Lecture 1: An Introduction & Motivation for R Programming + Installing Packages and Reading Data

Harris Coding Camp – Accelerated Track

Summer 2022

Who are we and why are we here?

Teaching Members

- Instructors
  - Standard Track: Arthur Cheib, Sheng-Hao Lo
  - Accelerated Track: Ari Anisfeld
- Head TA: Rubina Hundal
  - All logistics issues
- You will also have several TAs who will be helping you along the way!
  - TA sessions
  - Canvas Discussion Board

Why learn coding?

Policy jobs and the Harris curriculum rely on coding

- to quickly engage with policy data
- to conduct statistical analyses
- to make transparent, reproducible analyses

Examples

- Determine number of people eligible for debt relief
- Measure impact of debt forgiveness on future aid take-up

What policy problems do you want to tackle with data?

Gauging your background

Most of you have some data experience. What are you bringing?

- Excel / Sheets
- Stata
- R
- Python
- C++? Julia? SPSS? SAS? Other software / languages?
- Excited for a challenge?

Why R?

- R is a powerful programming language and statistical software environment
  - Great data manipulation and visualization suite
  - Strong statistical packages (e.g. program evaluation, machine learning)
- Open source and free
- Complete programming language with low barriers to entry
- We will use R for the entire Stats sequence in Fall and Winter

What will I learn?

This is just the beginning!

Camp covers:

0. Motivation/Installation of R *[Today]*
1. Installing Packages and Reading Data *[Today]*
2. Basic Data Manipulation and Analysis *[3]*
3. Data Visualization *[1]*
4. More on Data Manipulation *[3]*
   - Grouped Analysis, Iteration, Functions

In Stats 1/2 and other courses, you will build off of these lessons

Learning philosophy

- You are learning a (new) language
- Coding can be frustrating
- Coding requires a different modality of thinking
- We learn by producing code and experimenting

Coding lab is for you

How will we progress?

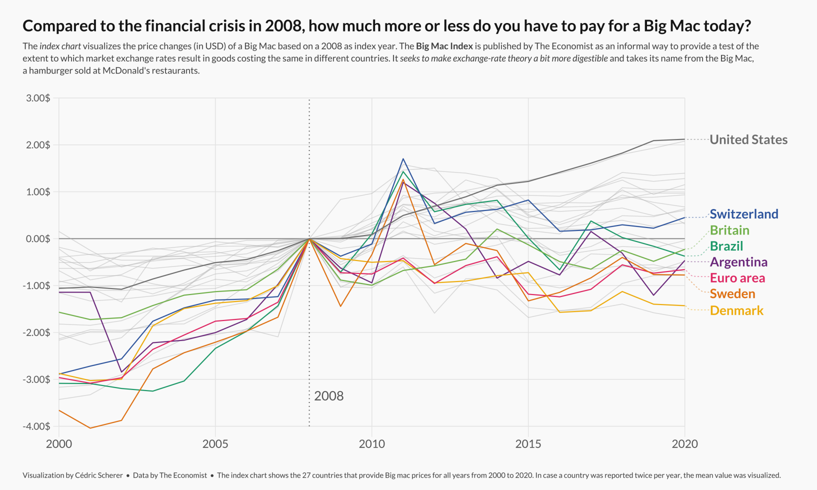
1. Live lectures:
   - Focus on main idea first
   - Try it yourself – you learn coding by coding!
2. Practice in TA sessions (Most important part!):
   - Learn coding by coding!
   - Work on problems with peers and have TA support
3. Additional help:
   - logistics: email Head TA
   - coding: Post questions to Canvas Discussion Board
4. Final project

Final project (optional)

You'll know you're ready for policy school coding, if you can open a data set of interest to you and produce meaningful analysis. For the final project, you will:

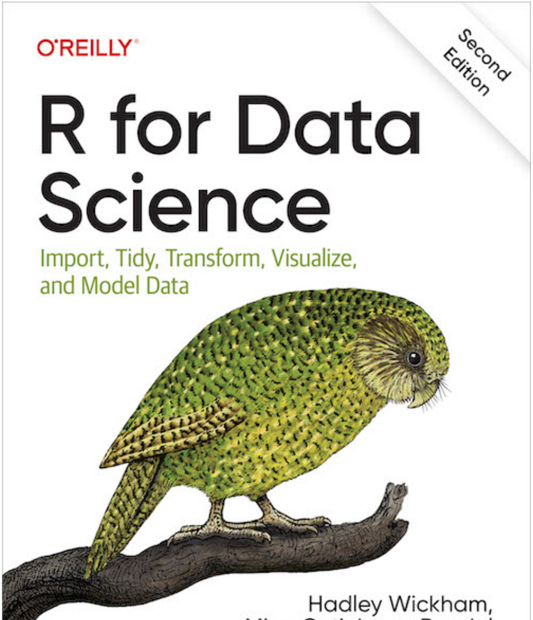
- Pick a data set aligned with your policy interests (or not)
- Use programming skills to engage with data and make a data visualization showing something you learned from the data

Final project goal



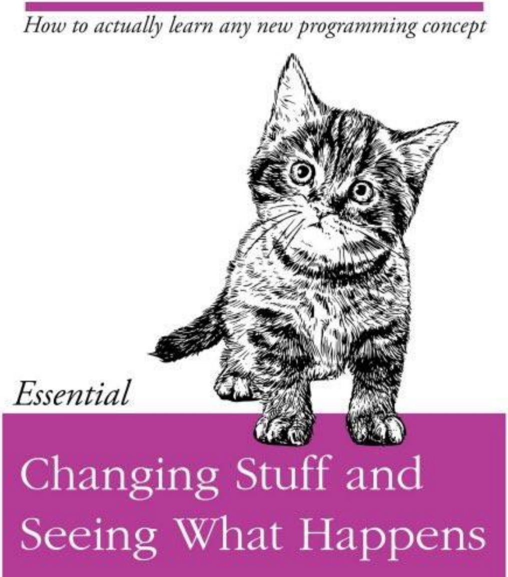
Textbooks and Resources

- Get situated with R for Data Science http://r4ds.hadley.nz/

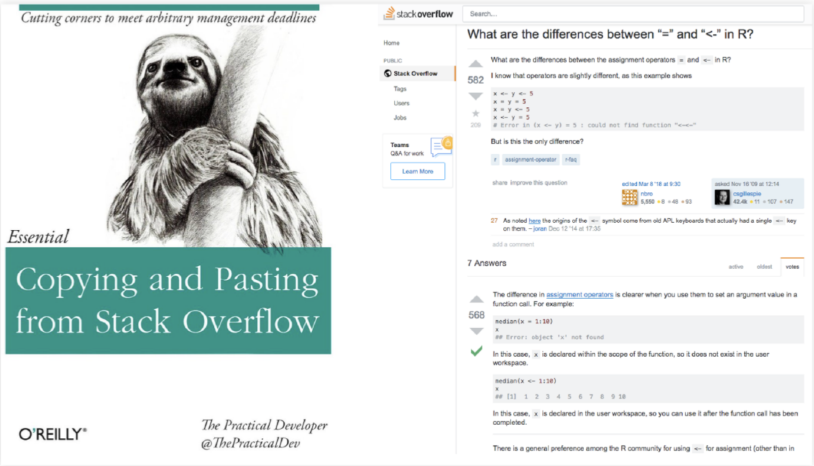


Textbooks and Resources

- Run code in the console. Change code and re-run. Does it make sense?



Learn to make it before your fake it.



- Google - Stack Overflow - ChatGPT

Provide credit where credit is due.

A quick introduction to R and RStudio

Using R and RStudio

We will

- Discuss what RStudio is
- Learn the basics of R
- Extend R with packages
- Bring data into R

What's the difference between R and RStudio?

R is a programming language–all the nuts and bolts.

RStudio provides tools that make it easier to use R

- It's an "integrated development environment" (IDE) for R

Demo (see appendix for material)

Try it yourself

1. $30 + 6 \times 5^8 - \log(50) = ?$
2. $-1^2 * (8 - \sqrt{16}) = ?$
3. $568 \times \frac{135}{\log(1)} = ?$
4. $\frac{15^0 - 1}{0} = ?$

Try it yourself: Did you get ..

```
30 + 6*5^8 - log(50)
```

```
## [1] 2343776
```

```
(-1)^2 * (8 - sqrt(16)) # ambiguous (-1)^2 or -1^2
```

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

```
568*135/log(1) # Inf is infinity (-Inf is negative)
```

```
## [1] Inf
```

```
(15^0 - 1)/0 # NaN means Not a Number
```

```
## [1] NaN
```

Comparison and Logical Operators

Compare two objects and give back a *Boolean*

```r
7 > 5  # greater than
```

```
## [1] TRUE
```

```r
7 < 5  # less than
```

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

```r
7 >= 5 # greater than or equal to
```

```
## [1] TRUE
```

Compare two objects and give back a *Boolean*

```r
7 <= 5 # less than or equal to
```

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

```r
7 == 5 # "is equal to"
```

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

```r
7 != 5 # "is not equal to"
```

```
## [1] TRUE
```

Notice: == is a comparison operator, = is an assignment operator

Logic operators

- `&` (and): Return `TRUE` if **both** terms are true
- `|` (or): Return `TRUE` if **either** terms are true
- `!` (not): Return the opposite. (not true is false)

& (and): Return `TRUE` if **both** terms are true

- TRUE & TRUE -> `TRUE`
- TRUE & FALSE -> `FALSE`
- FALSE & TRUE -> `FALSE`
- FALSE & FALSE -> `FALSE`

```r
(5 < 7) & (6 * 7 == 42)
```

```
## [1] TRUE
```

& (and): Return `TRUE` if **both** terms are true

```
(5 < 7) & (6 * 7 < 42)
```

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

```
(5 > 7) & (6 * 7 == 42)
```

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

| (or): Return `TRUE` if **either** terms are true

- TRUE | FALSE -> `TRUE`
- FALSE | TRUE -> `TRUE`
- TRUE | TRUE -> `TRUE`
- FALSE | FALSE -> `FALSE`

```r
(5 < 7) | (6 * 7 < 42)
```

```
## [1] TRUE
```

| (or): Return TRUE if **either** terms are true

```
(5 > 7) | (6 * 7 == 42)
```

```
## [1] TRUE
```

```
(5 > 7) | (6 * 7 != 42)
```

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

Try it yourself

Guess the output and then run the code to check your answer:

```
x <- 6
(x < 9) & (x > 3)
(x < 9) & (x > 7)
(x > 8) | (x > 9)
```

```
x <- 20
y <- 30
(x == 20) & (y != 30)
(x != 20) | (y == 50)
(x < 200)  | (log(0.04978) + y/10 == 0)
```

`NA` means Missing or Not Available

Common source of headaches

```r
NA + 4
```

```
## [1] NA
```

NA requires it's own test

```
5 == NA
```

```
## [1] NA
```

```
is.na(5)
```

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

```
5 != NA
```

```
## [1] NA
```

```
!is.na(5)
```

```
## [1] TRUE
```

Reference slide

<table>
<tr><th>operator</th><th>definition</th><th>operator</th><th>definition</th></tr>
<tr><td><</td><td>less than</td><td>x | y</td><td>x OR y</td></tr>
<tr><td><=</td><td>less than or equal to</td><td><code>is.na(x)</code></td><td>test if x is NA</td></tr>
<tr><td>></td><td>greater than</td><td><code>!is.na(x)</code></td><td>test if x is not NA</td></tr>
<tr><td>>=</td><td>greater than or equal to</td><td><code>x %in% y</code></td><td>test if x is in y</td></tr>
<tr><td>==</td><td>exactly equal to</td><td><code>!(x %in% y)</code></td><td>test if x is not in y</td></tr>
<tr><td>!=</td><td>not equal to</td><td>!x</td><td>not x</td></tr>
<tr><td><code>x & y</code></td><td>x AND y</td><td></td><td></td></tr>
</table>

Variables and names

Basic syntax: Variable assignment

We can think of a variable as a *container* with a name, such as

- `x`
- `stats_score`
- `harris_gpa_average`

Each container can contain *one or more* values

Basic syntax: Variable assignment

We use <- for assigning variables in R.

```
my_number <- 4
my_number
```

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

You can also use = for assigning variables

```
x = 5
x
```

```
## [1] 5
```

Variable assignment

We can re-assign a variable as we wish.

```
sqrt((12 * my_number) + 1)
```

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

```
my_number <- 2
sqrt((12 * my_number) + 1)
```

```
## [1] 5
```

Variable assignment: Use meaningful names

We assign all sorts of objects to names including data sets and statistical models so that we can refer to them later.

- **use names that are meaningful**

```
# not so good
s <- Z / secs

# better
speed <- distance / time

# not so good
x <- read_csv("fed_data.csv")

# better
fed_data <- read_csv("fed_data.csv")
```

Add comments using the # character

- Lets **future you** and teammates to follow what code is doing

```
# if you can do it with a name BETTER!, but
my_number <- 4 # sometimes you need more info.
```

- Anything after # is ignored by R when executes code

Functions

Using functions

Functions are procedures that take an input and typically provide an output.

```
sqrt(4)
```

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

```
median(c(3, 4, 5, 6, 7 ))
```

```
## [1] 5
```

Capture outputs with names for later use

```r
# mtcars is a built-in data set
# so you can run this locally!
lm(mpg ~ disp +  cyl, data = mtcars)
```

```
##
## Call:
## lm(formula = mpg ~ disp + cyl, data = mtcars)
##
## Coefficients:
## (Intercept)         disp          cyl
##    34.66099     -0.02058     -1.58728
```

```r
# notice no print out
model_fit <- lm(mpg ~ disp +  cyl, data = mtcars)
```

Function arguments

Function inputs are called arguments.

Functions know what the argument refers to based on

- name
- position

Arguments interpreted by *name*

I wrote a function `f` that expects `x` and `y` and returns `2*x + y`

```
# 2 * 7 + 0
f(x = 7, y = 0)
```

```
## [1] 14
```

Bad example for demonstration purposes only

```
# 2 * 0  + 7
f(y = 7, x = 0)
```

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

Arguments interpreted by *position*

I wrote a function `f` that expects `x` and `y` and returns `2*x + y`

```
# identical to f(x = 7, y = 0)
f(7, 0)
```

```
## [1] 14
```

Finding help with ?

```
?sum
```

- Description

```
sum returns the sum of all the values present in its arguments.
```

- Usage (API)

```
sum(..., na.rm = FALSE)
```

- Arguments

```
...    numeric or complex or logical vectors.
```

- Examples (scroll down!)

```
sum(1, 2, 3, 4, 5)
```

How to start working with data and packages

What are packages?

Packages are collections of *functions* and *data sets* developed by the community.

Benefits:

- Don't need to code everything from scratch (those are powerful tools!)
- Often functions are optimized using C or C++ code to speed up certain steps

installing and loading packages

To use a package we need two steps:

- install/download once from the internet

```
install.packages("readxl")  # do this one time
                            # directly in console
```

- load it *each time* we restart R

```
library(readxl) # add this to your script / Rmd
                # every time you want to use
read_xlsx("some_data.xls")
```

- `package::command()` lets you call a function without loading the library

```
readxl::read_xlsx("some_data.xls")
```

Q: What goes wrong here?

The package ‘readr’ provides a function to read .csv files called `read_csv()`.

```
install.packages("readr")
our_data <- read_csv("my_file.csv")

Error in read_csv("my_file.csv") :
  could not find function "read_csv"
```

A: We need to load the package using `library()`!

```
library(readr)
our_data <- read_csv("my_file.csv")
```

We can also use with one line of code:

```
our_data <- readr::read_csv("some_data.xls")
```

tidyverse: set of useful packages

Think of the tidyverse packages providing a new dialect for R.

```
library(tidyverse)
## -- Attaching packages ---------------------------------------
## v ggplot2 3.3.0  v purrr   0.3.4
## v tibble  2.1.3  v dplyr   0.8.5
## v tidyr   1.0.2  v stringr 1.4.0
## v readr   1.3.1  v forcats 0.5.0
## -- Conflicts ------------------------------------------
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

Try it yourself

Say we'd like to conduct data analysis using some powerful tools:

```r
# Run in console -- you only need to do this once!
install.packages("tidyverse")

# Add to your script -- re-run everytime
library(tidyverse)
storms
head(storms)
```

See the Data

- `View()`: look at the details of data (`view()` works if tidyverse loaded)
- `glimpse()`: structure of data frame – name, type and preview of data in each column
- `summary()`: displays min, 1st quartile, median, mean, 3rd quartile and max
- `head()`: shows first 6 rows

```
View(wealth_data)     # base
glimpse(wealth_data) # tidyverse
summary(wealth_data) # base
head(wealth_data)     # base
```

Attributes of the Data

- `names()` or `colnames()`: both show the names of columns of a data frame
- `nrow()`: number of rows
- `ncol()`: number of columns
- `dim()`: returns the dimensions of data frame (i.e. number of rows and number of columns)

```
names(wealth_data)
nrow(wealth_data)
ncol(wealth_data)
dim(wealth_data)
```

Try it yourself: Dataset `storms`

- Look at the data in multiple ways. What do you see?
- What are the names of all the columns/variables in `storms`?
- How many rows/observations are included?
- How many columns/variables are included?

Code bank: `names()`, `nrow()`, `ncol()`, `View()`, `glimpse()` and `head()`

Loading in data

Loading data is as easy as . . .

```r
library(readr)
housing_data <- read_csv("texas_housing_data.csv")
```

This requires that you consider:

- Format
- File location

Most common formats and their readers

file type	package	function
.csv	readr (tidyverse)	`read_csv()`
.csv	utils (base R)	`read.csv()`
.dta (stata)	haven	`read_dta()`
.xlsx	readxl	`read_xlsx()`

File location

Where on your computer is the data stored?

- You'll need to understand your file system

Detour: directory structure

Each file has a unique "address" or **file path**.

- `~/Documents/coding_lab/texas_housing_data.csv`

The files are stored in folders or directories, the "zip codes".

- `~/Documents/coding_lab/`

In Windows, file paths usually start with `C://...`

Detour: working directory

The ‘working directory’ is the folder R accesses by default

- `getwd()` shows your current working directory. Try it now!
- If you don’t provide an explicit directory, R looks in current directory.

Detour: working directory

Code works if `this_file.xlsx` is in the current working directory

```
library(readxl)
wealth_data <- read_xlsx("wealth_data.xlsx")
```

Otherwise you get an error like

```
Error: ‘path‘ does not exist: ‘wealth_data.xlsx’
```

Loading Data from original files

If the data were not in your current working directory, you could:

Set the directory as the **working directory**

```r
# After setting the correct directory
library(readr)
setwd("/the/path/to/the/right/folder/")
wealth_data <- read_csv("wealth_data.csv")
```

Detour: Alternatives

If the data were not in your current working directory, you could also:

- give the absolute address: `read_csv("~/Documents/coding_lab/file.csv")`
- give a relative address: `read_csv("coding_lab/file.csv")`
  - this assumes "~/Documents" is the current working directory
- move the file to the current working directory

Review: the basics

- How to navigate RStudio and run R code in the console and scripts
- How to use R operators for
    - math (`+`, `^`)
    - comparisons (`<=`, `!=`)
    - logic (`&`, `|`)
- How to assign names
- How to use and learn about functions (Go `?`!)

Review: using packages and reading data

- How to download packages from the internet with `install.packages()`
- How to load packages for use in R with `library()`
- How to distinguish between data formats (csv, xlsx, dta)
- How to navigate the file structure (`getwd()`, `setwd()`)
- How to programatically read data in to R
- How to get basic "see" data

Next up

Lab sessions:

- *today*: Review today's material
- *tomorrow*: Learn about Rmds. Load data (for your final project).
- Progress marker: I can load *relevant* policy data into R.

Lecture:

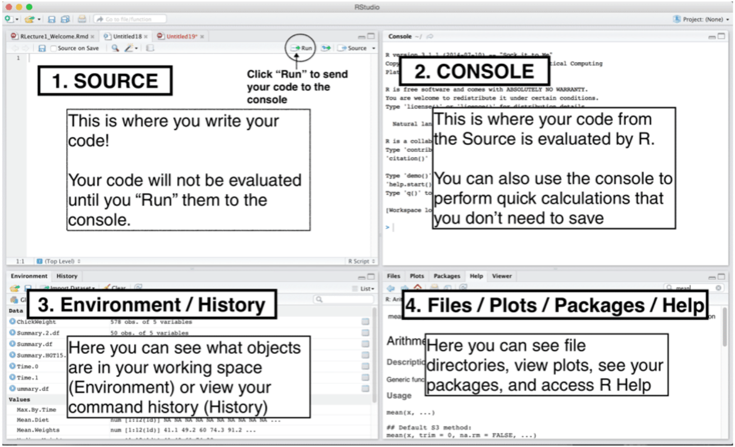
- *Thursday*: Vectors + data types & Data in base R

Appendix: Demo

RStudio basics (Demo)

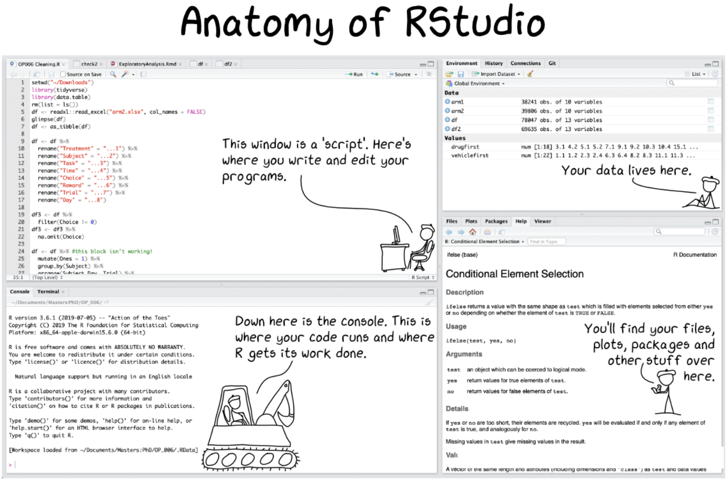
- It provides a console to access R directly
- A text editor to write R scripts and work with Rmds
- An environment and history tab that provide useful information about what objects you have in your R session
- A help / plots / files / packages etc. section

RStudio Layout (Demo)



(This layout may be different than yours)

RStudio Layout (Demo)



Executing commands in R (Demo)

Three ways to execute commands in R:

1. Type/copy commands directly into the console
2. R scripts (.R files)

- This is just a text file full of R commands
- Can execute one command at a time, several commands at a time, or the entire script

3. ‘code chunks’ in RMarkdown (.Rmd files)

- Can execute one command at a time, one chunk at a time, or “knit” the entire document

Using R as a calculator (Demo)

+, -, *, and /. Also, ^ (Exponent).

```
7 + 5
```

```
## [1] 12
```

```
(4 + 6) * 3 - 2
```

```
## [1] 28
```

```
7 / 5
```

```
## [1] 1.4
```

```
2^4
```

```
## [1] 16
```

Using R as a calculator (Demo)

- R has many built-in mathematical functions
- To call a function, we type its *name*, followed by parentheses
- Anything we type inside the parentheses is called the function's *arguments*

```
sin(1)   # trigonometric functions
```

```
## [1] 0.841471
```

```
log(1)   # natural logarithm
```

```
## [1] 0
```

```
exp(0.5) # e^(1/2)
```

```
## [1] 1.648721
```

```
sqrt(4)  # square root of 4
```

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