

# 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 part 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

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 we cover?

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:
- ▶ extend your capabilities with the functions we teach you
  - ▶ introduce statistics functions
  - ▶ introduce new packages and tools based on needs

This is just the beginning of your programming journey!

# 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



# 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)

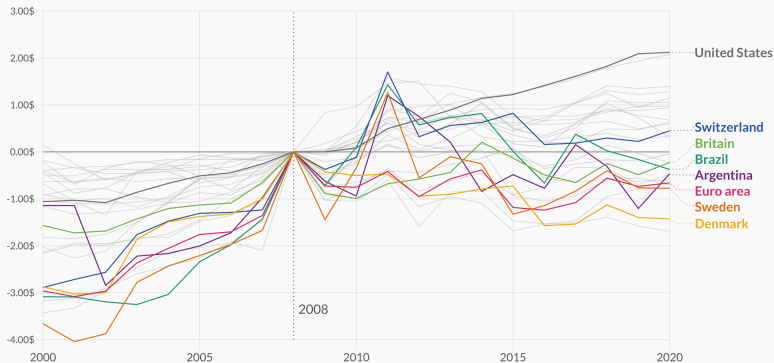
You'll know you're ready for policy school coding, if you can open a data set of interest to you and produce meaningful analysis. For the final project, you will:

- ▶ 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

# Final project goal

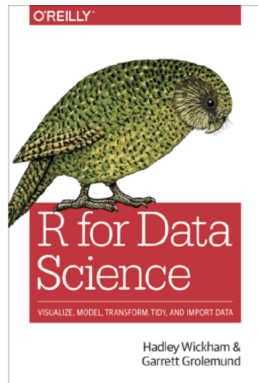
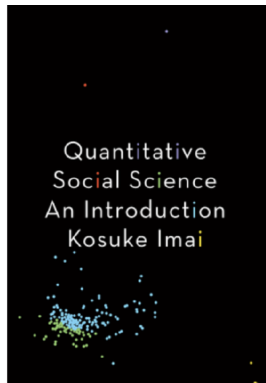
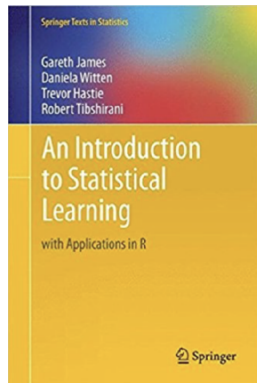
## Compared to the financial crisis in 2008, how much more or less do you have to pay for a Big Mac today?

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.



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

*How to actually learn any new programming concept*



*Essential*

Changing Stuff and  
Seeing What Happens

O RLY?

@ThePracticalDev

*The internet will make those bad words go away*



*Essential*

Googling the  
Error Message


O RLY?

*The Practical Developer*  
@ThePracticalDev

- ▶ Google is your friend for idiosyncratic problems

# Textbooks and Resources

*Cutting corners to meet arbitrary management deadlines*



*Essential*

## Copying and Pasting from Stack Overflow

O'REILLY\*

*The Practical Developer*  
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### What are the differences between "=" and "<=" in R?

What are the differences between the assignment operators `=` and `<=` in R?

I know that operators are slightly different, as this example shows

```
x <- y <- 5
x = y = 5
x <= y <- 5
x = y = 5
## Error in (x <- y) = 5 : could not find function "<=--"
```

But is this the only difference?

[assignment-operator](#) [faq](#)

share Improve this question

asked Mar 8 '18 at 9:30

rtore 5,500 ● 8 ● 48 ● 93

asked Nov 10 '18 at 12:14

cragflesce 42.4k ● 11 ● 107 ● 147

27 As noted [here](#) the origins of the `<=` symbol come from old APL keyboards that actually had a single `<=` key on them. — jordan Dec 12 '14 at 17:35

add a comment

7 Answers

active oldest votes

The difference in [assignment operators](#) is clearer when you use them to set an argument value in a function call. For example:

```
median(x = 1:10)
x
## Error: object "x" not found
```

✓ In this case, `x` is declared within the scope of the function, so it does not exist in the user workspace.

```
median(x <- 1:10)
x
## [1] 1 2 3 4 5 6 7 8 9 10
```

In this case, `x` is declared in the user workspace, so you can use it after the function call has been completed.

There is a general preference among the R community for using `<=` for assignment (other than in

- ▶ Stack Overflow is your another friend!
- ▶ ... In homework, give credit where it's due.

## 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)

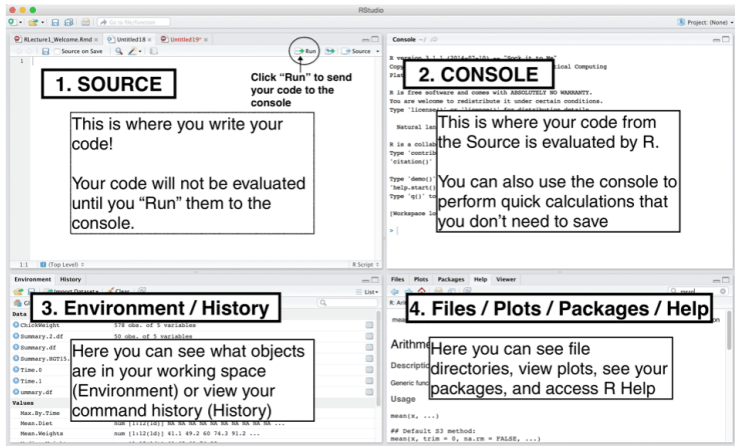
# Begin Live Demo

- ▶ 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)

## Anatomy of RStudio

The screenshot shows the RStudio interface with several windows and annotations:

- Source Editor (Top Left):** Contains R code for loading data and creating variables. A callout bubble points to this window with the text: "This window is a 'script'. Here's where you write and edit your programs." A small cartoon character is sitting at a desk with a computer.
- Environment (Top Right):** Shows the current environment with variables like 'data', 'df1', 'df2', and 'df3'. A callout bubble points to this window with the text: "Your data lives here." A small cartoon character is sitting at a desk with a computer.
- Console (Bottom Left):** Shows the output of the R code. A callout bubble points to this window with the text: "Down here is the console. This is where your code runs and where R gets its work done." A small cartoon character is sitting at a desk with a computer.
- Files (Bottom Right):** Shows the file explorer. A callout bubble points to this window with the text: "You'll find your files, plots, packages and other stuff over here." A small cartoon character is sitting at a desk with a computer.

The R code in the Source Editor is as follows:

```
1 setwd("~/Rstudio")
2 library(tidyverse)
3 library(data.table)
4 read_csv("data.csv")
5 df <- read_csv("data.csv", col_names = FALSE)
6 glimpse(df)
7
8
9 df <- df %>%
10   rename("Treatment" = "...1") %>%
11   rename("Subject" = "...2") %>%
12   rename("Task" = "...3") %>%
13   rename("Time" = "...4") %>%
14   rename("Choice" = "...5") %>%
15   rename("Reward" = "...6") %>%
16   rename("Trial" = "...7") %>%
17   rename("Day" = "...8")
18
19 df3 <- df %>%
20   filter(Choice != 0)
21 df3 <- df3 %>%
22   no.unit(Choice)
23
24 df <- df %>% #this block isn't working!
25   mutate(One = 1) %>%
26   group_by(Subject) %>%
27   summarise(Subtotal = sum(Trial))
28
29 # End of script
```

The console output shows the R version and the RStudio logo.

# Executing commands in R

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
  - ▶ More on this later

## Using R as a calculator

$+$ ,  $-$ ,  $*$ , 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

- ▶ 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.  $-1^2 * (8 - \text{sqrt}(16)) = ?$
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

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

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

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

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

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

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

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

& (and): Return TRUE if **all** terms are true.

- ▶ TRUE & TRUE -> TRUE
- ▶ TRUE & FALSE -> FALSE
- ▶ FALSE & TRUE -> FALSE
- ▶ FALSE & FALSE -> FALSE

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

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

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

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

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

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

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

- ▶ 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] FALSE
```



# Logical Operations

operator	definition	operator	definition
<	less than	<code>x   y</code>	x OR y
<=	less than or equal to	<code>is.na(x)</code>	test if x is NA
>	greater than	<code>!is.na(x)</code>	test if x is not NA
>=	greater than or equal to	<code>x %in% y</code>	test if x is in y
==	exactly equal to	<code>!(x %in% y)</code>	test if x is not in y
!=	not equal to	<code>!x</code>	not x
<code>x &amp; y</code>	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 <- 4  
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
```

```
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  $2*x + y$

```
# 2 * 7 + 0 = 14  
f(7, 0)
```

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

```
# 2 * 0 + 7 = 7  
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.

Loading data is as easy as

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

This requires that you consider:

- ▶ File type
- ▶ File location
- ▶ Funky formatting

# Loading data of various formats

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()

## 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

```
# 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

## 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