Coding for Reproducible Research

R Training for NISR

Luiza Andrade, Leonardo Viotti & Rob Marty

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TRANSFORM DEVELOPMENT

1. Introduction

2. Commenting

3. Creating a document outline in RStudio

4. Initial Settings

5. Using packages

6. Indenting

7. Functions inception

8. Section switches

Outline

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Agenda

Objective

Create an R Master Script.

Content

1. Comments
2. Using R Studio to create a code index
3. Indenting
4. File paths
5. If statements
6. Using functions within functions
7. Packages
8. Loops

Objectives

- The exercises on this section will help us create a Master R script
- To do them, go to the `Code` folder an open the file called *Lab 2 - Coding for Reproducible Research.R*
- A master script It's not specific to R, it's just good programing practice. Here we'll use it as an example to show you important features of R programing.

Master Script

- A Master script is the easiest way to guarantee the replicability of your data work
- It has three main functions:

1. Run all the scripts for your project
    - Without a master script, you either need to have one extremely long script, or write instructions about the order in which they should be run

Master Script

2. Create a road map to all data work
    - You should be able to reproduce all your work from raw data to all outputs by just running the master
    - Anyone should be able to follow and understand your work by reading the master

Master Script

3. Allow easy collaboration
    - If we share a project over DropBox or OneDrive all team member have the same folder structure
    - A master script allows multiple people to set their own file paths to the project folder
    - This way anyone sharing the project folder can easily run your codes

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Commenting

- Comments is text that R will ignore when running your code
- Comments are the difference between instructions that are easy to follow or impossible to understand
- Comments are used to document two things:
    1. What is being done in a given section of the code
    2. Why it is being done
- Number 2 is what makes the difference between a well-commented code and a code that is just commented

Commenting

- Let's take a look at the script we just opened
- You can see that the first few lines in the script are the header, but they're not commented out
- In R, errors will not always break your code, so you should still be able to run this script
- However, not commenting out comments is still bad practice, as it makes the code harder to read

Commenting

- To comment a line, write # as its first character
- You can also add # half way through a line to comment whatever comes after it
- In Stata, you can use `/*` and `*/` to comment part of a line's code. That is not possible in R: whatever comes after # will be a comment
- To comment a selection of lines, press `Ctrl + Shift + C`

Commenting

Exercise 1

Use the keyboard shortcut to comment the header of the script.

Exercise 2

Use the keyboard shortcut to comment the header of the script again. What happened?

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Creating a document outline in RStudio

- RStudio also allows you to create an interactive index for your scripts
- To add a section to your code, create a commented line with the title of your section and add at least 4 trailing dashes, pound signs or equal signs after it

Exercise 3

Open the script index and make `PART 0` a section header. Do the same for `PART 1`.

Exercise 4

Note that once you create a section header, an arrow appears right next to it. Click on the arrows of parts 0 and 1 to see what happens.

Creating a document outline in RStudio

- The outline can be accessed by clicking on the button on the top right corner of the script window. You can use it to jump from one section to another
- You can also use the keyboard shortcuts `Alt + L` (`Cmd + Option + L` on Mac) and `Alt + Shift + L` to collapse and expand sections

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Initial Settings

- A Stata do-file typically starts with a few settings:

```
clear
set maxvar 120000
set more off
```

Initial Settings

- We don't need to set the memory or the maximum number of variables in R, and `more` is automatically selected
- However, if you saved the last RStudio session in `.Rhistory`, the objects that were in RStudio's memory last time you closed it will still be there whenever you open it again
- Therefore, it's good practice to always clean the memory when starting a new session
- You can see all the objects currently in you memory in the *Environment* pane

Initial Settings

Exercise 5

1. Make sure the *Environment* window is open (it should be empty now)
2. Create an object called `foo` with any content you pick
3. Type `ls()` to print the names of the object in memory
4. Type `rm(foo)` to remove it
5. To remove all objects, use `rm(list=ls())`

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Using packages

- Since there is a lot of people developing for R, it can have many different functionalities
- To make it simpler, these functionalities are bundled into packages
- A package is the fundamental unit of shareable code
- It may contain new functions, but also more complex functionalities, such as a Graphic User Interface (GUI) or settings for parallel processing (similar to Stata MP)
- They can be shared through R's official repository - CRAN (10,000+ packages reviewed and tested) and many other online sources
- There are many other online sources such as Github, but it's important to be careful, as these probably haven't gone through a review process as rigorous as those in CRAN

Using packages

- To install and use packages you can either do it with the user interface or by the command prompt.

```r
# Installing a package
install.packages("stargazer",
                 dependencies = T)
# the dependencies argument also installs all other packages
# that it may depend upon
```

- You only have to install a package once, but you have to load it every new session. To load a package type:

```r
library(stargazer)
```

Using packages

Once a package is loaded, you can use its features and functions. Here's a list of some useful and cool packages:

- `Rcmdr`: Easy to use GUI
- `swirl`: An interactive learning environment for R and statistics.
- `ggplot2`: beautiful and versatile graphics (the syntax is a pain, though)
- `stargazer`: awesome latex regression and summary statistics tables
- `foreign`: reads dtas and other formats from other statistical software
- `zoo`: time series and panel data manipulation useful functions
- `data.table`: some functions to deal with huge data sets
- `sp and rgeos`: spatial analysis
- `multiwayvcov` and `sandwich`: clustered and robust standard errors
- `RODBC`, `RMySQL`, `RPostgresSQL`, `RSQLite`: for relational databases and using SQL in R.

Using packages

Exercise 6

Install the `swirl` and `stargazer` packages, including packages necessary for them to run.

- TIP: use the helpfile to `install.packages` by typing `?install.packages` if you're not sure about how to do this.

Using packages

```r
# Install stargazer and swirl
install.packages(c("stargazer", "swirl"),
                 dependencies = TRUE)
```

Using packages

Exercise 7

Call the packages you just installed. Note that the `library` function only accepts one argument, so you will need to load each of them separately.

Using packages

```r
library(stargazer)
```

```
##
## Please cite as:

##  Hlavac, Marek (2018). stargazer: Well-Formatted Regression and Summary Statisti

##  R package version 5.2.2. https://CRAN.R-project.org/package=stargazer
```

```r
library(swirl)
```

```
##
## | Hi! Type swirl() when you are ready to begin.
```

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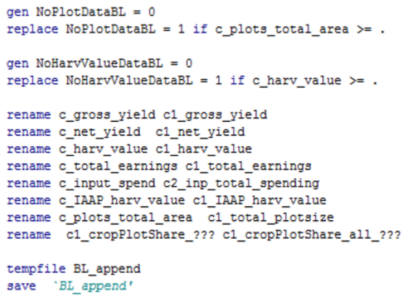
Indenting

- R does not distinguish between one empty space and many empty spaces, or one line break or many line breaks
- However, white space makes a big difference to the human eye and we would never share a Word document, an Excel sheet or a PowerPoint presentation without thinking about white space - although we call it formatting

Indenting

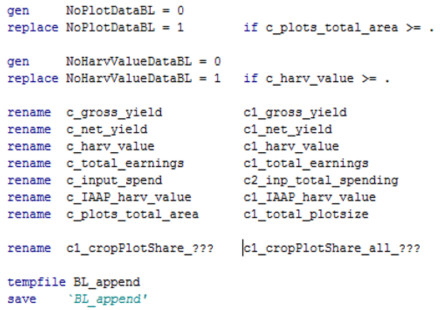


```
gen NoPlotDataBL = 0
replace NoPlotDataBL = 1 if c_plots_total_area >= .

gen NoHarvValueDataBL = 0
replace NoHarvValueDataBL = 1 if c_harv_value >= .

rename c_gross_yield c1_gross_yield
rename c_net_yield  c1_net_yield
rename c_harv_value c1_harv_value
rename c_total_earnings c1_total_earnings
rename c_input_spend c2_inp_total_spending
rename c_IAAP_harv_value c1_IAAP_harv_value
rename c_plots_total_area  c1_total_plotsize
rename  c1_cropPlotShare_??? c1_cropPlotShare_all_???

tempfile BL_append
save  `BL_append'
```



```
gen     NoPlotDataBL = 0
replace NoPlotDataBL = 1        if c_plots_total_area >= .

gen     NoHarvValueDataBL = 0
replace NoHarvValueDataBL = 1   if c_harv_value >= .

rename  c_gross_yield           c1_gross_yield
rename  c_net_yield             c1_net_yield
rename  c_harv_value            c1_harv_value
rename  c_total_earnings        c1_total_earnings
rename  c_input_spend           c2_inp_total_spending
rename  c_IAAP_harv_value       c1_IAAP_harv_value
rename  c_plots_total_area      c1_total_plotsize

rename  c1_cropPlotShare_???    c1_cropPlotShare_all_???

tempfile BL_append
save    `BL_append'
```

Indenting

- Indenting in R can be pretty different from what it looks like in Stata
- To indent a whole line, you can select that line and press `Tab`
- To unindent a whole line, you can select that line and press `Shift + Tab`
- However, this will not always work for different parts of a code in the same line
- In R, we typically don't introduce white space manually
- It's rather introduced by RStudio for us

Indenting

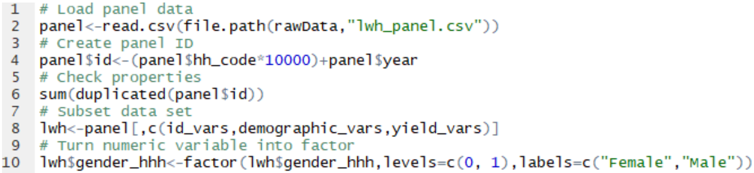
Exercise 8

To see an example of how indenting works in RStudio, add a line between the two arguments of the `install.packages` function (the vector of package names and the dependents option). Then add a line between the two package names. Note that RStudio formats the different arguments of the function differently.

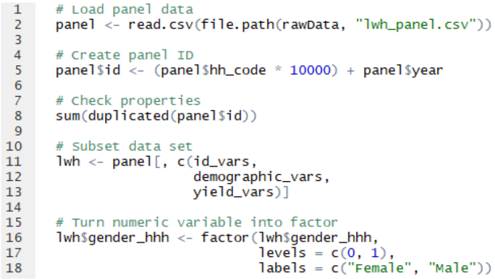
Indenting

```
# Same code, but this time easier to read
install.packages(c("stargazer",
                   "swirl"),
                 dependencies = TRUE)
```

Indenting



```
# Load panel data
panel<-read.csv(file.path(rawData,"lwh_panel.csv"))
# Create panel ID
panel$id<-(panel$hh_code*10000)+panel$year
# Check properties
sum(duplicated(panel$id))
# Subset data set
lwh<-panel[,c(id_vars,demographic_vars,yield_vars)]
# Turn numeric variable into factor
lwh$gender_hhh<-factor(lwh$gender_hhh,levels=c(0, 1),labels=c("Female","Male"))
```



```
# Load panel data
panel <- read.csv(file.path(rawData, "lwh_panel.csv"))

# Create panel ID
panel$id <- (panel$hh_code * 10000) + panel$year

# Check properties
sum(duplicated(panel$id))

# Subset data set
lwh <- panel[, c(id_vars,
                 demographic_vars,
                 yield_vars)]

# Turn numeric variable into factor
lwh$gender_hhh <- factor(lwh$gender_hhh,
                         levels = c(0, 1),
                         labels = c("Female", "Male"))
```

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Functions inception

- In R, you can use the output of one function as the input of another, as long as they have the same format
- In fact, that's exactly what we just did when installing the packages
- To see that, select just the first argument of the `install.packages` function and press `Ctrl + Enter`
- The `c()` function, as we know, creates a vector with its arguments

```
c("stargazer", "swirl")
```

```
## [1] "stargazer" "swirl"
```

Functions inception

- The resulting vector is used as an input to the `install.packages` function
- We could also have stored this vector in the memory as an object and used that object as the input
- In fact, that's exactly what we are going to do next, so the code doesn't get too polluted as we add new packages

Functions inception

```
# Create packages object
packages <- c("stargazer",
              "swirl")

# Use it as an input to the install.packageS() function
install.packages(packages,
                 dependencies = TRUE)
```

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Section switches

- Now, installing packages can be time-consuming, especially as the number of packages grow, and each package only needs to be installed once
- Adding switches to select what parts of the code to run allows you to only install the packages when you're using a computer that doesn't have them installed yet
- Adding switches is more efficient than commenting parts of the code out, because you can see all switches before running the code, so that avoids the mistake of saving a code with a commented section and forgetting to uncomment it later
- In Stata, section switches would be saved as locals. In R, the equivalent to that would be to create a new object

If statements

- To add a switch, you first create a dummy object with a self-explanatory name
- Then, you create an if statement that runs the code if that switch is on
- If statements in R look like this:

```r
# Turn switch on
PRINT_NAME <- 1

# Install packages
if (PRINT_NAME == 1) {
  print(Sys.getenv("USERNAME"))
}
```

Section switches

Exercise 10

Create a switch called INSTALL_PACKAGES and an if statement that only runs the `install.packages` function if the switch is activated.

- TIP: Section switches can also be Boolean objects.

Section switches

```r
# Turn switch on
INSTALL_PACKAGES <- 1

# Install packages
if (INSTALL_PACKAGES == 1) {
  install.packages(packages,
                   dependencies = TRUE)
}
```

Section switches

- Possible variations would include

```
# Turn switch on
INSTALL_PACKAGES <- TRUE

# Using a Boolean object
if (INSTALL_PACKAGES == TRUE) {
  install.packages(packages, dep = T)
}

# Which is the same as
if (INSTALL_PACKAGES) {
  install.packages(packages, dep = T)
}
```

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File paths

- The next important part of a Master script are file paths
- We suggest always using **explicit** and **dynamic** file paths

File paths

- Implicit and static file path:

```
# Set working directory
setwd("C:/Users/luiza/Documents/GitHub/R-Training/
      DataWork/DataSets/Final")

# Load data set
read.csv("lwh_clean.csv",
          header = T)
```

File paths

- Explicit and static file path:

```
# Load data set
read.csv("C:/Users/luiza/Documents/GitHub/R-Training/
         DataWork/DataSets/Final/lwh_clean.csv",
          header = T)
```

File paths

- Explicit and dynamic file path:

```r
# Define dynamic file path
finalData <- "C:/Users/luiza/Documents/GitHub/R-Training/
              DataWork/DataSets/Final"

# Load data set
lwh <- read.csv(file.path(finalData,"lwh_clean.csv"),
                header = T)
```

File paths

- Using dynamic file paths makes collaboration easier, since every user only needs to add their folder path once before running all the codes
- Using explicit file paths prevents mistakes. For example, when running just a few lines of code instead of the whole script, it's common to forget to run the line setting the directory and have output saved in the wrong folder

File paths

- File paths in R, as in Stata, are basically just strings
- Note, however, that in R we can only use forward slashes (/) to separate folder names

Exercise 11

Let's start by adding the folder path to the training's folder in your computer to the beginning of `PART 3`.

File paths

- You can set file paths in your master using the `file.path()` function
- This function concatenates strings using / as a separator to create file paths

File paths

```
# Project folder
projectFolder  <-
  "C:/Users/luiza/Documents/GitHub/R-Training"

# Data work folder
dataWorkFolder    <- file.path(projectFolder,"DataWork")

# Print data work folder
dataWorkFolder
```

```
## [1] "C:/Users/luiza/Documents/GitHub/R-Training/DataWork"
```

File paths

Let's check if that worked, as we will need your Master script to be running smoothly for the other sessions.

Exercise 12

1. Turn off the switch that installs packages in your Master script
2. Run the whole script
3. Type the following code to open a data set using the file paths you just set:

```
# Load data set
lwh <- read.csv(file.path(rawData,"lwh_panel.csv"),
                header = T)
```

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Looping

- We're almost at the end of this section
- But the DRY rule can still be applied to part of this code

```
# The DRY rule:
DONT REPEAT YOURSELF
```

Don't repeat yourself

- This is a rule borrow from computer science
- When coding, we often have to repeat the same operation multiple times
- If you do this by just copying and pasting a piece of code and changing a few arguments, it's easy to make mistakes such as forgetting to change the argument once or changing the wrong argument
- Copying and pasting a piece of code multiple times can also make your code really long and difficult to read
- Creating a loop may take more time to set up, but it's easier to read and reduces mistakes
- In particular, fixing bugs and adjusting the code is much quicker, since you only need to do it once

Looping

- In Stata, we'd usually use a `foreach` loop to go through a list of objects
- The equivalent to that in R would be to write a for loop like this

```
# A for loop in R
for (number in c(1.2,2.5)) {
    print(round(number))
}
```

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

Looping

- R, however, has a whole function family that allows users to loop through an object in a more efficient way
- They're called `apply` and there are many of them, for different use cases.
- For the purpose of this training, we will only use two of them, `sapply` and `apply`
- If you look for the `apply` help file, you can see all of them

Looping

- `sapply(X, FUN, ...)`: applies a function to all elements of a vector or list and returns the result in a vector. Its arguments are
  - **X:** a matrix (or data frame) the function will be applied to
  - **FUN:** the function you want to apply
  - **`...`:** possible function options

```r
# A much more elegant for loop in R
sapply(c(1.2,2.5), round)
```

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

Looping

Exercise 13

Use the `sapply()` function to apply the `library()` function to all packages you have selected. TIP: Set the `character.only` argument equal to `TRUE`

Looping

```r
# Load all listed packages
sapply(packages,
       library, character.only = TRUE)
# it's necessary to use the character.only option because
# originally the library function did not accept strings
```

Looping

A more generic version is the `apply` function.

- `apply(X, MARGIN, FUN, ...)`: applies a function to all columns or rows of matrix. Its arguments are
  - **X:** a matrix (or data frame) the function will be applied to
  - **MARGIN:** 1 to apply the function to all rows or 2 to apply the function to all columns
  - **FUN:** the function you want to apply
  - **...:** possible function options

Looping

```r
# Create a matrix
matrix <- matrix(c(1, 24, 9, 6, 9, 4, 2, 74, 2),
                 nrow = 3)

# Look at the matrix
matrix
```

```
##      [,1] [,2] [,3]
## [1,]    1    6    2
## [2,]   24    9   74
## [3,]    9    4    2
```

Looping

```r
# Row means
apply(matrix, 1, mean)
```

```
## [1]  3.00000 35.66667  5.00000
```

```r
# Column means
apply(matrix, 2, mean)
```

```
## [1] 11.333333  6.333333 26.000000
```

That's all, folks

- Now you have a template master script to use across this training's sessions
- Save the script that you created during this session in the *DataWork* folder. Call it *MASTER.R*
- You can run scripts from the Master script by using the `source()` function as you write scripts for future sessions, but we will do that on the next session

That's all, folks

Homework

In the next slide here's a list of all the packages we'll need for the next sessions. Installing them might take a while, so paste them to your Master script and run it again before the next session:

```r
packages  <- c("readstata13","foreign",
               "doBy", "broom",
               "stargazer",
               "ggplot2", "plotly", "ggrepel",
               "RColorBrewer",
               "sp", "rgdal", "rgeos", "raster", "velox",
               "ggmap", "rasterVis", "leaflet")
```

Thank you!

Bonus exercise

- You can customize your loops in R by defining your own function
- This is done using a function conveniently called `function()`
- For example, if instead of just printing a number we want to print it's square, we could create a function that does both:

```r
# A much more elegant for loop in R
sapply(c(1,2), function(x) x^2)
```

```
## [1] 1 4
```