R Training Session 1: Basics of R Programming

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Outline

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R Training Session 1: Basics of R Programming

All materials can be accessed through:
`https://github.com/davicenna/R-Training-FEB-UGM`

What is R?

R is a powerful programming language and environment for statistical computing, it can be used for many data-related tasks and economic analysis, including:

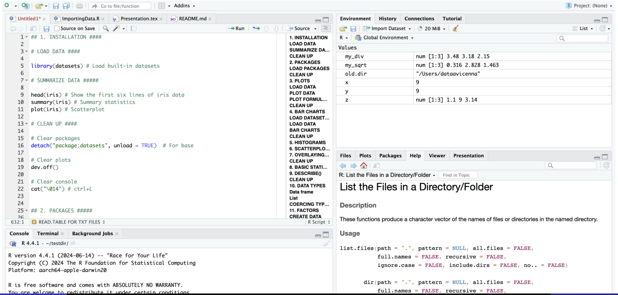
- Load and manipulate data from almost any source
- Make descriptive statistics and advanced graphs
- Fit all sorts of econometric models
- Write your own functions/ programs and share them

Why use R for economics?

- **Free and open-source** - No licensing costs unlike Stata or MATLAB
- **Powerful** - Advanced statistical and econometric capabilities
- **Flexible** - From simple calculations to complex economic models
- **Reproducible** - Code documents every step of your analysis
- **Industry-relevant** - Used in academia, economic research institutions, etc.
- **Growing community** - Extensive packages available
- **Publication-quality outputs** - Good-looking graphs and reports

Installing R

- R download link: `https://cran.rstudio.com`. RStudio download link: `www.rstudio.com/products/rstudio/download/`.
- Download the core programming language *R* itself and *RStudio* which is an *IDE* (integrated development environment), optimized for *R*. Using an IDE makes R more user-friendly, which helps you handle the program better.



```r
## 1. INSTALLATION ####

# LOAD DATA ####

library(datasets) # Load built-in datasets

# SUMMARIZE DATA #####

head(iris) # Show the first six lines of iris data
summary(iris) # Summary statistics
plot(iris) # Scatterplot

# CLEAN UP ####

# Clear packages
detach("package:datasets", unload = TRUE)  # For base

# Clear plots
dev.off()

# Clear console
cat("\014") # ctrl+L


## 2. PACKAGES #####
```

Values

```
my_div     num [1:3] 3.48 3.18 2.15
my_sqrt    num [1:3] 0.316 2.828 1.463
old.dir    "/Users/dataavicenna"
x          9
y          9
z          num [1:3] 1.1 9 3.14
```

```
R version 4.4.1 (2024-06-14) -- "Race for Your Life"
Copyright (C) 2024 The R Foundation for Statistical Computing
Platform: aarch64-apple-darwin20

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
```

List the Files in a Directory/Folder

Description

These functions produce a character vector of the names of files or directories in the named directory.

Usage

```r
list.files(path = ".", pattern = NULL, all.files = FALSE,
           full.names = FALSE, recursive = FALSE,
           ignore.case = FALSE, include.dirs = FALSE, no.. = FALSE)

       dir(path = ".", pattern = NULL, all.files = FALSE,
           full.names = FALSE, recursive = FALSE,
```

The Four Panes in RStudio

1. **Script pane** (top left): Where you write, edit, and save R codes. Create reproducible documents. Note: You may use comments (#) to write notes in your script.
2. **Environment pane** (top right): List all objects in memory and tracks command history.
3. **Console pane** (bottom left): Where commands are executed. Shows results of code execution. Direct interaction with R.
4. **Files/Plots/Packages/Help** (bottom right):
   - File browser and working directory management
   - Display plots and visualizations
   - Install and load packages
   - Access documentation

Basic Operations

At its simplest level, R can function as an interactive calculator:

```
> 5+7
[1] 12
```

Instead of repeating calculations, we can store results in objects:

```
> x <- 5+7
```

The assignment operator (<-) stores values but doesn't display them automatically. You can print the value:

```
> x
[1] 12
```

More Arithmetic Operations

R supports all other common arithmetic operations useful for calculations:

```
# Multiplication
> 100*100
[1] 10000

# Square root and division
> sqrt(25) + (200/5)
[1] 45

# Exponentiation
> 1000 * (1.05)^3
[1] 1157.625
```

A Brief Look at Objects and Functions in R

- In R, we create objects by assigning values to names:

```
a <- 1                # a single value object
a <- c(1, 2, 3)       # vector with multiple elements
```

- Functions process input objects and return output objects:

```
# Using the built-in sum function
# Calculates sum and stores in new object
sum_of_a <- sum(a)
```

Atomic Objects in R

Atomic Objects

R has five types of atomic objects:

1. **numeric** objects are all real numbers on a continuous scale
   e.g., `1.23456`
2. **integer** are all full numbers
   e.g., `1`, typed as `1L`
   If you want an integer you have to explicitly use the `L` suffix.
   Otherwise, R will assign the number to the numeric class.
3. **complex** is used for complex numbers
   e.g., `a + bi`, i.e., real + imaginary

Atomic Objects in R

Atomic Objects (continued)

4. **boolean** values are logical values like `TRUE` and `FALSE`.
5. **strings** are characters [e.g., `"Hello World!"`].
   Use the `'` or the `"`.
   Note that all other atomic objects can be converted into strings.

Data Structures in R

These data structures organize atomic objects for different analytical needs:

- **Vectors**: several elements of a single atomic type
- **Matrices**: collections of equal-length vectors
- **Factors**: categorical data (ordered, unordered)
- **Data frames**: a data set, collections of equal-length vectors of *different* types
- **Lists**: collections of unequal-length vectors of *different* types

We'll focus primarily on vectors, which are fundamental for understanding all other data structures.

Vectors

- Vectors are one of the most fundamental data structures in R.
- Create vectors using the `c()` function ("combine" or "concatenate")
- Useful for storing related data (like time series, multiple observations, etc.)

Vectors

```
# Numeric vector
> y <- c(1, 2, 3, 4, 5)
> y
[1] 1 2 3 4 5

# Character vector
> hello <- c("Hello", "World")
> hello
[1] "Hello" "World"

# Mixing types (converts to most flexible type)
> mixed <- c(1, "text", TRUE)
> mixed
[1] "1"    "text" "TRUE"
```

Vector Operations

```
# Creating a vector
> prices <- c(10, 15, 20, 25)
# Operations apply to each element
> prices * 2  # Double all prices
[1] 20 30 40 50
# Calculate total revenue if quantities sold are:
> quantities <- c(5, 3, 2, 1)
> revenue <- prices * quantities
> revenue
[1] 50 45 40 25
# Get the total
> sum(revenue)
[1] 160
```

Vectors of Atomic Objects

R automatically assigns the correct object type. Let's look at this in practice: (Remember: Vectors only contain a single atomic type!)

```
x <- c(1.1, 2.2, 3.3)
is.numeric(x)
> [1] TRUE

x <- c(1L, 2L, 3L)
is.integer(x)
> [1] TRUE

x <- c(1+0i, 2+4i, 3+6i)
is.complex(x)
> [1] TRUE
```

Vectors of Atomic Objects

```
x <- c(TRUE, FALSE, TRUE)
is.logical(x)
> [1] TRUE

x <- c("I", "like", "R")
is.character(x)
> [1] TRUE

# Use the following commands to identify the object type:
typeof()
mode()
```

Exercise 1.1

1. Answer the following (type your answers in an R script or directly in the console):
   - Create a vector containing the numbers 1.1, 9, and 3.14. Store the result in a variable called `z`.
   - Create a new vector that contains `z`, 555, then `z` again in that order. Don't assign this vector to a new variable, so that we can just see the result immediately.
   - Take the square root of `z - 1` and assign it to a new variable called `my_sqrt` (Hint: Use the `sqrt()` function).
   - What do you think `my_sqrt` contains? (Choose one from below)
     a. a vector of length 0 (i.e., an empty vector)
     b. a vector of length 3
     c. a single number (i.e., a vector of length 1)

Exercise 1.1

2. Vector recycling.
   - For z containing the elements 1.1, 9, and 3.14, compute z * 2 + 100. After that, compute z * c(2, 2, 2) + c(100, 100, 100). Are the answers different?
   - Add c(1, 2, 3, 4) and c(0, 10). What do you observe?
   - Add c(1, 2, 3, 4) and c(0, 10, 100). What do you observe?

Logical Operators in R

Logical operators are (vectors of) TRUE and FALSE statements. They are helpful for example for checking outcomes.

Operator	Description
`<`	Test for less than
`<=`	Test for less than or equal to
`>`	Test for greater than
`>=`	Test for greater than or equal to
`==`	Test for equality
`!=`	Test for if not equality
`!x`	Boolean negation, for vectors
`x | y`	Boolean x OR y, for vectors
`x & y`	Boolean x AND y, for vectors
`x || y`	Boolean x OR y, for scalars
`x && y`	Boolean x AND y, for scalars
`isTRUE(x)`	Boolean test if X is TRUE, for scalars

Note: scalars = vectors of length one.

Logical Operators in R

Examples:

```
x <- 5; y <- 10
x < y           # TRUE
x == (2+3)      # TRUE
(x > 3) & (y < 20)  # TRUE (vector AND)
(x > 7) | (y == 10) # TRUE (vector OR)
is.logical(x < y)   # TRUE (returns logical value)
```

Factors: Categorical Vectors

- **Factors** are special vectors for categorical data (ordered and unordered). Examples:

```
# Creating a basic factor
education <- factor(c("High School", "Bachelor", "Master",
                      "Bachelor", "PhD", "High School"))
# Examining the factor
levels(education)  # Shows all unique categories
# [1] "Bachelor"    "High School" "Master"      "PhD"

# Creating a factor with custom levels and order
income_level <- factor(c("Medium", "Low", "High", "Medium", "Low
                      levels = c("Low", "Medium", "High"),
                      ordered = TRUE)
# Now we can use comparison operators
income_level[1] > income_level[2]  # TRUE - Medium > Low
```

Functions

Just like mathematical functions, e.g. $y = f(x)$, an R function receives one or multiple inputs, then does something with these inputs, and returns something.

- c() & sum() are examples of functions!

  ```
  > c(1, 2, 3)
  [1] 1 2 3
  > sum(1, 2, 3)
  [1] 6
  ```

- You can create your own functions:

  ```
  my_function <- function(x, y) {
    # Function body goes here
    return(x + y)
  }
  ```

Functions

- Create your own functions example:

```
> x <- c(1, 2); y <- c(2, 3)
> my_function <- function(x, y) {
  # Function body goes here
  return((x + y)/2)
}
> my_function(x, y)
[1] 1.5 2.5
```

Functions

- You can view function documentation with `?function_name`:

```r
?sum # Opens help for the sum() function
?c   # Opens help for the c() function
```

- R functions are polymorphic - their behavior adapts to the input type:

```r
# Summary of numeric vector
summary(1:10)
# Summary of factor
summary(factor(c("A", "B", "A")))
```

Common R Functions for Vectors

- `mean(x)` computes the mean
- `sd(x)` computes the sample standard deviation
- `var(x)` computes the sample variance
- `median(x)` computes the median of a vector
- `quantile(x,probs=...)` computes the supplied quantiles
- `summary(x)` summarizes the input object
- `cor(x,y)` computes the correlation of two vectors
- `cov(x,y)` computes the covariance of two vectors
- `abs(x)` takes the absolute value of a vector
- `sqrt(x)` takes the square root of a vector
- `log(x)` takes the natural logarithm
- `exp(x)` exponentiates the vector
- `min(x)` returns the minimum of a vector
- `max(x)` returns the maximum of a vector
- `sum(x)` returns the sum of a vector
- `prod(x)` returns the product of a vector
- `round(x, digits)` rounds to specified digits
- `trunc(x)` truncates the vector to an integer
- `cumsum(x)` returns the running sum of a vector

Functions in Practice

Examples:

```
gdp_growth <- c(2.1, 2.5, 3.0, 2.7, 1.8)
mean(gdp_growth)      # [1] 2.42
sd(gdp_growth)        # [1] 0.4764452
median(gdp_growth)    # [1] 2.5
summary(gdp_growth)   # Min: 1.80, 1st Qu: 2.10,
                    # Median: 2.50, Mean: 2.42,
                    # 3rd Qu: 2.70, Max: 3.00
```

Conditional Statements in R

- Sometimes code should only run under certain conditions
- Conditional statements let your code make decisions
- In R, we use `if`, `else if`, and `else` statements

Basic if statement

The basic syntax of an `if` statement:

```
if (condition) {
  # Code to execute when condition is TRUE
}
```

Example: Print a message if GDP growth is positive

```
gdp_growth <- 2.5  # Annual GDP growth rate

if (gdp_growth > 0) {
  print("The economy is growing")
}
# Output: [1] "The economy is growing"
```

if-else statements

Adding `else` for alternative actions:

```
if (condition) {
  # Code to execute when condition is TRUE
} else {
  # Code to execute when condition is FALSE
}
```

Example: Determine economic condition

```
gdp_growth <- -0.5  # Annual GDP growth rate

if (gdp_growth > 0) {
  print("The economy is growing")
} else {
  print("The economy is contracting")
}
# Output: [1] "The economy is contracting"
```

if-else if-else statements

Multiple conditions with `else if`:

```r
if (condition1) {
  # Code for condition1 TRUE
} else if (condition2) {
  # Code for condition1 FALSE, condition2 TRUE
} else {
  # Code for all conditions FALSE
}
```

Example: Classify economic conditions

```r
gdp_growth <- 1.2  # Annual GDP growth rate

if (gdp_growth > 5) {
  print("Strong economic growth")
} else if (gdp_growth > 0) {
  print("Moderate economic growth")
} else if (gdp_growth > -1) {
  print("Economic slowdown")
} else {
  print("Economic recession")
}
```

The ifelse() Function

R has a vectorized `ifelse()` function for element-wise operations:

```
ifelse(test, yes, no)
```

This is much faster than using loops with if-else for vectors:

```
# Create vector of growth rates for different regions
regional_growth <- c(2.1, -0.5, 3.2, 0.1, -1.2)

# Classify each region
region_status <- ifelse(regional_growth > 0,
                        "growing",
                        "contracting")

region_status
# [1] "growing" "contracting" "growing" "growing" "contracting"
```

Assignment 1

You need to submit your answers to this assignment to obtain a training certificate. Submit your R script to this link: `https://tinyurl.com/R-Assignment-1-2025`. Contact `dataavicenna@mail.ugm.ac.id` for any questions.

Submission deadline: **13 May 2025 at 23.59pm**

Assignment 1

Write your answers in an R script:

1. Create a vector consisting of integers from 0 to 1000 and assign it to a variable called A. Use the appropriate functions to calculate the mean, standard deviation, and median of A.
2. Logical operations with vectors:
    a. Create a vector gdp_growth containing the values 2.1, 2.5, 3.0, 2.7, and 1.8.
    b. Create logical vectors that identify: (i) Which values are greater than 2.5; (ii) Which values are less than or equal to 2.0; (iii) Which values are exactly 2.7. Store each of the logical vector into an R object and name them however you want.
    c. Use the sum() function on each of these logical vectors. What does the result represent?
    d. Create a single logical vector that identifies which values are between 2.0 and 3.0 inclusive (those equal to 2 or 3 should also be included).

References

Schmidt, S. S., & Turbanisch, F. (n.d.). *Economic Analysis with R*. University of Göttingen. Retrieved from `https://economic-analysis-with-r.uni-goettingen.de/`

Team swirl. (n.d.). *R Programming*. GitHub. Retrieved from `https://github.com/swirldev/swirl_courses`

Appendix: R Time-Saving Tricks

- Use the up arrow ↑ on your keyboard to cycle through previous commands in your Console.
- If you forgot the name of a variable that you have created, type the first two letters of the variable name, then hit the Tab key. A list of variables will appear.
- R script shortcuts: (Use Command instead of control in MacOS)
  a. CTRL + SHIFT + N to create a new R script
  b. CTRL + SHIFT + ENTER to run all lines
  c. CTRL + ALT + B to run until current line (Command + Option + B in MacOS)
  d. CTRL + ENTER to run the code line by line while ignoring comments
  e. rm(list = ls()) → code to remove all objects in the environment
  f. CTRL + L to clean the console