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

Harris Coding Camp – Accelerated Track

Summer 2022

Welcome to Coding Camp!

- Why are we here?
- What are we going to do?
- A quick introduction to R and RStudio
- How to start working with data

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?

- Computation is an essential party of modern-day applied statistics and *quantitative* policy analysis
- Many public policy jobs and the Harris curriculum rely on programming
  - to quickly engage with policy data
  - to complete statistical analyses
- Examples
  - Determine how many people are eligible for debt forgiveness
  - Analyze changes in test scores among different groups due to online education
  - What policy problems do you want to tackle with data?

Gauging your background

What experience are you entering with?

- Excel / Sheets
- Stata
- Python
- R
- 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)
- Complete programming language with low barriers to entry
- Open source and free
- We will use R for the entire Stats sequence in Fall and Winter

What will we cover?

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

- In Stats 1/2 and other courses, you will build off of these lessons:
    - extend your capabilities with the functions we teach you
    - introduce statistics functions
    - introduce new packages and tools based on needs

Learning philosophy

- We learn coding by experimenting with code
- Coding can be frustrating
- Coding requires a different modality of thinking
- We develop self-sufficiency by learning where to get help and how to ask for help
- Coding lab is for you
- This is just the beginning of your programming journey!

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!):

- Again – you learn coding by coding!
- Break up into small groups and work on problems with peer and TA support

3. Additional help:

- Send emails to Head TA for logistics issues
- Post questions to Canvas Discussion Board (Teaching team will monitor and reply)

4. Final project:

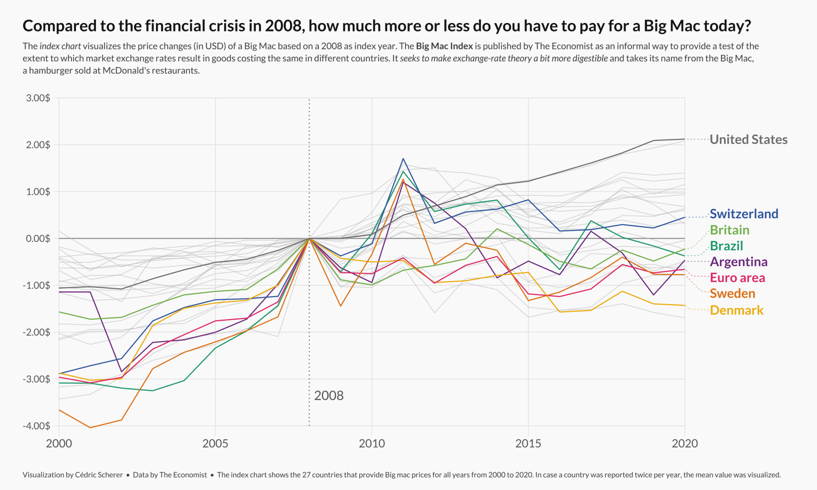
- It's optional; more details on next slide

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:

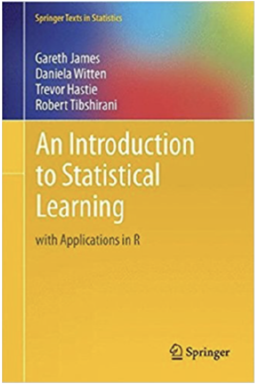
- Pick a data set aligned with your policy interests (or not)
- Use programming skills to engage with data and make a data visualization showing something you learned from the data

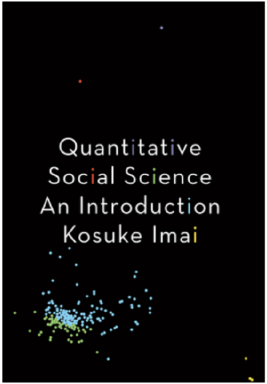
An Example

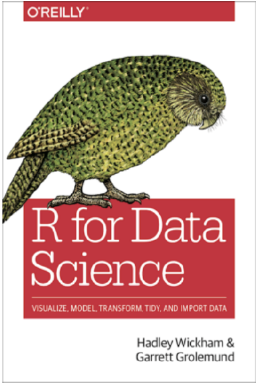


Compared to the financial crisis in 2008, how much more or less do you have to pay for a Big Mac today?
The index chart visualizes the price changes (in USD) of a Big Mac based on a 2008 as index year. The Big Mac Index is published by The Economist as an informal way to provide a test of the extent to which market exchange rates result in goods costing the same in different countries. It seeks to make exchange-rate theory a bit more digestible and takes its name from the Big Mac, a hamburger sold at McDonald's restaurants.
3.00$
2.00$
1.00$
0.00$
-1.00$
-2.00$
-3.00$
-4.00$
2000
2005
2008
2010
2015
2020
United States
Switzerland
Britain
Brazil
Argentina
Euro area
Sweden
Denmark
Visualization by Cédric Scherer • Data by The Economist • The index chart shows the 27 countries that provide Big mac prices for all years from 2000 to 2020. In case a country was reported twice per year, the mean value was visualized.

Textbooks and Resources





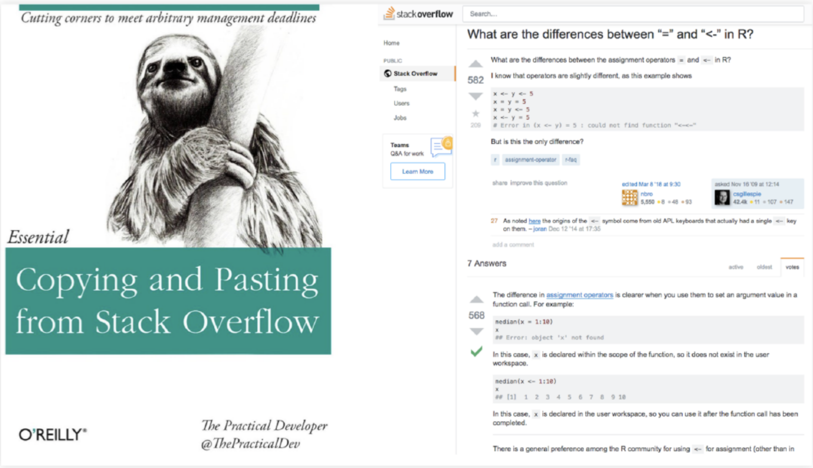


- Get situated with R for Data Science https://r4ds.had.co.nz/

Textbooks and Resources

- Google is your friend for idiosyncratic problems

Textbooks and Resources



- Stack Overflow is your another friend!

Using R and RStudio

Getting to business

We will

- Discuss what RStudio is
- Introduce minimal information to get started working with R
- Learn different types of operators
- Extending R with packages
- Bringing in data to R

Why R *and* RStudio?

R is a language and environment for statistical computing and graphics.

RStudio is an “integrated development environment” for R.

In order to use RStudio, you must also have both RStudio and R installed on your computer (R is the “engine” for RStudio)

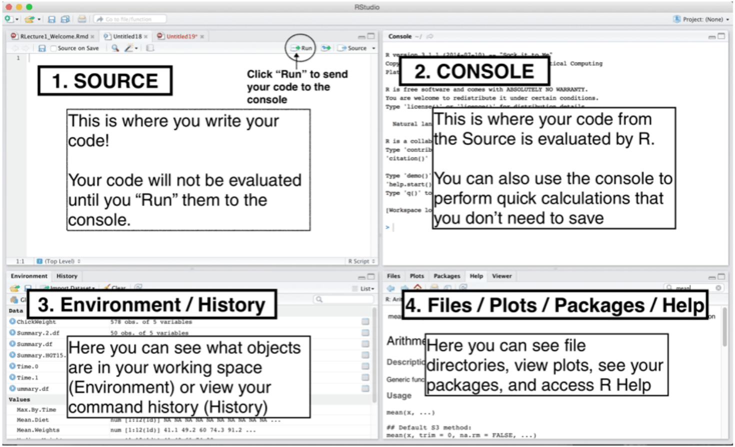
Begin Live Demo

- Navigating R Studio
- Rmds and Scripts
- R as calculator

RStudio basics

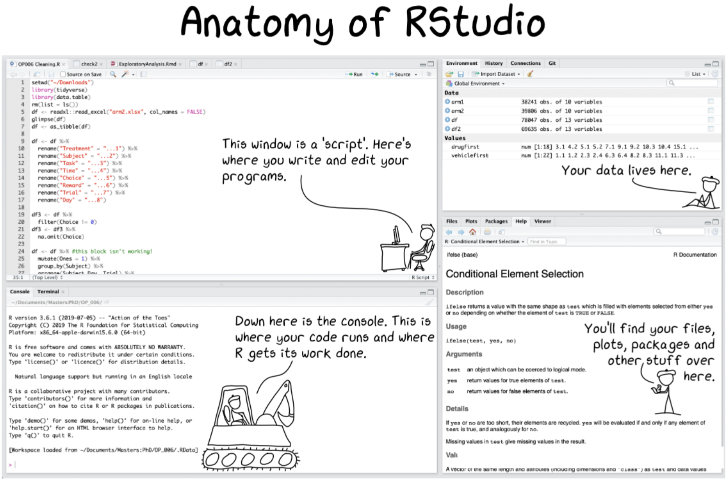
- It provides a console to access R directly
- A text editor to write R scripts and work with Rmds
- An environment and history tab that provide useful information about what objects you have in your R session
- A help / plots / files / packages etc. section

RStudio Layout



(This layout may be different than yours)

RStudio Layout



Executing commands in R

Three ways to execute commands in R:

Using R as a calculator

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

```r
7 + 5
```

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

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

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

```r
7 / 5
```

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

```r
2^4
```

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

Using R as a calculator

- 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
```

End Live Demo

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 ..

```
# answer
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)
```

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

```
(15^{0} - 1)/0
```

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

Operators can return special values

`Inf` is infinity. You can have either positive or negative infinity.

```
1 / 0
```

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

```
-5 / 0
```

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

`NaN` means Not a Number. It's an undefined value.

```
0 / 0
```

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

`NA` means Missing or Not Available. (More later!)

```
NA + 4
```

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

Comparison Operators

These are also binary operators; they take two objects, and give back a *Boolean*

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

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

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

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

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

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

Comparison Operators

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

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

```r
7 == 5 # equality (two equals signs, read as "is equal to",
```

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

```r
7 != 5 # inequality (read as "is not equal to")
```

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

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

& (and)

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

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

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

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

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

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

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

| (or)

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

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

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

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

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

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

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

Logical Operations

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

Try it yourself

Guess the output of the following codes, and then run the codes 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 + 5^8 - log(50) < 2000000) | (3*y - log(500) == 0)
```

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
```

Basic syntax: Add comments using the # character

- Allow others (and future you) to have an easier time following what the code is doing

```
# comments help us remember ...
my_number - 10 # This should be equal to -6
```

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

- Anything after # is ignored by R when executes code

Variable assignment

We can re-assign a variable as we wish. This is useful if we want to try the same math with various different numbers.

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

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**

```
# mtcars is a built-in data set, so you can run this local
model_fit <- lm(mpg ~ disp +  cyl + hp, data = mtcars)
summary(model_fit)
```

Using functions

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

```
sqrt(4)
```

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

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

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

Function arguments

Function inputs are called arguments.

Functions know what the argument is supposed to do based on

- name
- position

e.g. `f` is a function that expects `x` and `y` and returns `2*x + y`

```
f(7, 0)
```

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

```
f(y = 7, x = 0)
```

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

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)
```

Review: intro to R and Rstudio

We learned

- How to navigate RStudio and run R code in the console and scripts
- How to use R operators for math and comparisons
- How to assign names to objects for future enjoyment
- How to use functions and find help with ?

Extend R with Packages and Load in Data

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")
```

common package error

The package 'readr' provides a function to read .csv files called `read_csv()`. What goes wrong here?

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

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

common package error

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:

- Install the package `tidyverse`
- Then import it with the `library()` function
- Then run the command `storms` directly. What do you get?

So you found some data

Say you find a spreadsheet on the internet and want to start exploring it with R.

Sometimes loading data is as easy as

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

But often you'll need to consider:

- File type
- File location
- Funky formatting

Loading data of various formats

Most common formats and

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

Detour: directory structure

Computer hard drives are organized using a file system. In this way, each file has a unique "address" or **file path**.

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

The files are stored in folders or directories which are analogous to "zip codes".

- `~/Documents/coding_lab/`

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

Detour: working directory

The ‘working directory’ is the folder in which you are currently working

- This is where R looks for files/data

```
# If the data is in the same folder as the current working directory
fed_data <- read_xlsx("SCE-Public-LM-Quarterly-Microdata.xlsx")
```

`getwd()` shows your current working directory.

Loading Data from original files

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

1. Locate the directory that your file is in
2. Set the directory as the **working directory**
3. Load the data into R using the correct function

```
# 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:

- change the current working directory: `setwd("~/Documents/coding_lab")` and use `read_csv("file.csv")`
- 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

Overview of 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)
glimpse(wealth_data)
summary(wealth_data)
head(wealth_data)
```

Attributes of the Data

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

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

Try it yourself: Dataset `storms`

```r
# Load dataset
storms
```

- Try `view()`, `glimpse()` and `head()`. What do you see?
- What are the names of all the columns/variables included in `storms`?
- How many rows/observations are included?
- How many columns/variables are included?

Review: using packages and reading data

We learned

- 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