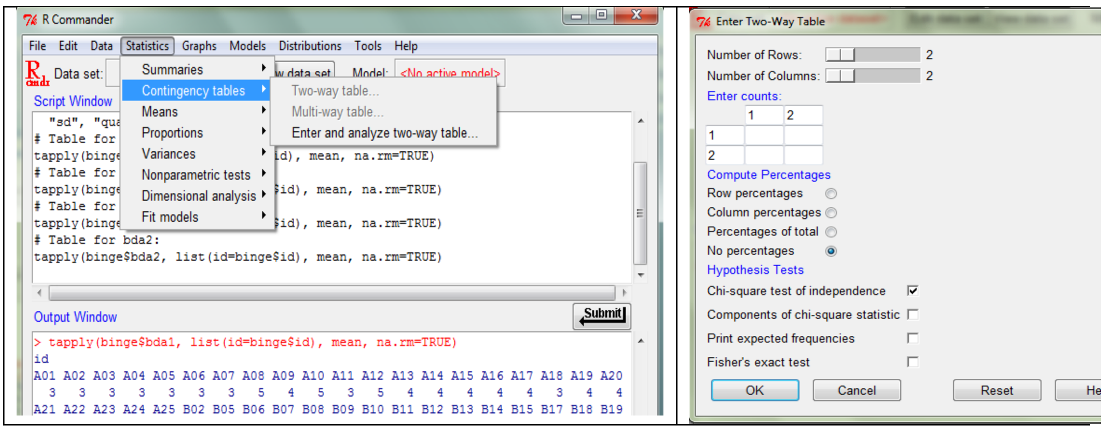
Numerical Summaries – can also provide mean, standard deviation, skewness, kurtosis etc..



g) Mean, Standard Deviation, Skewness, Kurtosis



h) Contingency Tables

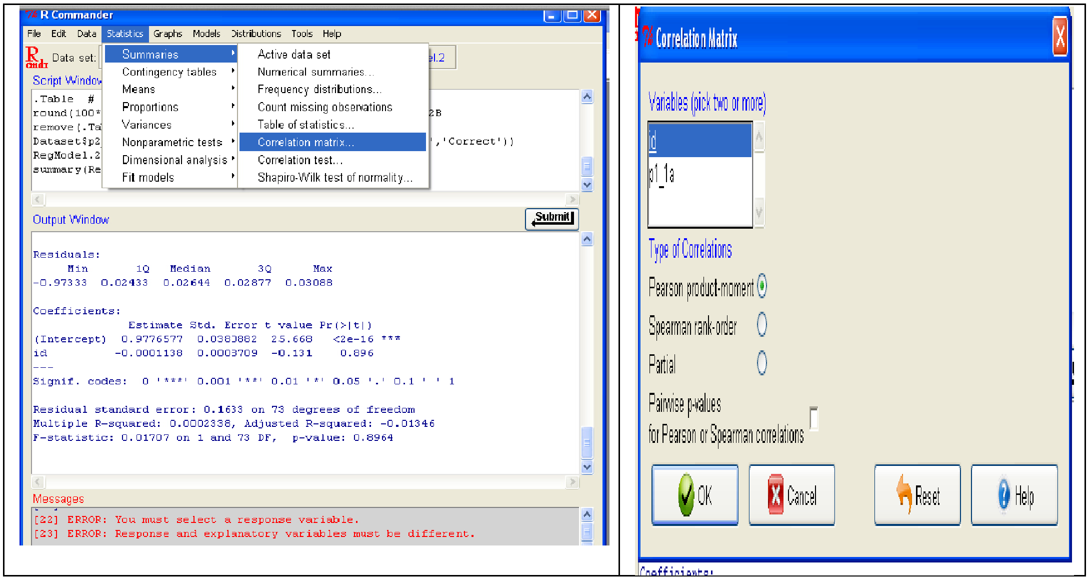


i) Correlations in R Commander

Correlation analysis can be done with R as follows.

Correlation is a bivariate analysis that measures the strengths of association between two variables and the direction of the relationship. In terms of the strength of relationship, the value of the correlation coefficient varies between +1 and -1. When the value of the correlation coefficient lies around ± 1, then it is said to be a perfect degree of association between the two variables. As the correlation coefficient value goes towards 0, the relationship between the two variables will be weaker. the direction of the relationship is simply the + (indicating a positive relationship between the variables) or - (indicating a negative relationship between the variables) sign of the correlation.

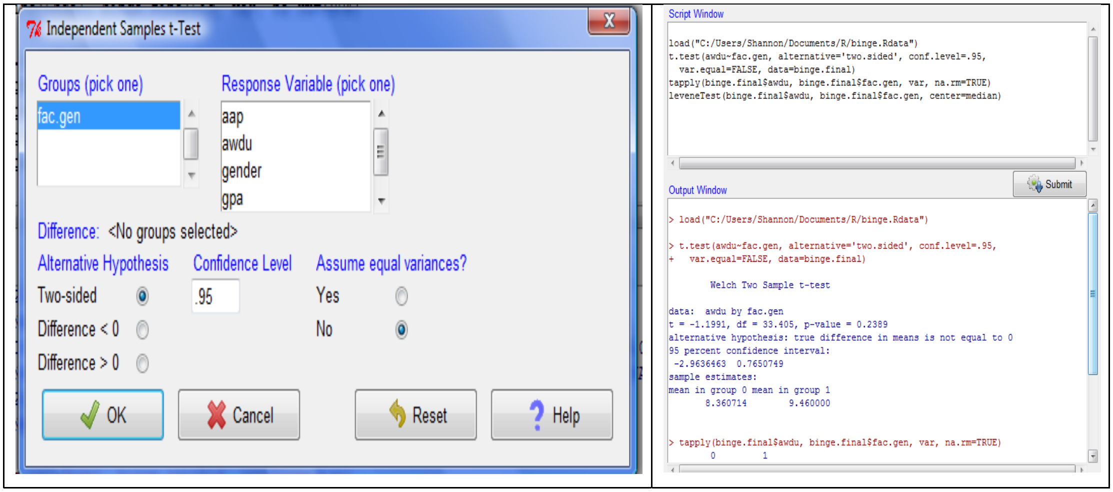
Usually, in statistics, we measure four types of correlations: Pearson Correlation,Kendall rank correlation, Spearman correlation, and the Point-Biserial correlation. The software below allows you to very easily conduct a correlation.



j) Independent T-Test

The independent t-test, also referred to as an independent-samples t-test, independent measures t-test or unpaired t-test, is used to determine whether the mean of a dependent variable (e.g., weight, anxiety level, salary, reaction time, etc.) is the same in two unrelated, independent groups (e.g., males vs females, employed vs unemployed, under 21 year olds vs those 21 years and older, etc.). Specifically, you use an independent t-test to determine whether the mean difference between two groups is statistically significantly different to zero.

Statistics->Independent T Test



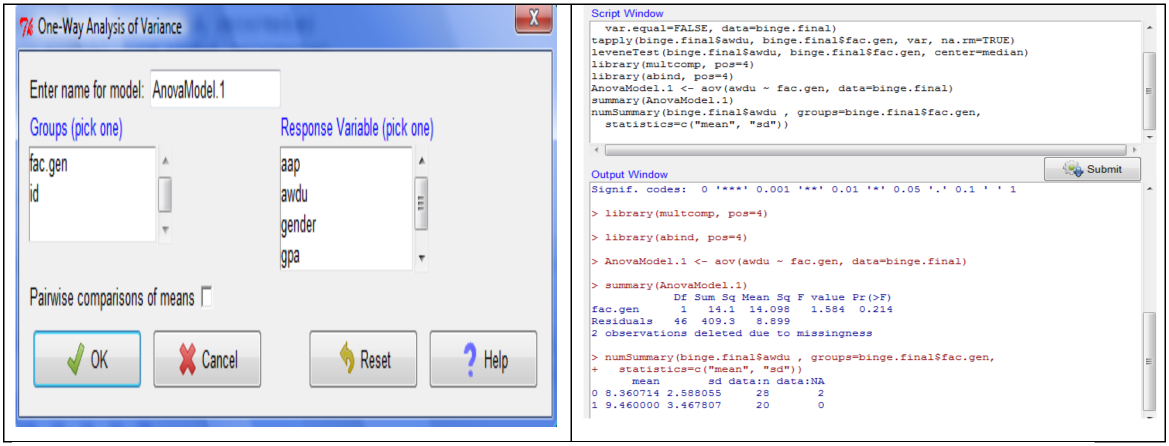
k) One Way ANOVA

ANOVA(Analysis of Variance) is a statistical technique that assesses potential differences in a scale-level dependent variable by a nominal-level variable having 2 or more categories. For example, an ANOVA can examine potential differences in IQ scores by Country (US vs. Canada vs. Italy vs. Spain). The ANOVA, developed by Ronald Fisher in 1918, extends the *t* and the *z* test which have the problem of only allowing the nominal level variable to have just two categories. This test is also called the Fisher analysis of variance.ANOVAs are used in three ways: one –way Anova, two-way ANOVA, and N-way Multivariate ANOVA.

One-Way ANOVA

A one-way ANOVA refers to the number of independent variables--not the number of categories in each variables. A one-way ANOVA has just one independent variable. For example, difference in IQ can be assessed by Country, and County can have 2, 20, or more different Countries in that variable. The software below allows you to easily conduct an ANOVA.

Statistics->One Way ANOVA



I) Factor Analysis

Factor analysis is a technique that is used to reduce a large number of variables into fewer numbers of factors. This technique extracts maximum common variance from all variables and puts them into a common score. As an index of all variables, we can use this score for further analysis. Factor analysis is part of general linear model(GLM) and this method also assumes several assumptions: there is linear relationship, there is no multicollinearity, it includes relevant variables into analysis, and there is true correlation between variables and factors. Several methods are available, but principle component analysis is used most commonly.

Types of factoring:

There are different types of methods used to extract the factor from the data set:

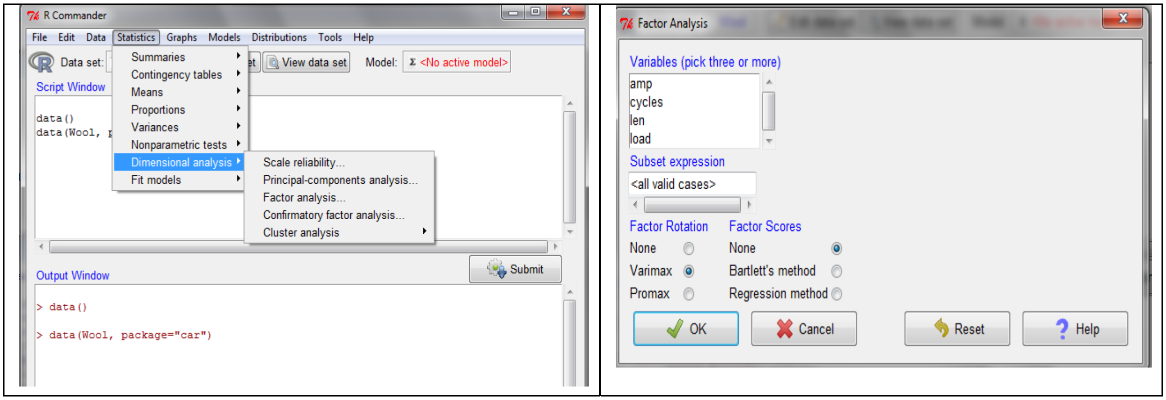
1.**Principal component analysis**: This is the most common method used by researchers. PCA starts extracting the maximum variance and puts them into the first factor. After that, it removes that variance explained by the first factors and then starts extracting maximum variance for the second factor. This process goes to the last factor.

2. **Common factor analysis:** The second most preferred method by researchers, it extracts the common variance and puts them into factors. This method does not include the unique variance of all variables. This method is used in SEM.

3. **Image factoring:** This method is based on correlation matrix. OLS Regression method is used to predict the factor in image factoring.

4. **Maximum likelihood method:** This method also works on correlation metric but it uses maximum likelihood method to factor.

5. **Other methods of factor analysis:** Alfa factoring outweighs least squares. Weight square is another regression based method which is used for factoring.

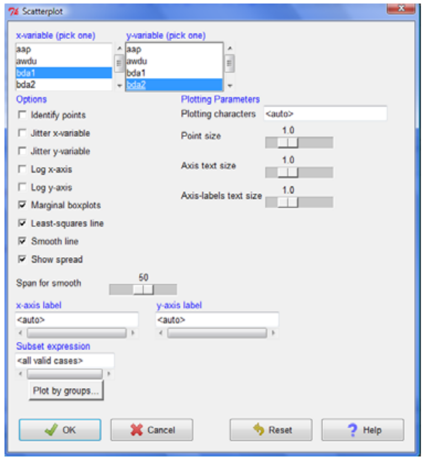


Result are shown as follows

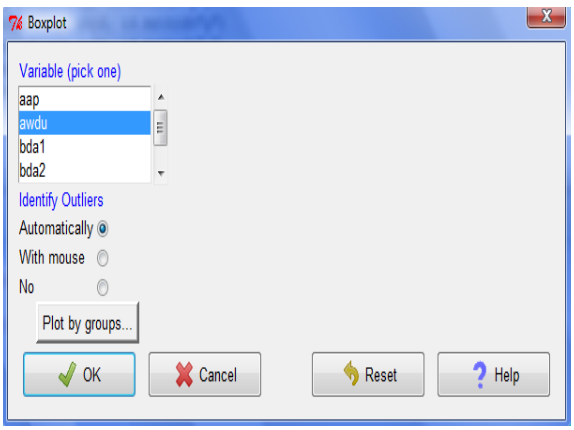
```
Script Window
.FA <- factanal(~aap+awdu+bda1, factors=1, rotation="varimax",
  scores="none", data=binge.orig)
.FA
remove(.FA)
library(sem, pos=4)

> .FA <- factanal(~aap+awdu+bda1, factors=1, rotation="varimax",
+   scores="none", data=binge.orig)

> .FA

Call:
factanal(x = ~aap + awdu + bda1, factors = 1, data = binge.orig,     scores = "none", rotation = "varimax")

Uniquenesses:
  aap  awdu  bda1
0.849 0.324 0.596

Loadings:
     Factor1
aap  0.388
awdu 0.822
bda1 0.636

               Factor1
SS loadings      1.231
Proportion Var   0.410

The degrees of freedom for the model is 0 and the fit was 0

> remove(.FA)

> library(sem, pos=4)
```

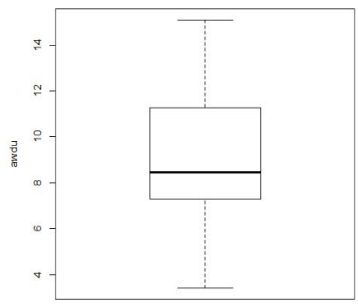
J) Graphs

Graphs->Scatter plot



Graphs->Box plot





Chapter4:-R Basics

R is object base

Types of objects (scalar, vector, matrices and arrays Assignment of objects)

Building a data frame

Operation Symbols

Symbol	Meaning
+	Addition
-	Subtraction
*	Multiplication
/	Division
%%	**Modulo (estimates remainder in a division)**
^	Exponential

R as a Calculator

```
1550+2000

## [1] 3550
```

or various calculations in the same row

```
2+3; 5*9; 6-6

## [1] 5

## [1] 45

## [1] 0
```

AsMathematics

```
1+1

## [1] 2

2+2*7

## [1] 16

(2+2)*7

## [1] 28
```

AsVariables

```
x<-2
x
```

```
## [1] 2

y<-3
y

## [1] 3

5->z

(x*y)+z

## [1] 11
```

Numbers in R: NAN and NA

NAN (not a number) NA (missing value) -Basic handling of missing values

Missing values are noise to statistical estimations. We are going to learn a basic command for handling missing values.

```
x<-c(1,2,3,4,5,6,NA)
mean(x)

## [1] NA

mean(x,na.rm=TRUE)

## [1] 3.5
```

Objects in R

Objects in R obtain values by assignment.
This is achieved by the gets arrow, <-, and not the equal sign, =.
Objects can be of different kinds.

Built in Functions

R has many built in functions that compute different statistical procedures.

Functions in R are followed by ( ). Inside the parenthesis we write the object (vector, matrix, array, dataframe) to which we want to apply the function.

```
# Create a sequence of numbers from 32 to 44.
print(seq(32,44))

##  [1] 32 33 34 35 36 37 38 39 40 41 42 43 44

# Find mean of numbers from 25 to 82.
print(mean(25:82))
```

```
## [1] 53.5
# Find sum of numbers frm 41 to 68.

print(sum(41:68))
## [1] 1526
```

Vectors

Vectors are variables with one or more values of the same type. A variable with a single value is known as scalar. In R a scalar is a vector of length 1. There are at least three ways to create vectors in R: (a) sequence, (b) concatenation function, and (c) scan function.

Create two vectors of different lengths.

```
vector1 <-c(5,9,3)
vector2 <-c(10,11,12,13,14,15)
vector1
## [1] 5 9 3
vector2
## [1] 10 11 12 13 14 15
```

Arrays

Arrays are numeric objects with dimension attributes. The difference between a matrix and an array is that arrays have more than two dimensions.

```
# Take the above  vectors as input to the array.
result <-array(c(vector1,vector2),dim =c(3,3,2))
print(result)
## , , 1
##
##      [,1] [,2] [,3]
## [1,]    5   10   13
## [2,]    9   11   14
## [3,]    3   12   15
##
## , , 2
##
##      [,1] [,2] [,3]
## [1,]    5   10   13
## [2,]    9   11   14
## [3,]    3   12   15
```

Matrices

A matrix is a two dimensional array. The command colnames

```
# Elements are arranged sequentially by row.
M <-matrix(c(3:14), nrow =4, byrow =TRUE)
print(M)

##      [,1] [,2] [,3]
## [1,]    3    4    5
## [2,]    6    7    8
## [3,]    9   10   11
## [4,]   12   13   14
```

String Characters

In R, string variables are defined by double quotation marks.

```
letters<-c("a","b","c")
letters

## [1] "a" "b" "c"
```

Subscripts and Indices

Select only one or some of the elements in a vector, a matrix or an array. We can do this by using subscripts in square brackets [ ].
In matrices or dataframes the first subscript refers to the row and the second to the column.

Dataframe

Researchers work mostly with dataframes . With previous knowledge you can built dataframes in R Also, import dataframes into R.

```
# Create the data frame.
emp.data <-data.frame(
emp_id =c (1:5),
emp_name =c("Rick","Dan","Michelle","Ryan","Gary"),
salary =c(623.3,515.2,611.0,729.0,843.25),

start_date =as.Date(c("2012-01-01", "2013-09-23", "2014-11-15", "2014-05-11",
"2015-03-27")),
stringsAsFactors =FALSE
)
```

```
# Print the data frame.
print(emp.data)

##   emp_id emp_name salary start_date
## 1      1     Rick 623.30 2012-01-01
## 2      2      Dan 515.20 2013-09-23
## 3      3 Michelle 611.00 2014-11-15
## 4      4     Ryan 729.00 2014-05-11
## 5      5     Gary 843.25 2015-03-27
```

A journey wading through the amazing summarizing and analytical capabilities of R- a case study.

Let the presumed data pertain to landings and standardized effort of a maritime state estimated by ICAR-CMFRIduring the interregnum 1997 to 2013

Calling file in R

```
klm<-read.csv("C:/Users/cmfri/Desktop/cpue_spcode_kldata.csv",header=TRUE)
```

To know header portion of the data set

```
head(klm)

##   year month species    raised   nomeff   stdcpue
## 1 1997     1      40  20595.35 122.0811  3.634042
## 2 1997     2      40  24201.10 114.3719  4.532246
## 3 1997     3      40  23497.64 255.0315  3.926130
## 4 1997     4      40  50176.75 154.7663  6.762821
## 5 1997     5      40 137626.24 314.6413 13.805531
## 6 1997     6      40  38149.38 649.1328 16.071358
```

To check the last few rows of the dataset

```
tail(klm)

##        year month species raised   nomeff  stdcpue
## 245815 2013     7    4580      0 0.000000 0.000000
## 245816 2013     8    4580   1674 2.059835 1.667304
## 245817 2013     9    4580      0 0.000000 0.000000
## 245818 2013    10    4580      0 0.000000 0.000000
## 245819 2013    11    4580      0 0.000000 0.000000
## 245820 2013    12    4580      0 0.000000 0.000000
```

to know the observations in the data

```
length(klm)
```

```
## [1] 6
```

to know the structure of the dataframe

```
str(klm)
## 'data.frame':    245820 obs. of  6 variables:
##  $ year   : int  1997 1997 1997 1997 1997 1997 1997 1997 1997 1997 ...
##  $ month  : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ species: int  40 40 40 40 40 40 40 40 40 40 ...
##  $ raised : num  20595 24201 23498 50177 137626 ...
##  $ nomeff : num  122 114 255 155 315 ...
##  $ stdcpue: num  3.63 4.53 3.93 6.76 13.81 ...
```

Descriptive statistics analysis

```
summary(klm)
##       year          month          species         raised
##  Min.   :1997   Min.   : 1.00   Min.   :   0   Min.   :       0
##  1st Qu.:2001   1st Qu.: 3.75   1st Qu.: 867   1st Qu.:       0
##  Median :2005   Median : 6.50   Median :1513   Median :       0
##  Mean   :2005   Mean   : 6.50   Mean   :2201   Mean   :   42699
##  3rd Qu.:2009   3rd Qu.: 9.25   3rd Qu.:4016   3rd Qu.:       0
##  Max.   :2013   Max.   :12.00   Max.   :9999   Max.   :71536031
##                                                NA's   :30
##      nomeff            stdcpue
##  Min.   :     0.0   Min.   :   0.000
##  1st Qu.:     0.0   1st Qu.:   0.000
##  Median :     0.0   Median :   0.000
##  Mean   :   154.2   Mean   :   7.112
##  3rd Qu.:     0.0   3rd Qu.:   0.000
##  Max.   :119100.1   Max.   :5600.000
##
```

If further enhanced list of summary statistics information about the data like third and fourth order moments, then the describe function of psych or summary function would come in handy.

```
library(psych)
describe(klm[,3:6])

##         vars      n     mean        sd median trimmed     mad min
## species    1 245820  2201.15   1951.83   1513 1941.16 1257.24   0
## raised     2 245790 42699.02 719150.48      0   62.52    0.00   0
## nomeff     3 245820   154.25   1543.66      0    0.16    0.00   0
## stdcpue    4 245820     7.11     52.38      0    0.11    0.00   0
##                max      range  skew kurtosis      se
## species     9999.0     9999.0  1.40     1.91    3.94
## raised  71536030.7 71536030.7 44.70  2681.18 1450.57
```

```
## nomeff    119100.1   119100.1 22.83   770.70     3.11
## stdcpue     5600.0     5600.0 21.65   971.06     0.11
```

If one wants to study monthly catch grouped information so that an idea about issues like which month (used as a group) would have etched up maximum landings/ catch, then simple literally rooted commands like describeBy (psych) or aggregate would come in handy.

```
library(psych)
describeBy(klm$raised,klm$month)

##
##  Descriptive statistics by group
## group: 1
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20485 41379.48 784622.6      0  146.65   0   0 51193526 51193526
##     skew kurtosis      se
## X1 46.55  2497.42 5482.05
## --------------------------------------------------------
## group: 2
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20485 32904.06 535506.3      0  113.45   0   0 45468199 45468199
##     skew kurtosis      se
## X1 49.62  3259.68 3741.51
## --------------------------------------------------------
## group: 3
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20485 39087.37 569052.1      0  162.51   0   0 31762665 31762665
##    skew kurtosis      se
## X1 38.4  1796.15 3975.89
## --------------------------------------------------------
## group: 4
##    vars     n     mean     sd median trimmed mad min      max    range
## X1    1 20471 33795.18 477389      0   64.13   0   0 31931384 31931384
##     skew kurtosis      se
## X1 42.59  2353.01 3336.59
## --------------------------------------------------------
## group: 5
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20485 37566.67 469275.5      0    96.2   0   0 30492626 30492626
##     skew kurtosis      se
## X1 33.18  1478.99 3278.76
## --------------------------------------------------------
## group: 6
```

```
##    vars     n    mean       sd median trimmed mad min      max    range
## X1    1 20485 34552.2 655525.6      0   30.67   0   0 65432961 65432961
##     skew kurtosis      se
## X1 61.23  5239.89 4580.07
## --------------------------------------------------------
## group: 7
##    vars     n    mean       sd median trimmed mad min      max    range
## X1    1 20485 32621.2 643003.1      0       0   0   0 49428947 49428947
##     skew kurtosis      se
## X1 42.19  2362.03 4492.57
## --------------------------------------------------------
## group: 8
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20484 57397.86 713381.8      0   31.03   0   0 38795185 38795185
##     skew kurtosis      se
## X1 26.21   920.16 4984.42
## --------------------------------------------------------
## group: 9
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20485 55833.65 901880.9      0    34.3   0   0 71536031 71536031
##     skew kurtosis      se
## X1 41.11  2415.63 6301.32
## --------------------------------------------------------
## group: 10
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20484 57071.88 915432.9      0   89.05   0   0 55973676 55973676
##     skew kurtosis      se
## X1 34.05  1453.38 6396.16
## --------------------------------------------------------
## group: 11
##    vars     n     mean     sd median trimmed mad min      max    range
## X1    1 20485 51210.52 915220      0  133.56   0   0 49127745 49127745
##     skew kurtosis      se
## X1 36.33  1488.92 6394.51
## --------------------------------------------------------
## group: 12
##    vars     n     mean       sd median trimmed mad min      max    range
## X1    1 20471 38960.92 830555.4      0  134.37   0   0 66844967 66844967
##    skew kurtosis      se
## X1   56  3639.25 5804.96
```

Selecting subsets of data:

```
#to know the whole species entries
t<-klm$species
length(t)

## [1] 245820

# to know the june species entries
d<-klm$species[klm$month=="6"]
length(d)

## [1] 20485
```

to exclude some data

```
#exclude june catch and know the entries
e<-klm$species[klm$month!="6"]
length(e)

## [1] 225335
```

correlation of the data

```
# correlation between catch and effort for the whole period
attach(klm)
cor.test(raised,nomeff,method="pearson")

##
##  Pearson's product-moment correlation
##
## data:  raised and nomeff
## t = 434.94, df = 245790, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.6572472 0.6617152
## sample estimates:
##       cor
## 0.659487
```

##multiple correlation

```
##Here we select the oilsardine catch.
The oil sardine species code as 362
##we pick all the years monthly  oil sardine
sp362<-klm[(klm$species=="362"),]
cordat<-sp362[,4:6]
cor(cordat)
```

```
raised     nomeff     stdcpue
raised  1.0000000 0.45713639 0.61135090
nomeff  0.4571364 1.00000000 0.06860281
stdcpue 0.6113509 0.06860281 1.00000000
```

Linear regression & ANOVA

```
fit <-lm(raised~year +month +nomeff, data=sp362)

# show results
summary(fit)

##
## Call:
## lm(formula = raised ~ year + month + nomeff, data = sp362)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -24406856  -5945766   -838374   4725596  40857882
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.148e+09  2.787e+08  -7.706 5.93e-13 ***
## year         1.072e+06  1.389e+05   7.716 5.59e-13 ***
## month        7.997e+05  1.969e+05   4.062 6.97e-05 ***
## nomeff       3.997e+02  4.493e+01   8.897 3.44e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9689000 on 200 degrees of freedom
## Multiple R-squared:  0.4275, Adjusted R-squared:  0.4189
## F-statistic: 49.78 on 3 and 200 DF,  p-value: < 2.2e-16

# model coefficients
coefficients(fit)

##   (Intercept)          year         month        nomeff
## -2.147604e+09  1.072090e+06  7.997178e+05  3.997276e+02

# CIs for model parameters
confint(fit, level=0.95)

##                     2.5 %        97.5 %
## (Intercept) -2.697162e+09 -1.598046e+09
## year         7.980987e+05  1.346082e+06
## month        4.115344e+05  1.187901e+06
## nomeff       3.111348e+02  4.883205e+02
```

```
# predicted values
fitted(fit)

##       10609       10610       10611       10612       10613       10614 
## -3789651.96   -75345.54 15111313.36 13412874.31 17168949.26   120681.70 
##       10615       10616       10617       10618       10619       10620 
## 11475956.42  2176177.37  4491241.24 20281254.70 10248865.43  6278101.08 
##       10621       10622       10623       10624       10625       10626 
## -1848628.97  -945019.58 10648970.16 18599757.89  1915100.95  4945529.10 
##       10627       10628       10629       10630       10631       10632 
##  1844457.32  4524979.63  8480021.57 27270345.64 26410785.24  7449598.25 
##       10633       10634       10635       10636       10637       10638 
##  8195286.59 18056830.84 12504031.29  4797286.88   690139.61  7333241.94 
##       10639       10640       10641       10642       10643       10644 
##  9086615.20 12777192.22 16114211.77 21825496.12 23957847.88 30125417.82 
##       10645       10646       10647       10648       10649       10650 
## 16794955.21  8159428.15 18423291.70 38539644.49 22526843.37 15428828.71 
##       10651       10652       10653       10654       10655       10656 
## 19942372.43  8463199.11 16820433.97 16852255.88 19772511.73 16832240.83 
##       10657       10658       10659       10660       10661       10662 
##  6812947.52  2187489.33  3280344.12 24388104.43 18000977.41 15107404.98 
##       10663       10664       10665       10666       10667       10668 
## 11071325.90  8804492.99 11659447.99 15882452.30 13614255.15 14360781.30 
##       10669       10670       10671       10672       10673       10674 
##  4963345.25  3874425.71  8638896.83 15820079.63  9947652.94 10608928.30 
##       10675       10676       10677       10678       10679       10680 
## 11831223.68 10715678.08 18370843.69 18033007.59 24787443.71 20792659.27 
##       10681       10682       10683       10684       10685       10686 
## 10734553.89 14786524.50 23586068.72 15174415.81 14696669.45 21641645.35 
##       10687       10688       10689       10690       10691       10692 
## 16169395.71 12954237.15 18327299.72 26652093.45 23775360.33 20813243.93 
##       10693       10694       10695       10696       10697       10698 
## 21399224.55 14748593.10 17040545.01 16656182.65 24538822.27 12033993.05 
##       10699       10700       10701       10702       10703       10704 
## 19365173.86 13378906.14 16135355.04 20944717.11 22152925.25 23350707.08 
##       10705       10706       10707       10708       10709       10710 
## 12137727.49 12362516.34 15647882.15 17728272.88 25610912.49 11483182.33 
##       10711       10712       10713       10714       10715       10716 
## 16228410.19 14066458.06 21735642.49 16489766.28 22863440.68 25217568.20 
##       10717       10718       10719       10720       10721       10722 
## 14835803.84 16495146.39 22063158.91 16594990.87 22768308.44 15220954.75 
##       10723       10724       10725       10726       10727       10728 
## 17405975.76 16749989.07 21071396.44 26135139.19 34594122.49 25311911.45 
##       10729       10730       10731       10732       10733       10734 
```

```
## 16213850.04 18560659.25 20910497.95 17148441.29 23064011.08 11548843.47
##       10735       10736       10737       10738       10739       10740
## 19107866.87 25146512.87 23611984.56 42060769.69 32661334.03 33443082.46
##       10741       10742       10743       10744       10745       10746
## 26843089.98 15219653.93 27987085.90 25288610.68 27765987.37 14731658.59
##       10747       10748       10749       10750       10751       10752
## 17559758.01 21155741.90 25500961.51 24405053.32 39326020.64 25050900.94
##       10753       10754       10755       10756       10757       10758
## 19830935.26 14206507.84 14964046.91 16055186.14 17867665.14 13526068.97
##       10759       10760       10761       10762       10763       10764
## 17068671.46 25656764.37 20949202.17 25406915.94 27419616.94 18691846.63
##       10765       10766       10767       10768       10769       10770
## 19797610.39 12647096.61 14383437.39 14983527.60 19213873.26 20770627.04
##       10771       10772       10773       10774       10775       10776
## 16985410.38 15938248.25 21060373.50 34082753.83 40548912.21 30156164.56
##       10777       10778       10779       10780       10781       10782
## 29631248.55 19454957.10 19789660.52 20025809.52 21633117.75 17439149.02
##       10783       10784       10785       10786       10787       10788
## 20005697.35 24040773.06 21080888.19 26283510.76 26352521.83 31706623.55
##       10789       10790       10791       10792       10793       10794
## 24439494.21 27241932.83 22930440.38 23641969.90 27794243.34 19988084.70
##       10795       10796       10797       10798       10799       10800
## 21491465.81 25726079.40 30678149.02 31537346.13 36756187.66 34532571.26
##       10801       10802       10803       10804       10805       10806
## 26224188.37 24391818.16 20675677.20 23963221.50 20784503.22 18502261.85
##       10807       10808       10809       10810       10811       10812
## 19268540.54 18341131.67 23102919.88 26747332.20 27817053.16 27904369.27
```

```r
# residuals
residuals(fit)
```

```
##        10609        10610        10611        10612        10613
##   5952459.84  12255563.09  -3371411.14  -4445741.27  -8889076.47
##        10614        10615        10616        10617        10618
##    986134.71  -5748266.48   -336390.21   2807133.26   1645172.74
##        10619        10620        10621        10622        10623
##  -3629105.70  -4577842.81   3072907.21   3243308.73  -5672890.07
##        10624        10625        10626        10627        10628
## -15696727.40    289232.12   2042122.32   1117366.99   2926082.40
##        10629        10630        10631        10632        10633
##   5230228.43 -20382271.56  -5264124.44  -5075967.51   1491577.71
##        10634        10635        10636        10637        10638
##  -9837151.49  -6712232.19   -764792.30   -437886.38   2231690.27
##        10639        10640        10641        10642        10643
```

```
## -1443831.23 -2440345.04 14926587.99 -6794617.92  2635516.43
##       10644       10645       10646       10647       10648
## -17311907.92 -5709093.26  4952910.28 -6048902.56 -6642668.40
##       10649       10650       10651       10652       10653
## -9406029.73 11491464.13 29486574.30  2963737.40  3482526.36
##       10654       10655       10656       10657       10658
##   764926.90  5721591.58 -8014761.85  -334238.52  5160023.79
##       10659       10660       10661       10662       10663
##  3802703.26 -10108379.25 -2107670.27 -3238790.51  6520269.00
##       10664       10665       10666       10667       10668
##  6117951.47  3707721.08  4118584.97   744008.66 -2535146.08
##       10669       10670       10671       10672       10673
##  5587891.61   247621.47 -2882708.00   800991.54  -911955.00
##       10674       10675       10676       10677       10678
##  -655352.63  5390336.84  4162722.58 18880213.59 11462880.43
##       10679       10680       10681       10682       10683
## 24340300.82 -5444209.40  6331098.26  2063500.35  8101582.03
##       10684       10685       10686       10687       10688
## -1076762.56 -1485004.62  1129099.86 -3023048.68  1233356.51
##       10689       10690       10691       10692       10693
##  4825705.45 29321582.28 12866219.97 -8588656.22 -3474768.56
##       10694       10695       10696       10697       10698
## -3342387.93 -1561293.84 -7985942.92 -13492569.39 -6264977.56
##       10699       10700       10701       10702       10703
##  7369859.10 -2554169.18  8312707.30 10394757.30  7502086.94
##       10704       10705       10706       10707       10708
##  8077227.47 -2014108.57   -95116.07 16114782.51 -9058033.14
##       10709       10710       10711       10712       10713
## -14564659.61 -2664396.26 -4418287.27 -1765118.25  8881219.38
##       10714       10715       10716       10717       10718
## -5440633.74  4224442.28 19111300.40  6924490.79  3747711.16
##       10719       10720       10721       10722       10723
## -9990097.04 -6651295.63 -5039648.82    -6308.56  2483670.82
##       10724       10725       10726       10727       10728
## -5713224.42 -2679256.50  6910723.16 -3562131.49 -9394292.44
##       10729       10730       10731       10732       10733
## 12292491.48  4692225.99 -9441901.08 -2161564.02 -5911665.98
##       10734       10735       10736       10737       10738
## -4985852.10  7434834.02 -6325219.34 -9242339.89  2630232.74
##       10739       10740       10741       10742       10743
##  2220095.43 -24406855.54 19131720.29 -3262974.07 -10889120.28
##       10744       10745       10746       10747       10748
## -10903121.99 -17763414.88 -6822302.77 -6103458.03  4173221.59
##       10749       10750       10751       10752       10753
```

```
##   1798780.05  -2210622.30 -11946665.58 -13681047.30  -2168599.28
##        10754        10755        10756        10757        10758
##  -6048066.31  -2150199.30 -13368549.99 -13612130.58  -5616599.80
##        10759        10760        10761        10762        10763
##  -8493152.82  13138420.47   5906816.91  -5632275.23 -14413805.47
##        10764        10765        10766        10767        10768
## -11756970.84  13432590.65  -4590320.74  11802983.94 -11719864.10
##        10769        10770        10771        10772        10773
##  -5872175.91  -6074743.34  -1524686.00 -11526464.03    588741.05
##        10774        10775        10776        10777        10778
##  -6270584.46   3002161.46  17526668.12  21562277.07   4623242.69
##        10779        10780        10781        10782        10783
##   -574423.50   -461153.44   8859508.60  -6850722.29     20410.18
##        10784        10785        10786        10787        10788
##   1833438.73  -6721423.87   -120768.46   6155767.42  16332840.98
##        10789        10790        10791        10792        10793
##  11567778.03  -5252033.21   7628370.24 -14204807.69  -8731475.08
##        10794        10795        10796        10797        10798
##  -3574565.94   3934677.40   -701966.67  40857881.71   3374642.37
##        10799        10800        10801        10802        10803
##   6228081.96  32312395.41  18534222.08  21076380.64  -3225724.08
##        10804        10805        10806        10807        10808
##   7968162.75  -5060877.16  -8144023.17  -9024300.07 -16068197.43
##        10809        10810        10811        10812
## -15246302.20  -2792914.14  -5883562.15 -13014993.94
```

```
# anova table
anova(fit)
```

```
## Analysis of Variance Table
##
## Response: raised
##            Df     Sum Sq    Mean Sq F value    Pr(>F)
## year        1 4.6080e+15 4.6080e+15  49.083 3.663e-11 ***
## month       1 1.9813e+15 1.9813e+15  21.104 7.689e-06 ***
## nomeff      1 7.4316e+15 7.4316e+15  79.159 3.445e-16 ***
## Residuals 200 1.8776e+16 9.3882e+13
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# covariance matrix for model parameters
vcov(fit)
```

```
##               (Intercept)          year        month        nomeff
## (Intercept)  7.767104e+16 -3.872335e+13 28849322448.9 -1.085409e+09
```

```
## year       -3.872335e+13  1.930661e+10  -132736938.4  5.147853e+05
## month       2.884932e+10 -1.327369e+08 38753042588.4 -5.204691e+05
## nomeff     -1.085409e+09  5.147853e+05     -520469.1  2.018502e+03

# regression diagnostics
influence(fit)

## $hat
##       10609       10610       10611       10612       10613       10614
## 0.042348953 0.032174152 0.030947216 0.024014063 0.027363125 0.031587019
##       10615       10616       10617       10618       10619       10620
## 0.018101845 0.031744185 0.029944584 0.028749417 0.028915850 0.042004060
##       10621       10622       10623       10624       10625       10626
## 0.036951680 0.032836278 0.020628210 0.029105061 0.025090117 0.020127986
##       10627       10628       10629       10630       10631       10632
## 0.028928511 0.025311220 0.021317185 0.041136744 0.038894083 0.038442958
##       10633       10634       10635       10636       10637       10638
## 0.024751425 0.032951924 0.018613317 0.018864207 0.027982400 0.015391058
##       10639       10640       10641       10642       10643       10644
## 0.014401572 0.013346093 0.015061997 0.022355644 0.027879390 0.046154691
##       10645       10646       10647       10648       10649       10650
## 0.031627027 0.018558780 0.023833019 0.112821017 0.025427226 0.010871644
##       10651       10652       10653       10654       10655       10656
## 0.014936315 0.016434376 0.012730547 0.015052097 0.018993675 0.022811653
##       10657       10658       10659       10660       10661       10662
## 0.021590355 0.025598024 0.021891454 0.030677847 0.012303026 0.008431467
##       10663       10664       10665       10666       10667       10668
## 0.010270283 0.015731396 0.014200211 0.013621161 0.019758522 0.024082289
##       10669       10670       10671       10672       10673       10674
## 0.023275260 0.022651222 0.013566370 0.010244787 0.009973309 0.009427607
##       10675       10676       10677       10678       10679       10680
## 0.009064497 0.012642349 0.009371723 0.011822949 0.018824179 0.019203515
##       10681       10682       10683       10684       10685       10686
## 0.018230843 0.014847325 0.025124352 0.008429436 0.006662158 0.010162920
##       10687       10688       10689       10690       10691       10692
## 0.005886809 0.009761653 0.008305723 0.017501582 0.015513961 0.018205378
##       10693       10694       10695       10696       10697       10698
## 0.028403775 0.013710461 0.011213122 0.007992116 0.015776039 0.008437031
##       10699       10700       10701       10702       10703       10704
```

```
## 0.005524255 0.009895498 0.009330121 0.010167001 0.013503398 0.017684780
##       10705       10706       10707       10708       10709       10710
## 0.017555766 0.013732230 0.009968803 0.007831239 0.015806655 0.010548861
##       10711       10712       10713       10714       10715       10716
## 0.005897979 0.010109522 0.007643304 0.013336595 0.013258812 0.017830567
##       10717       10718       10719       10720       10721       10722
## 0.017580339 0.013641063 0.014828321 0.007707093 0.009130653 0.007002906
##       10723       10724       10725       10726       10727       10728
## 0.005964200 0.008107635 0.007712046 0.011939769 0.030339564 0.017690478
##       10729       10730       10731       10732       10733       10734
## 0.018267899 0.014779064 0.012677183 0.008396088 0.008933566 0.015077042
##       10735       10736       10737       10738       10739       10740
## 0.006182481 0.008291578 0.008441482 0.057347133 0.023330100 0.027175075
##       10741       10742       10743       10744       10745       10746
## 0.034145133 0.015598509 0.024922266 0.014620930 0.015971049 0.011818535
##       10747       10748       10749       10750       10751       10752
## 0.009166620 0.007953467 0.009838765 0.011779321 0.041442536 0.019370448
##       10753       10754       10755       10756       10757       10758
## 0.021496796 0.018615226 0.015482224 0.012810535 0.010316345 0.017445774
##       10759       10760       10761       10762       10763       10764
## 0.012517804 0.009671274 0.012428820 0.013209037 0.016669564 0.030352449
##       10765       10766       10767       10768       10769       10770
## 0.022778573 0.024013621 0.019359402 0.017364762 0.011868764 0.010639665
##       10771       10772       10773       10774       10775       10776
## 0.016097657 0.020932289 0.015185078 0.023064462 0.042076891 0.022982715
##       10777       10778       10779       10780       10781       10782
## 0.039314848 0.020642852 0.017495861 0.015307288 0.013370033 0.017670901
##       10783       10784       10785       10786       10787       10788
## 0.015229820 0.013478258 0.018677831 0.017442482 0.021062576 0.025585033
##       10789       10790       10791       10792       10793       10794
## 0.029795969 0.028346084 0.020069570 0.017557692 0.017992944 0.017991668
##       10795       10796       10797       10798       10799       10800
## 0.017279735 0.015915981 0.018925877 0.021355814 0.030908716 0.029985740
##       10801       10802       10803       10804       10805       10806
## 0.033882901 0.027040425 0.023711906 0.020546316 0.021026489 0.024976776
##       10807       10808       10809       10810       10811       10812
## 0.025242356 0.030110086 0.024279989 0.023872198 0.027053249 0.031774203
##
```

```
## $coefficients
##       (Intercept)          year         month       nomeff
## 10609  2.217824e+07 -1.095925e+04 -1.325088e+04  -3.148198546
## 10610  4.411931e+07 -2.183848e+04 -2.228032e+04  -4.498752468
## 10611 -1.067489e+07  5.318300e+03  5.379473e+03  -1.436946526
## 10612 -1.430707e+07  7.125744e+03  5.005198e+03  -1.244058740
## 10613 -2.792623e+07  1.393898e+04  6.644383e+03  -3.898604484
## 10614  3.637567e+06 -1.803856e+03 -6.792737e+01  -0.548821439
## 10615 -1.912700e+07  9.531031e+03 -1.168978e+03  -0.136134257
## 10616 -1.236679e+06  6.142401e+02 -2.614444e+02   0.182574103
## 10617  1.017484e+07 -5.060185e+03  3.311361e+03  -1.300911103
## 10618  5.221933e+06 -2.616049e+03  2.285340e+03   0.594874799
## 10619 -1.269309e+07  6.332354e+03 -7.146199e+03   0.885644012
## 10620 -1.689093e+07  8.416379e+03 -1.142621e+04   2.385068449
## 10621  9.988869e+06 -4.931698e+03 -6.845283e+03  -1.449495213
## 10622  1.048887e+07 -5.182988e+03 -5.814728e+03  -1.523215775
## 10623 -1.631084e+07  8.103095e+03  8.519957e+03  -0.699865368
## 10624 -4.218674e+07  2.105372e+04  1.871018e+04  -8.082331986
## 10625  9.242638e+05 -4.579190e+02 -1.489350e+02  -0.132336511
## 10626  6.358893e+06 -3.155937e+03 -2.504379e+02  -0.691128004
## 10627  3.641035e+06 -1.805648e+03  3.989493e+02  -0.629386219
## 10628  9.337116e+06 -4.637748e+03  2.201757e+03  -1.355018464
## 10629  1.613545e+07 -8.032158e+03  5.891577e+03  -1.534779365
## 10630 -5.312552e+07  2.673259e+04 -2.690472e+04 -14.346919347
## 10631 -1.395324e+07  7.020519e+03 -9.319379e+03  -3.177538009
## 10632 -1.646696e+07  8.204834e+03 -1.260786e+04   2.577627287
## 10633  3.760187e+06 -1.861128e+03 -3.473579e+03   0.051669502
## 10634 -2.234622e+07  1.112837e+04  2.018246e+04  -5.245393316
## 10635 -1.628359e+07  8.088006e+03  1.014416e+04  -1.151932610
## 10636 -2.047850e+06  1.013844e+03  7.423967e+02   0.229688220
## 10637 -1.247581e+06  6.168874e+02  2.124380e+02   0.254137855
## 10638  5.894615e+06 -2.925287e+03 -3.169306e+02  -0.578830806
## 10639 -3.769840e+06  1.873573e+03 -3.804838e+02   0.307087073
## 10640 -6.158875e+06  3.068716e+03 -1.564194e+03   0.147604594
## 10641  3.662943e+07 -1.829673e+04  1.530656e+04   1.079832230
## 10642 -1.581303e+07  7.932421e+03 -9.414976e+03  -2.292732097
## 10643  6.064794e+06 -3.048607e+03  4.741647e+03   1.073663875
## 10644 -3.778883e+07  1.909829e+04 -3.788386e+04 -12.327285258
```

```
## 10645 -1.077920e+07  5.352968e+03  1.401354e+04  -2.618544383
## 10646  1.060570e+07 -5.242426e+03 -9.252015e+03  -0.347635974
## 10647 -1.132823e+07  5.641363e+03  9.615886e+03  -2.693177220
## 10648 -9.507136e+06  4.843114e+03  1.053421e+04 -10.992044696
## 10649 -1.695109e+07  8.482417e+03  7.344435e+03  -5.387675286
## 10650  2.306200e+07 -1.148565e+04 -2.772593e+03   1.485708039
## 10651  5.621407e+07 -2.811061e+04  3.670604e+03   9.641509106
## 10652  6.729828e+06 -3.341545e+03  2.126468e+03  -1.036254290
## 10653  7.108220e+06 -3.551032e+03  3.575657e+03   0.201266255
## 10654  1.582467e+06 -7.910911e+02  1.116079e+03   0.007929597
## 10655  1.152837e+07 -5.779663e+03  1.061769e+04   0.692447633
## 10656 -1.710168e+07  8.560121e+03 -1.874231e+04   0.721627113
## 10657 -5.929103e+05  2.917234e+02  7.601162e+02   0.049510964
## 10658  1.002366e+07 -4.923779e+03 -9.198676e+03  -2.342143138
## 10659  7.327219e+06 -3.604714e+03 -5.164301e+03  -1.679766149
## 10660 -1.353175e+07  6.778596e+03  1.248477e+04  -6.827556929
## 10661 -3.213203e+06  1.600485e+03  1.461190e+03  -0.560386836
## 10662 -5.268267e+06  2.619912e+03  7.210039e+02  -0.190793353
## 10663  1.154913e+07 -5.730482e+03  1.707015e+03  -1.365261647
## 10664  1.144985e+07 -5.676987e+03  4.440678e+03  -2.347823170
## 10665  6.705866e+06 -3.334416e+03  4.132369e+03  -1.025737232
## 10666  7.032453e+06 -3.511565e+03  6.112911e+03  -0.393054841
## 10667  1.345926e+06 -6.713397e+02  1.456790e+03  -0.200903934
## 10668 -4.611241e+06  2.303236e+03 -6.060086e+03   0.709429363
## 10669  8.053249e+06 -3.938302e+03 -1.250602e+04  -1.696860825
## 10670  3.705611e+05 -1.813324e+02 -4.426178e+02  -0.102288769
## 10671 -3.939973e+06  1.936750e+03  4.059715e+03   0.572834588
## 10672  9.419679e+05 -4.666418e+02 -8.618175e+02   0.114659646
## 10673 -1.250211e+06  6.167518e+02  5.154677e+02   0.205175878
## 10674 -9.007893e+05  4.451602e+02  9.586014e+01   0.155957310
## 10675  7.341548e+06 -3.636302e+03  1.425342e+03  -1.188810295
## 10676  5.924946e+06 -2.935061e+03  2.957010e+03  -1.379088741
## 10677  2.301099e+07 -1.150280e+04  1.942244e+04   0.687768760
## 10678  1.439071e+07 -7.198515e+03  1.679264e+04  -0.355463468
## 10679  2.651039e+07 -1.340312e+04  4.410324e+04   7.047794792
## 10680 -6.703334e+06  3.371961e+03 -1.252879e+04  -0.114757586
## 10681  5.541159e+06 -2.697350e+03 -1.452595e+04  -0.247387790
## 10682  1.603446e+06 -7.856451e+02 -3.948057e+03   0.274442552
```

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## 10683  4.441413e+06 -2.216849e+03 -1.315567e+04  4.618659090
## 10684 -8.700043e+05  4.284249e+02  1.132074e+03 -0.059475986
## 10685 -1.253417e+06  6.181170e+02  9.149269e+02  0.029129447
## 10686  7.539905e+05 -3.770922e+02 -3.244721e+02  0.348491682
## 10687 -2.562626e+06  1.271214e+03 -6.547688e+02  0.113695338
## 10688  1.194618e+06 -5.910220e+02  8.516612e+02 -0.322441202
## 10689  4.025099e+06 -2.010676e+03  5.027373e+03 -0.089717606
## 10690  1.819959e+07 -9.292996e+03  4.003722e+04 11.363767502
## 10691  9.363500e+06 -4.747078e+03  2.359376e+04  2.319518098
## 10692 -7.222097e+06  3.641319e+03 -1.986024e+04  0.265940573
## 10693 -6.056861e+05  2.898511e+02  8.536768e+03 -1.727667047
## 10694 -1.305227e+06  6.257896e+02  6.340178e+03 -0.260270335
## 10695 -5.404923e+05  2.614907e+02  2.335034e+03 -0.239252458
## 10696 -3.033790e+06  1.475310e+03  8.449588e+03 -0.662450304
## 10697 -2.362064e+06  1.199732e+03  1.007671e+04 -6.274776280
## 10698 -3.521929e+06  1.715006e+03  8.703304e+02  1.664513748
## 10699  2.733217e+06 -1.358053e+03  1.366920e+03  0.610078755
## 10700 -1.458547e+06  7.165223e+02 -1.783467e+03  0.743524545
## 10701  4.271917e+06 -2.117273e+03  9.037041e+03 -1.581853695
## 10702  4.131753e+06 -2.087052e+03  1.506093e+04  0.226903260
## 10703  2.904535e+06 -1.479497e+03  1.400255e+04  0.289243941
## 10704  3.048377e+06 -1.566427e+03  1.848898e+04  0.443212896
## 10705 -1.143376e+05  3.516276e+01  4.602683e+03  0.137875177
## 10706 -7.011967e+03  2.551064e+00  1.759407e+02  0.010002868
## 10707  1.826903e+04  1.014222e+02 -2.353720e+04  0.397682389
## 10708  3.251151e+05 -2.043634e+02  9.595275e+03 -0.801320482
## 10709  3.554089e+06 -1.748180e+03  1.089865e+04 -6.854712077
## 10710 -5.167254e+05  2.371035e+02  3.141253e+02  0.929696189
## 10711 -3.470363e+05  1.570767e+02 -1.072941e+03  0.615906683
## 10712 -2.925253e+05  1.379845e+02 -1.239762e+03  0.541044957
## 10713 -3.072306e+05  1.381465e+02  9.063973e+03  0.541680208
## 10714 -7.765932e+05  3.799752e+02 -8.323130e+03  1.489904557
## 10715 -8.593698e+04  2.628041e+01  7.898327e+03  0.103047003
## 10716 -1.259419e+06  5.068377e+02  4.351076e+04  1.987339499
## 10717 -2.845605e+06  1.485801e+03 -1.599330e+04  0.181059556
## 10718 -1.627264e+06  8.403740e+02 -7.098327e+03  0.252218086
## 10719  5.738343e+06 -2.891791e+03  1.542928e+04 -3.217688027
## 10720  2.575890e+06 -1.325706e+03  6.849368e+03  0.170024856
```

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## 10721  2.743464e+06 -1.373642e+03  3.476782e+03  -1.312834809
## 10722  1.891144e+03 -9.794033e-01  9.849642e-01   0.001247668
## 10723 -8.431059e+05  4.291345e+02  5.959896e+02  -0.318369889
## 10724  1.699317e+06 -8.661153e+02 -3.867812e+03   1.216859700
## 10725  1.070784e+06 -5.326297e+02 -2.795782e+03   0.073939846
## 10726 -3.634180e+06  1.778932e+03  9.715614e+03   1.373827064
## 10727  2.721464e+06 -1.315127e+03 -6.229100e+03  -2.214626452
## 10728  4.293151e+06 -2.087533e+03 -2.150113e+04  -0.526242586
## 10729 -1.033050e+07  5.266972e+03 -2.848234e+04   0.596359927
## 10730 -4.140989e+06  2.097702e+03 -8.969896e+03   0.596746653
## 10731  8.740758e+06 -4.401930e+03  1.426929e+04  -1.942572590
## 10732  1.704127e+06 -8.639063e+02  2.214883e+03   0.104151101
## 10733  5.543927e+06 -2.774150e+03  4.021768e+03  -1.323301838
## 10734  2.900244e+06 -1.491977e+03  4.589080e+02   2.258154884
## 10735 -5.746351e+06  2.887983e+03  1.708556e+03  -0.658799504
## 10736  5.863621e+06 -2.911538e+03 -3.625998e+03  -1.200248796
## 10737  7.936993e+06 -3.943310e+03 -9.448384e+03  -0.532097381
## 10738 -3.799404e+06  1.852009e+03  3.297152e+03   2.792589403
## 10739 -2.424007e+06  1.187533e+03  3.945937e+03   1.015428594
## 10740  2.673316e+07 -1.306522e+04 -5.391394e+04 -11.044007437
## 10741 -2.998799e+07  1.500246e+04 -4.771143e+04  11.234460799
## 10742  3.826148e+06 -1.940949e+03  6.044669e+03   0.353303805
## 10743  1.675273e+07 -8.356773e+03  1.760887e+04  -5.936400688
## 10744  1.547598e+07 -7.733429e+03  1.234295e+04  -3.738592715
## 10745  2.611850e+07 -1.300653e+04  1.310536e+04  -7.628145733
## 10746  7.224511e+06 -3.654449e+03  8.377321e+02   2.258058551
## 10747  6.805481e+06 -3.423328e+03 -1.621965e+03   1.376820132
## 10748 -4.986467e+06  2.493240e+03  2.680961e+03  -0.330865273
## 10749 -2.339139e+06  1.162491e+03  1.818326e+03   0.193486833
## 10750  2.757010e+06 -1.370125e+03 -3.221227e+03   0.002231249
## 10751  2.044704e+07 -1.003019e+04 -2.065058e+04  -9.384825508
## 10752  1.680124e+07 -8.323089e+03 -3.179199e+04   0.884179476
## 10753  3.751150e+06 -1.888552e+03  5.092878e+03  -0.305438599
## 10754  9.283990e+06 -4.699767e+03  1.106898e+04   1.314300194
## 10755  3.286791e+06 -1.661185e+03  3.019905e+03   0.482833713
## 10756  2.048982e+07 -1.033521e+04  1.318982e+04   2.856629756
## 10757  2.120923e+07 -1.066864e+04  7.912063e+03   2.228364085
## 10758  7.963005e+06 -4.022772e+03  5.211376e+02   2.538605474
```

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## 10759  1.266087e+07 -6.364137e+03 -2.438977e+03   2.598379782
## 10760 -2.251378e+07  1.121529e+04  7.805354e+03   1.476114842
## 10761 -9.195523e+06  4.595975e+03  6.444720e+03  -1.139421617
## 10762  9.377180e+06 -4.664159e+03 -8.216497e+03  -0.004043853
## 10763  2.459176e+07 -1.220144e+04 -2.690524e+04  -0.885468388
## 10764  1.699698e+07 -8.491030e+03 -2.886275e+04   5.548338501
## 10765 -2.849576e+07  1.433161e+04 -3.139603e+04   1.152496207
## 10766  8.667243e+06 -4.384161e+03  8.282529e+03   1.642954860
## 10767 -2.250246e+07  1.135701e+04 -1.638369e+04  -3.664811034
## 10768  2.222611e+07 -1.120462e+04  1.127902e+04   3.825802265
## 10769  1.166217e+07 -5.854050e+03  3.449565e+03   0.842605075
## 10770  1.218204e+07 -6.103551e+03  1.094079e+03   0.654610620
## 10771  2.868529e+06 -1.440760e+03 -4.620766e+02   0.555959114
## 10772  2.116036e+07 -1.063087e+04 -8.671706e+03   5.458520491
## 10773 -1.149062e+06  5.744290e+02  6.512743e+02  -0.141506136
## 10774  1.460430e+07 -7.234601e+03 -8.553998e+03  -2.664872208
## 10775 -7.643539e+06  3.771626e+03  5.224049e+03   2.239007014
## 10776 -3.793829e+07  1.880890e+04  4.009159e+04   1.916947871
## 10777 -6.147477e+07  3.071463e+04 -5.402415e+04  12.582237726
## 10778 -1.142963e+07  5.742630e+03 -8.695424e+03  -0.166766045
## 10779  1.407505e+06 -7.066625e+02  8.318138e+02   0.038518304
## 10780  1.119671e+06 -5.617728e+02  4.693291e+02   0.047646704
## 10781 -2.167545e+07  1.085816e+04 -5.392837e+03  -0.573298309
## 10782  1.582477e+07 -7.945378e+03  8.266039e+02   2.357102011
## 10783 -4.808225e+04  2.408581e+01  5.590822e+00  -0.005150303
## 10784 -4.484881e+06  2.239632e+03  1.185089e+03  -0.148714333
## 10785  1.578188e+07 -7.891115e+03 -7.552015e+03   1.971122788
## 10786  2.988220e+05 -1.488566e+02 -1.787522e+02   0.006945175
## 10787 -1.515295e+07  7.543606e+03  1.180438e+04  -0.637321651
## 10788 -4.259410e+07  2.113152e+04  3.732562e+04   2.314337478
## 10789 -3.541430e+07  1.774364e+04 -2.767970e+04   2.732233148
## 10790  1.636634e+07 -8.184845e+03  1.046740e+04  -1.790939131
## 10791 -2.241748e+07  1.123094e+04 -1.130989e+04   0.396006193
## 10792  4.159560e+07 -2.082176e+04  1.502035e+04  -0.586778663
## 10793  2.643894e+07 -1.320083e+04  5.980054e+03  -1.914906596
## 10794  9.916625e+06 -4.969398e+03  5.111495e+02   0.921178949
## 10795 -1.098800e+07  5.499053e+03  1.051415e+03  -0.883903995
## 10796  2.028247e+06 -1.012302e+03 -4.477825e+02   0.029640129
```

```
## 10797 -1.234049e+08  6.141495e+04  4.093550e+04   7.340044191
## 10798 -1.022276e+07  5.083079e+03  4.809996e+03   0.599668816
## 10799 -1.987209e+07  9.854067e+03  1.122356e+04   2.609591178
## 10800 -1.000787e+08  4.964740e+04  7.332152e+04   7.924476981
## 10801 -6.529009e+07  3.268233e+04 -4.475353e+04   5.236688538
## 10802 -7.206740e+07  3.609092e+04 -4.080151e+04   2.726204116
## 10803  1.055969e+07 -5.295507e+03  4.652551e+03   0.405043300
## 10804 -2.658305e+07  1.330478e+04 -8.378138e+03   0.046214950
## 10805  1.629572e+07 -8.165072e+03  2.904723e+03   1.105528974
## 10806  2.558239e+07 -1.282763e+04  8.884004e+02   3.217167593
## 10807  2.834348e+07 -1.420069e+04 -2.841140e+03   3.633854651
## 10808  4.988753e+07 -2.499597e+04 -1.231960e+04   8.133609667
## 10809  4.883875e+07 -2.440287e+04 -1.721099e+04   4.428098543
## 10810  9.177389e+06 -4.576010e+03 -4.219677e+03   0.388898756
## 10811  1.944169e+07 -9.685203e+03 -1.139177e+04   0.767636896
## 10812  4.293545e+07 -2.137868e+04 -3.100402e+04   2.295963898
##
## $sigma
##   10609   10610   10611   10612   10613   10614   10615   10616   10617
## 9704033 9673382 9710573 9708368 9692571 9713348 9704899 9713577 9711506
##   10618   10619   10620   10621   10622   10623   10624   10625   10626
## 9712887 9710099 9707947 9711071 9710794 9705104 9647742 9713585 9712507
##   10627   10628   10629   10630   10631   10632   10633   10634   10635
## 9713275 9711335 9706375 9600885 9706147 9706674 9713017 9687689 9701725
##   10636   10637   10638   10639   10640   10641   10642   10643   10644
## 9713453 9713556 9712299 9713060 9712046 9654918 9701385 9711759 9631991
##   10645   10646   10647   10648   10649   10650   10651   10652   10653
## 9704897 9707140 9703907 9700734 9690097 9679013 9482552 9711297 9710429
##   10654   10655   10656   10657   10658   10659   10660   10661   10662
## 9713454 9704972 9696589 9713578 9706537 9709783 9686303 9712444 9710871
##   10663   10664   10665   10666   10667   10668   10669   10670   10671
## 9702490 9703766 9710000 9709158 9713461 9711904 9705335 9713591 9711428
##   10672   10673   10674   10675   10676   10677   10678   10679   10680
## 9713440 9713390 9713495 9706020 9709067 9620081 9679152 9556146 9705788
##   10681   10682   10683   10684   10685   10686   10687   10688   10689
## 9703041 9712489 9696177 9713305 9713033 9713274 9711229 9713210 9707532
##   10690   10691   10692   10693   10694   10695   10696   10697   10698
## 9484558 9670016 9694154 9710393 9710677 9712970 9696964 9665645 9703363
```

```
##   10699   10700   10701   10702   10703   10704   10705   10706   10707
## 9699470 9711903 9695548 9685330 9698839 9696413 9712539 9713605 9645521
##   10708   10709   10710   10711   10712   10713   10714   10715   10716
## 9692194 9657695 9711752 9708527 9712793 9693026 9705844 9708928 9616936
##   10717   10718   10719   10720   10721   10722   10723   10724   10725
## 9700975 9709924 9687368 9702069 9706975 9713608 9712002 9705092 9711736
##   10726   10727   10728   10729   10730   10731   10732   10733   10734
## 9701097 9710222 9690341 9673713 9707825 9690224 9712389 9704482 9707077
##   10735   10736   10737   10738   10739   10740   10741   10742   10743
## 9699210 9703167 9691298 9711709 9712302 9553906 9615084 9710809 9682102
##   10744   10745   10746   10747   10748   10749   10750   10751   10752
## 9682351 9630307 9701417 9703878 9709066 9712762 9712328 9675017 9664111
##   10753   10754   10755   10756   10757   10758   10759   10760   10761
## 9712364 9703962 9712393 9666666 9665059 9705299 9694694 9668416 9704465
##   10762   10763   10764   10765   10766   10767   10768   10769   10770
## 9705289 9658802 9676664 9665730 9708021 9676792 9677383 9704577 9703955
##   10771   10772   10773   10774   10775   10776   10777   10778   10779
## 9712996 9678443 9713516 9703191 9711173 9631938 9587608 9707961 9713521
##   10780   10781   10782   10783   10784   10785   10786   10787   10788
## 9713552 9693008 9701242 9713607 9712726 9701692 9713604 9703590 9642534
##   10789   10790   10791   10792   10793   10794   10795   10796   10797
## 9677866 9706262 9698235 9660336 9693505 9710241 9709532 9713478 9263021
##   10798   10799   10800   10801   10802   10803   10804   10805   10806
## 9710597 9703249 9431081 9621196 9594785 9710850 9696826 9706838 9695996
##   10807   10808   10809   10810   10811   10812
## 9691973 9644505 9651788 9711540 9704400 9668249
##
## $wt.res
##        10609        10610        10611        10612        10613
##   5952459.84  12255563.09  -3371411.14  -4445741.27  -8889076.47
##        10614        10615        10616        10617        10618
##    986134.71  -5748266.48   -336390.21   2807133.26   1645172.74
##        10619        10620        10621        10622        10623
##  -3629105.70  -4577842.81   3072907.21   3243308.73  -5672890.07
##        10624        10625        10626        10627        10628
## -15696727.40    289232.12   2042122.32   1117366.99   2926082.40
##        10629        10630        10631        10632        10633
##   5230228.43 -20382271.56  -5264124.44  -5075967.51   1491577.71
```

```
##       10634       10635       10636       10637       10638
##  -9837151.49  -6712232.19   -764792.30   -437886.38   2231690.27
##       10639       10640       10641       10642       10643
##  -1443831.23  -2440345.04  14926587.99  -6794617.92   2635516.43
##       10644       10645       10646       10647       10648
## -17311907.92  -5709093.26   4952910.28  -6048902.56  -6642668.40
##       10649       10650       10651       10652       10653
##  -9406029.73  11491464.13  29486574.30   2963737.40   3482526.36
##       10654       10655       10656       10657       10658
##    764926.90   5721591.58  -8014761.85   -334238.52   5160023.79
##       10659       10660       10661       10662       10663
##   3802703.26 -10108379.25  -2107670.27  -3238790.51   6520269.00
##       10664       10665       10666       10667       10668
##   6117951.47   3707721.08   4118584.97    744008.66  -2535146.08
##       10669       10670       10671       10672       10673
##   5587891.61    247621.47  -2882708.00    800991.54   -911955.00
##       10674       10675       10676       10677       10678
##   -655352.63   5390336.84   4162722.58  18880213.59  11462880.43
##       10679       10680       10681       10682       10683
##  24340300.82  -5444209.40   6331098.26   2063500.35   8101582.03
##       10684       10685       10686       10687       10688
##  -1076762.56  -1485004.62   1129099.86  -3023048.68   1233356.51
##       10689       10690       10691       10692       10693
##   4825705.45  29321582.28  12866219.97  -8588656.22  -3474768.56
##       10694       10695       10696       10697       10698
##  -3342387.93  -1561293.84  -7985942.92 -13492569.39  -6264977.56
##       10699       10700       10701       10702       10703
##   7369859.10  -2554169.18   8312707.30  10394757.30   7502086.94
##       10704       10705       10706       10707       10708
##   8077227.47  -2014108.57    -95116.07  16114782.51  -9058033.14
##       10709       10710       10711       10712       10713
## -14564659.61  -2664396.26  -4418287.27  -1765118.25   8881219.38
##       10714       10715       10716       10717       10718
##  -5440633.74   4224442.28  19111300.40   6924490.79   3747711.16
##       10719       10720       10721       10722       10723
##  -9990097.04  -6651295.63  -5039648.82     -6308.56   2483670.82
##       10724       10725       10726       10727       10728
##  -5713224.42  -2679256.50   6910723.16  -3562131.49  -9394292.44
```

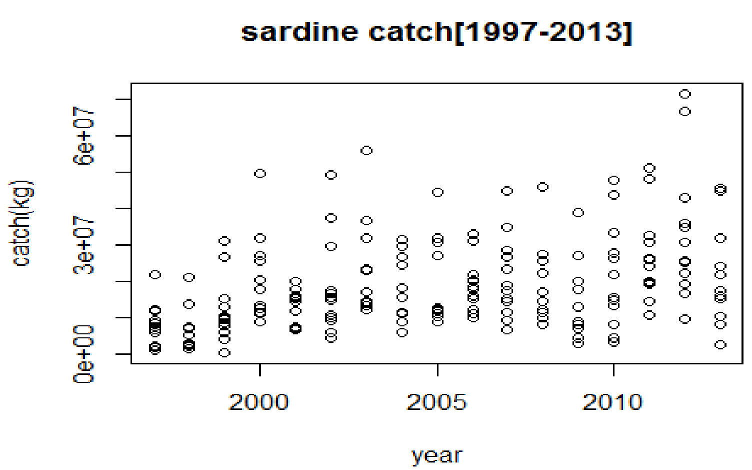
```
##       10729       10730       10731       10732       10733
##  12292491.48   4692225.99  -9441901.08  -2161564.02  -5911665.98
##       10734       10735       10736       10737       10738
##  -4985852.10   7434834.02  -6325219.34  -9242339.89   2630232.74
##       10739       10740       10741       10742       10743
##   2220095.43 -24406855.54  19131720.29  -3262974.07 -10889120.28
##       10744       10745       10746       10747       10748
## -10903121.99 -17763414.88  -6822302.77  -6103458.03   4173221.59
##       10749       10750       10751       10752       10753
##   1798780.05  -2210622.30 -11946665.58 -13681047.30  -2168599.28
##       10754       10755       10756       10757       10758
##  -6048066.31  -2150199.30 -13368549.99 -13612130.58  -5616599.80
##       10759       10760       10761       10762       10763
##  -8493152.82  13138420.47   5906816.91  -5632275.23 -14413805.47
##       10764       10765       10766       10767       10768
## -11756970.84  13432590.65  -4590320.74  11802983.94 -11719864.10
##       10769       10770       10771       10772       10773
##  -5872175.91  -6074743.34  -1524686.00 -11526464.03    588741.05
##       10774       10775       10776       10777       10778
##  -6270584.46   3002161.46  17526668.12  21562277.07   4623242.69
##       10779       10780       10781       10782       10783
##   -574423.50   -461153.44   8859508.60  -6850722.29     20410.18
##       10784       10785       10786       10787       10788
##   1833438.73  -6721423.87   -120768.46   6155767.42  16332840.98
##       10789       10790       10791       10792       10793
##  11567778.03  -5252033.21   7628370.24 -14204807.69  -8731475.08
##       10794       10795       10796       10797       10798
##  -3574565.94   3934677.40   -701966.67  40857881.71   3374642.37
##       10799       10800       10801       10802       10803
##   6228081.96  32312395.41  18534222.08  21076380.64  -3225724.08
##       10804       10805       10806       10807       10808
##   7968162.75  -5060877.16  -8144023.17  -9024300.07 -16068197.43
##       10809       10810       10811       10812
## -15246302.20  -2792914.14  -5883562.15 -13014993.94
```

Chapter 5: Plots in R

##scatter plot

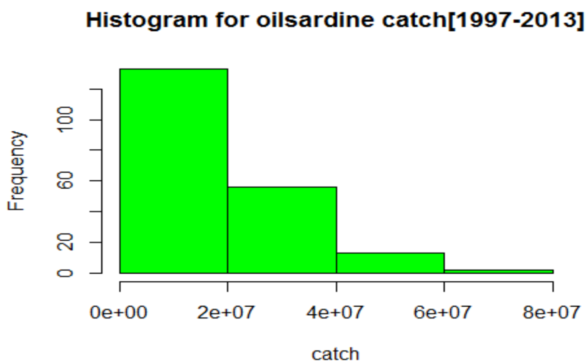
```
sp3621<-sp362[c(1:2,4)]
attach(sp3621)

## The following objects are masked from klm:
##     month, raised, year
plot(year,raised,main="sardine catch[1997-2013]",xlab="year",ylab="catch(kg))
```



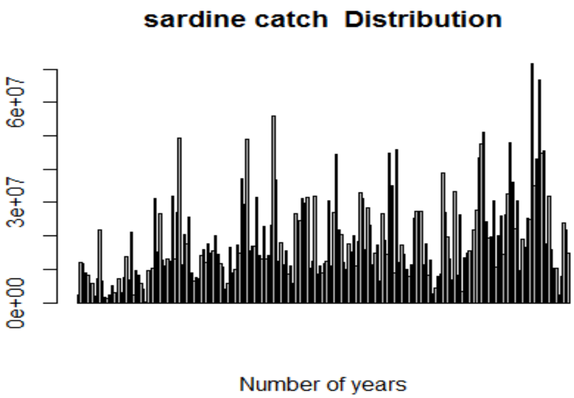
##Histogram

```
hist(raised,main="Histogram for
oilsardine catch[1997-2013]",
xlab="catch",
col="green",
breaks=5)
```



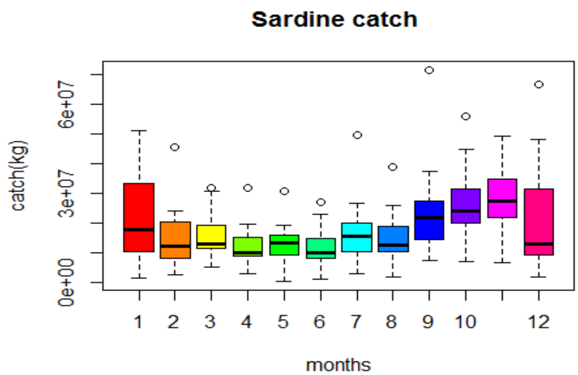
##Bar plot

```
barplot(raised, main="sardine catch
Distribution",
xlab="Number of years")
```



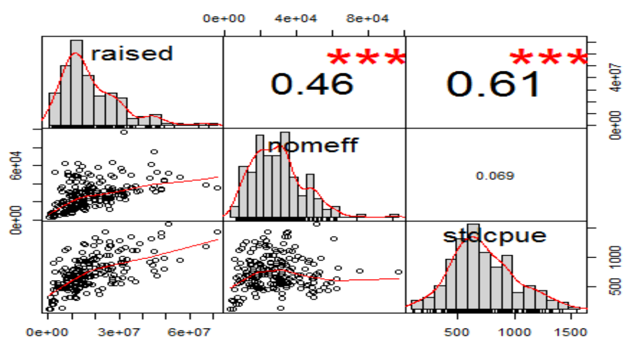
Boxplot in r

```
# Boxplot of catch vs month
boxplot(raised~month,data=sp3621,
main="Sardine catch ",
xlab="months",
ylab="catch(kg)",col=rainbow(length
(unique(month))))
```



to plot a correlation in r

```
##we select sardine  correlations
cordat<-sp362[,4:6]
library(PerformanceAnalytics)
chart.Correlation(cordat,method=
"pearson")
```



Suggested Reading

Bryant, F. B. and Yarnold, P. R. 1995. Principal components analysis and exploratory and confirmatory factor analysis. In L. G. Grimm & P. R. Yarnold (Eds.), Reading and understanding multivariate analysis. Washington, DC: American Psychological Association.

Crowley, M. J. 2007. The R Book.Chichester, New England: John Wiley & Sons, Ltd.

Dunteman, G. H. 1989. Principal components analysis. Newbury Park, CA: Sage Publications.

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C. and Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. Psychological Methods, 4(3), 272-299.

Fox, J. 2005. R commander: A basic-statistics user interface to R. Journal of Statistical Software. 14, (9), 1-42.

Gorsuch, R. L. 1983. Factor Analysis. Hillsdale, NJ: Lawrence Erlbaum Associates.

Hair, J. F., Jr., Anderson, R. E., Tatham, R. L. and Black, W. C. (1995). Multivariate data analysis with readings (4th ed.). Upper Saddle River, NJ: Prentice-Hall.

Hatcher, L. 1994. A step-by-step approach to using the SAS system for factor analysis and structural equation modeling. Cary, NC: SAS Institute.

http://www.statisticssolutions.com.

Hutcheson, G. and Sofroniou, N. 1999. The multivariate social scientist: Introductory statistics using generalized linear models. Thousand Oaks, CA: Sage Publications.

Kim, J. -O. and Mueller, C. W. 1978a. Introduction to factor analysis: What it is and how to do it. Newbury Park, CA: Sage Publications.

Kim, J. -O. and Mueller, C. W. 1978b. Factor Analysis: Statistical methods and practical issues. Newbury Park, CA: Sage Publications.

Lawley, D. N. and Maxwell, A. E. 1962. Factor analysis as a statistical method. The Statistician, 12(3), 209-229.

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Levine, M. S. 1977. Canonical analysis and factor comparison. Newbury Park, CA: Sage Publications.

Pett, M. A., Lackey, N. R., and Sullivan, J. J. 2003. Making sense of factor analysis: The use of factor analysis for instrument development in health care research. Thousand Oaks, CA: Sage Publications.

Shapiro, S. E., Lasarev, M. R., and McCauley, L. 2002. Factor analysis of Gulf War illness: What does it add to our understanding of possible health effects of deployment, American Journal of Epidemiology, 156, 578-585.

Teetor, P. 2011. 25 Recipes for Getting Started with R. Sebastopol, CA: O'Reilly Media Inc.

Teetor, P. 2011. R cookbook. Sebastopol, CA: O'Reilly Media Inc.

Velicer, W. F., Eaton, C. A. and Fava, J. L. 2000. Construct explication through factor or component analysis: A review and evaluation of alternative procedures for determining the number of factors or components. In R. D. Goffin& E. Helmes (Eds.), Problems and solutions in human assessment: Honoring Douglas Jackson at seventy. Boston, MA: Kluwer.

Widaman, K. F. 1993. Common factor analysis versus principal component analysis: Differential bias in representing model parameters, Multivariate Behavioral Research, 28, 263-311.