ECON 1190: Econometrics 2: Slides 2: Getting started in R

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Starting up in R

Setting up your account

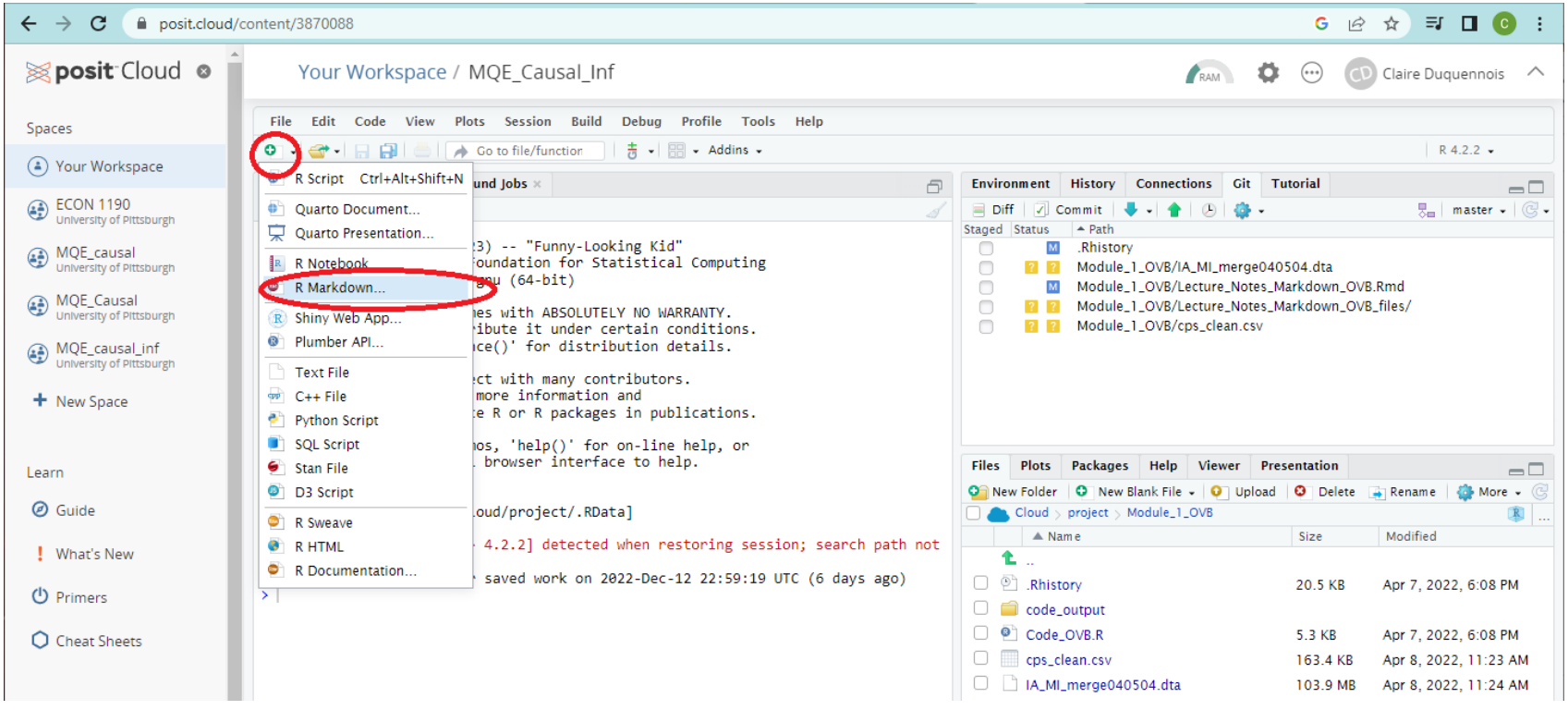
R Markdown

- We're going to do most of our work using R Markdown.
- Why it's nice
  - `Run multiple lines of code at once.`
  - `But don't have to run all code at once.`
  - `Add comments between chunks of code.`
  - `Compile output into pretty documents.`

All of my lecture slides and notes are made in R Markdown!

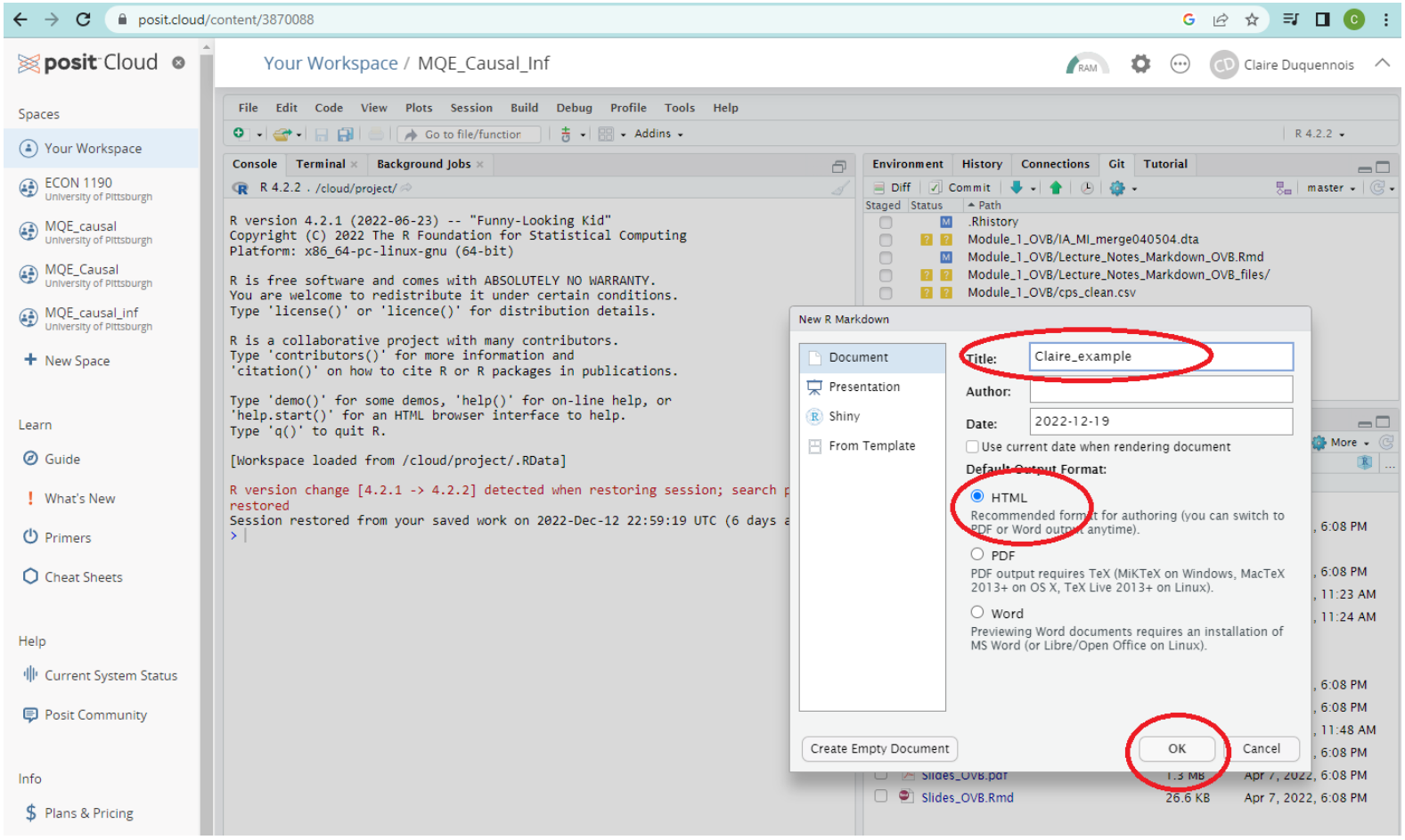
R Markdown: Getting started

- Create file: File -> New File -> R Markdown...

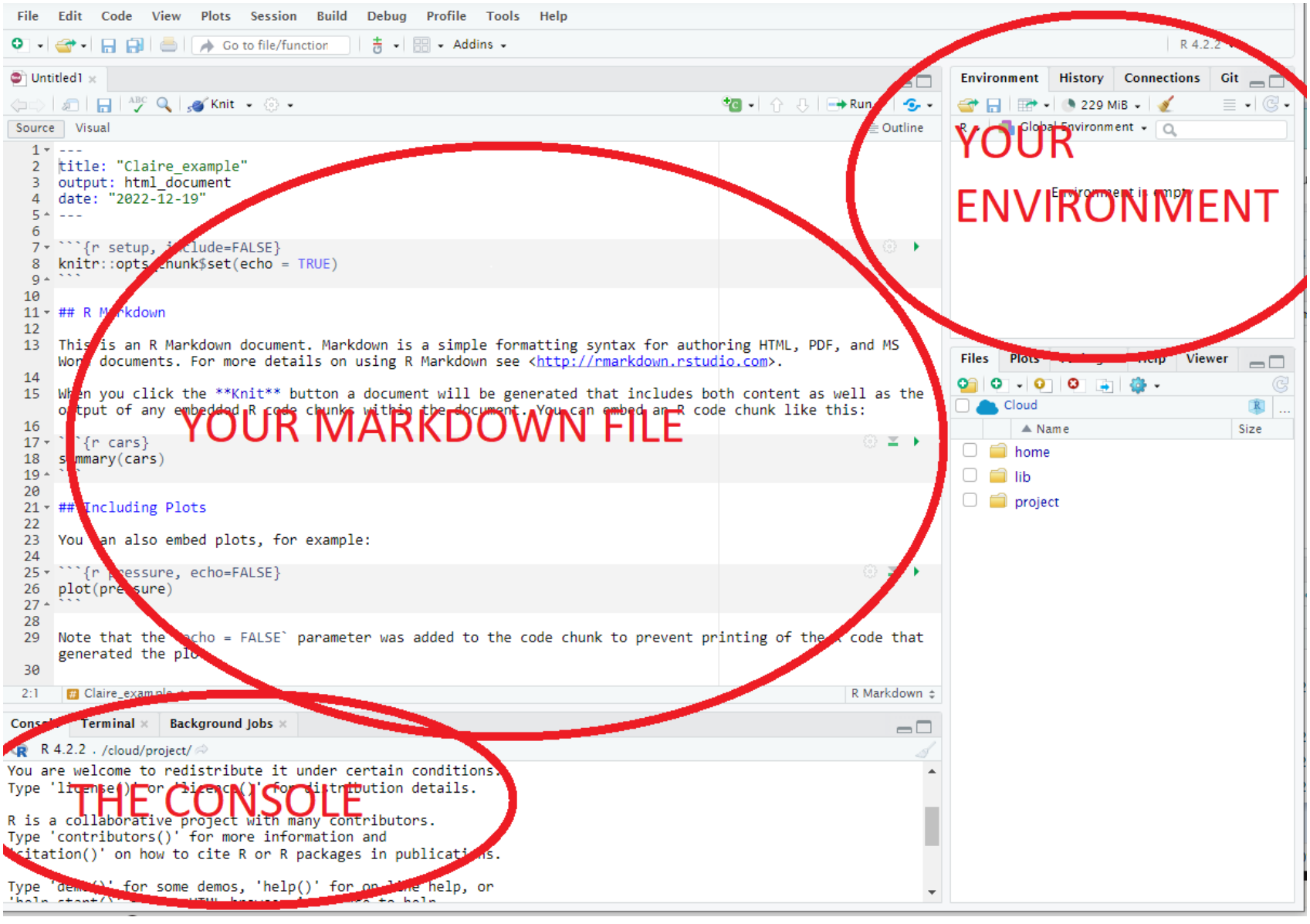


R Markdown: Getting started

- Give your file a title
- Set it to compile to HTML
- Click OK



R Markdown: The workspace

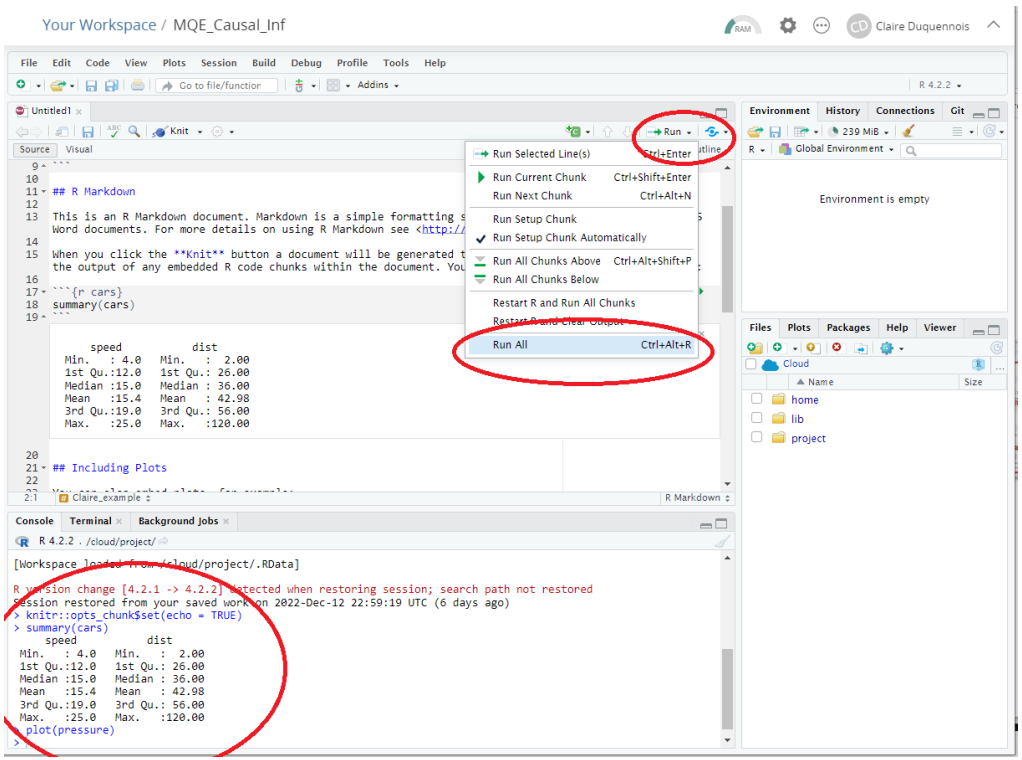


R Markdown: The Console

When you run code, in the console you will see:

- the lines that were run
- called output
- errors and warnings

You can type commands directly into the console **BUT** these will not be saved



R Markdown: Your R Markdown File

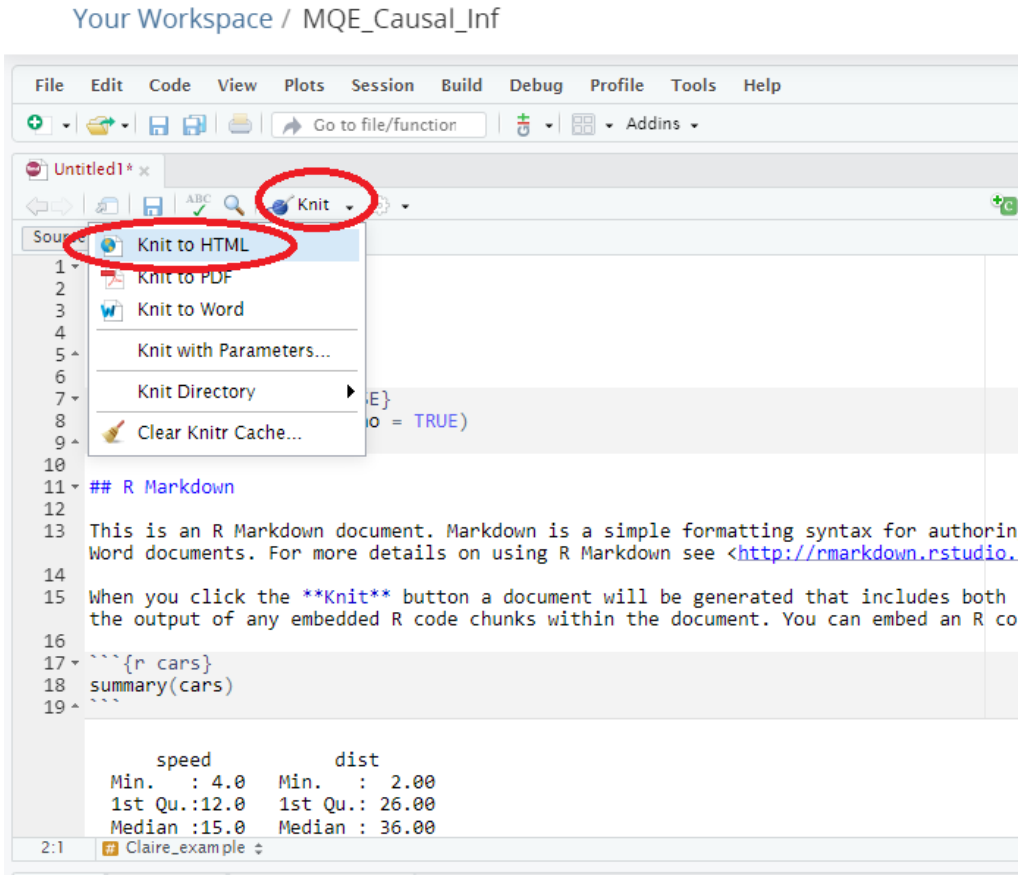
This is where the action is!

This file is a combination of:

- Markdown text (in the white parts)
- R code in the chunks (the grey parts)

When you "Knit'' an R markdown file, you will produce an HTML document (or PDF or WORD...) that combines your text, code and code output.

R Markdown: Your R Markdown File



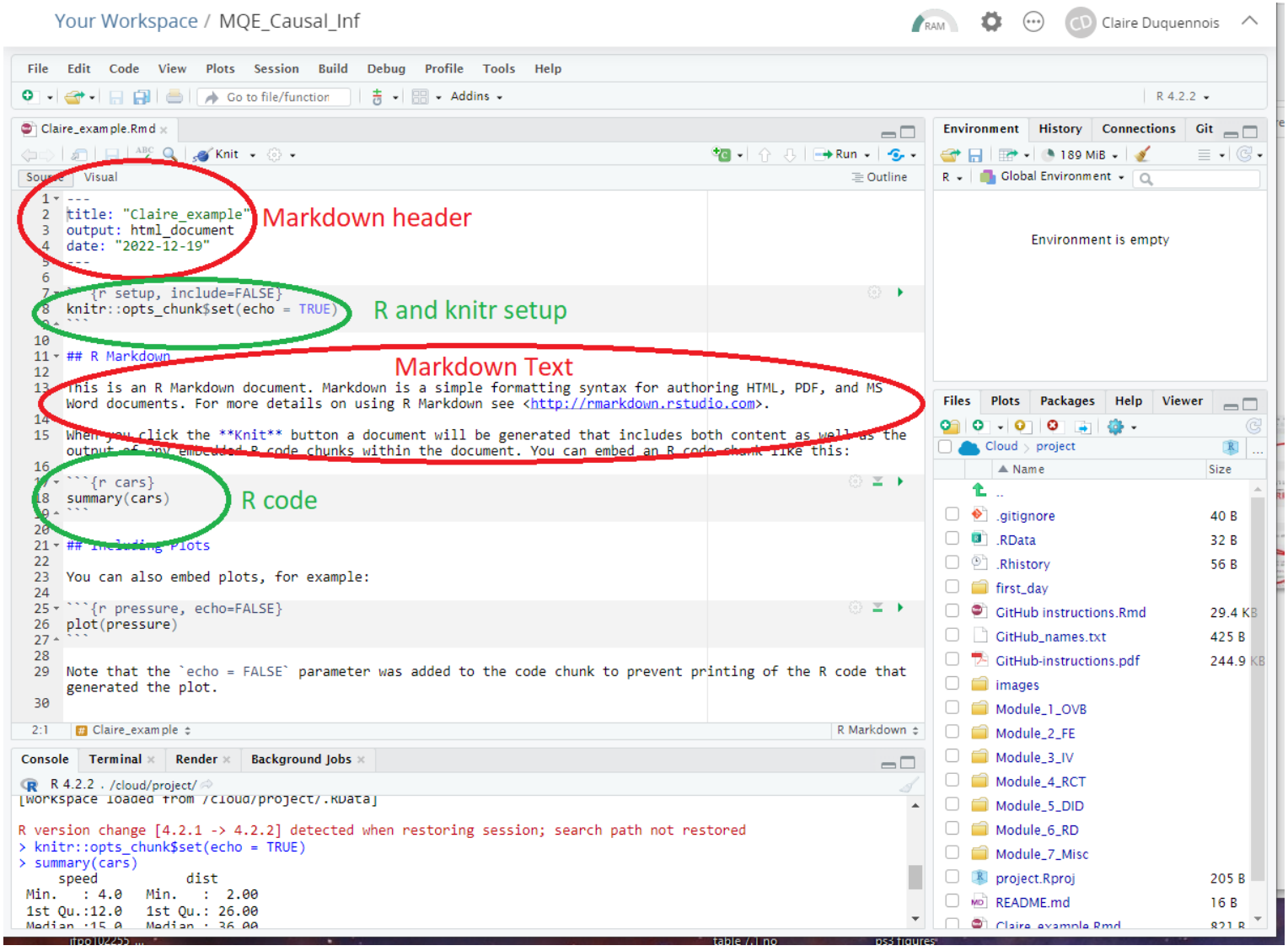
And when prompted, save your html file to your workspace

R Markdown: Your R Markdown File

Congrats! You now have an html document with the default Rmarkdown example code and text!

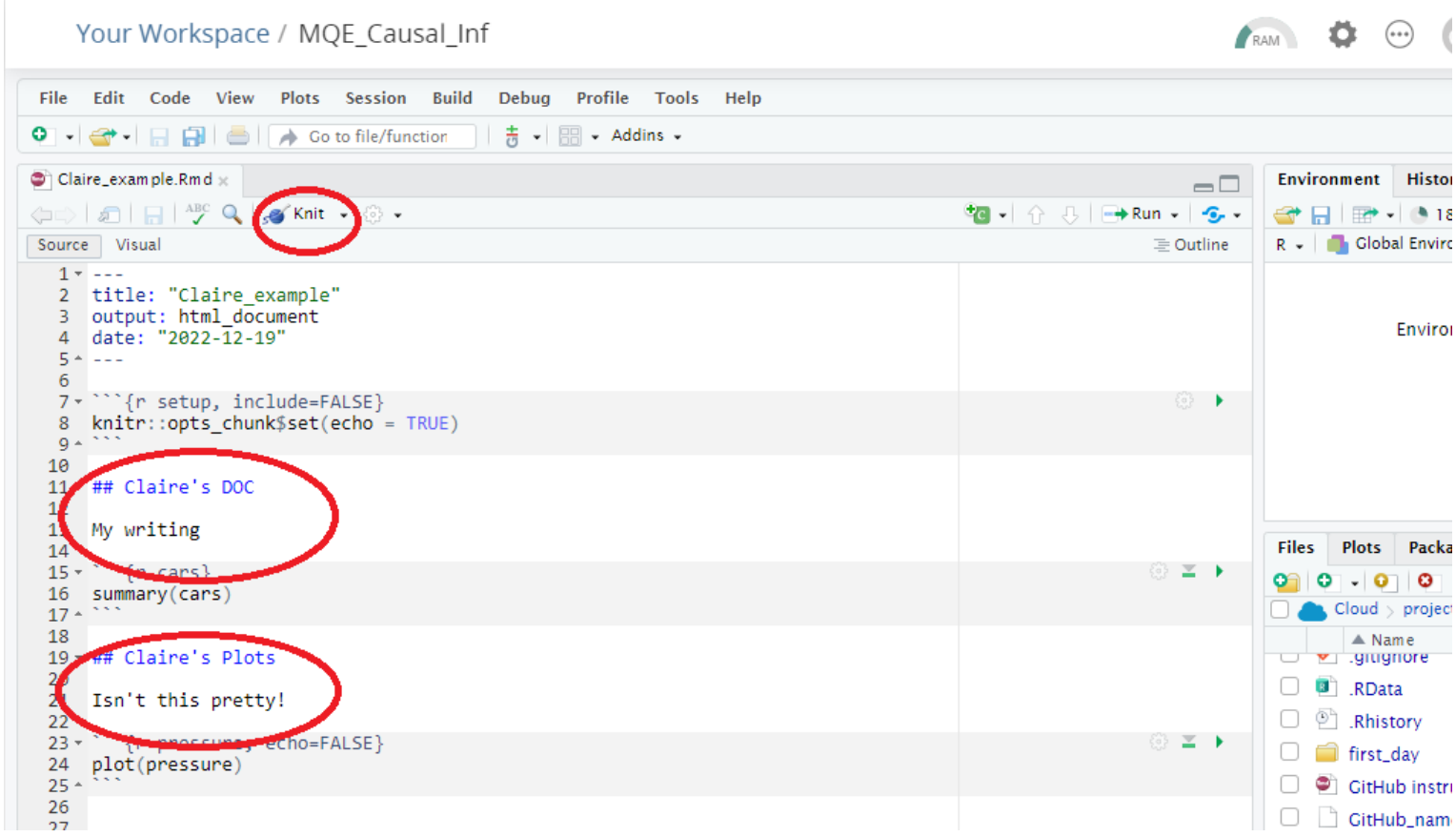
Let's move beyond the default...

R Markdown File Elements



R Markdown: Edit the markdown text

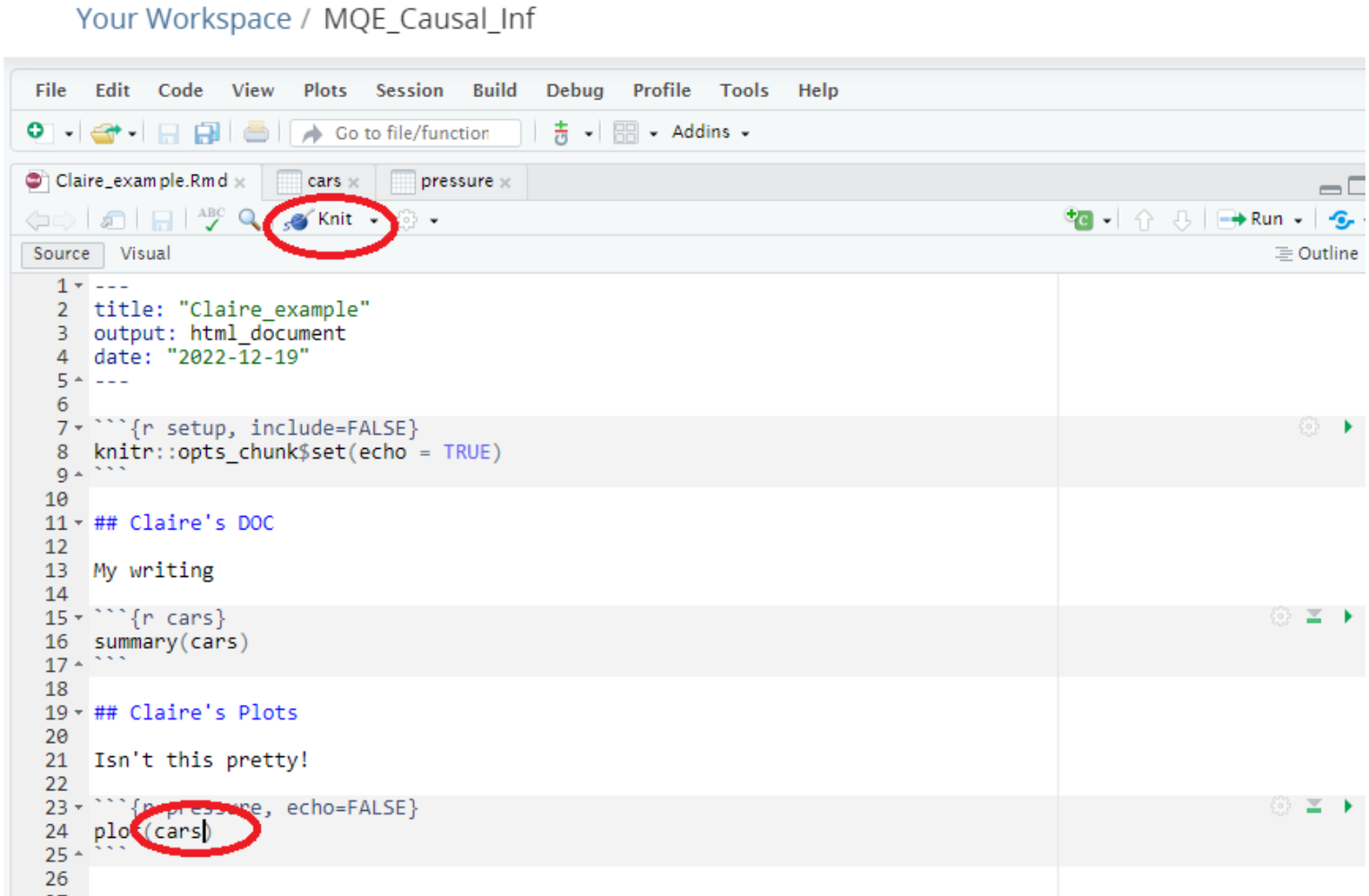
- Edit the Markdown text
- Re-knit your document and see your changes



R Markdown: Edit the R code

Why are we summarizing the data in the cars data set but plotting the data in the pressure data set?

Let's fix that. Replace the word pressure with cars in the `plot()` function and re-knit your document



R Markdown: Edit the R code

Congrats! Your html file should now show a new scatterplot of the cars data.

R Markdown: Code "chunks"

- Always write code in "grey' ' regions called chunks
- Creating a new chunk
  - `Green +C box`
  - `option-command-i (Mac)`
  - `control-alt-i (Windows)`
- the first line of the chunk, in brackets is the chunk header

R Markdown: Chunk headers

The UNIQUE chunk name:

- the 1st element (before first comma)
- If you use the same name for multiple chunks your file will not knit
- Ex: try replacing *r pressure* with *r cars* in the third chunk: your file will not knit

R Markdown: Chunk headers

Other chunk options that determine how your code shows up in your document (separate multiple options with commas):

- `include = FALSE` prevents code and results from appearing in the finished file. R Markdown still runs the code in the chunk, and the results can be used by other chunks.
- `echo = FALSE` prevents code, but not the results from appearing in the finished file. This is useful to embed figures.
- `message = FALSE` prevents messages that are generated by code from appearing in the finished file.
- `warning = FALSE` prevents warnings that are generated by code from appearing in the finished file.

Notice: the line `knitr::opts_chunk$set(echo = TRUE)` is setting the default for all the chunks to have `echo=TRUE`.

R Markdown: Code "chunks"

- Execute code
  - Green arrow in upper right of chunk.
  - command-shift-enter (Mac) [click inside chunk first]
  - control-shift-enter (Windows) [click inside chunk fir
  - Let's run some code!

R Code

Create a chunk and type the following:

```
x <- 2 # Assign the value 2 to the variable x
y <- 3 # Assign the value 3 to the variable y
z <- x + y # Add x and y
z
```

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

- The operator "<-" is how we assign the value to a variable. The value could be a number but also a list, string, matrix, etc.
- To add comments, put a "#" before comment. Comments appear green. R ignores these when it executes the code.
- R printed 5 under the chunk. If you perform an operation and don't store the result as a variable, R will print it.
- Note that the code and output was printed in the Console.
- The values you created x, y, z now appear in your Environment.

R Packages

- A package is a set of functions/commands which have already been programmed.
- To use a package you must load it from the library: use library() function.

```
library(stats) #loading the stats package
```

- If a package is not in the library it is not yet installed. To install packages use the install.packages() command.

```
#install.packages("ggplot2")
```

- We can now load ggplot2 from the library when we want to use it.

Loading data

Let's load the `olympics_data.csv` data:

- this is already in the RStudio cloud workspace
- it is also on the course canvas page
- this is a csv (Comma Separated Vales) file, to load it we need the function `read.csv`

```
olympics <- read.csv("olympics_data.csv")

View(olympics) #opens the data in the data viewer

head(olympics,5) #prints the first 5 rows of data in the console (or knitr doc)
```

```
##       country country_abbrev continent year   type gold silver bronze
## 1 Afghanistan            AFG      Asia 2000 summer    0      0      0
## 2 Afghanistan            AFG      Asia 2002 winter    0      0      0
## 3 Afghanistan            AFG      Asia 2004 summer    0      0      0
## 4 Afghanistan            AFG      Asia 2006 winter    0      0      0
## 5 Afghanistan            AFG      Asia 2008 summer    0      0      1
##   population       gdp g8
## 1   21.60699        NA  0
## 2   22.60077  7.228792  0
## 3   24.72669  7.978512  0
## 4   26.43306  9.349917  0
## 5   27.72228 11.060389  0
```

Data Management with Dplyr

You're going to be using a lot of data. Dplyr makes working with data less overwhelming.

- Dplyr is a data management package.
- Dplyr allows us to apply multiple transformations to our data at once using the pipe operator: %<%
- First let's load the dplyr package (we installed it earlier)

```
# Load Dplyr
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 4.1.2
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

Selecting Data

When working with a large data set, it can be helpful to select the columns you will use.

Create a new dataset `olympics2` that only contains the columns we will use (drops country_abbrev, continent, g8)

```
olympics2<-olympics %>% select(country, year, type, gold, silver, bronze, population, gdp)
head(olympics2)
```

```
##       country year   type gold silver bronze population       gdp
## 1 Afghanistan 2000 summer    0      0      0   21.60699        NA
## 2 Afghanistan 2002 winter    0      0      0   22.60077  7.228792
## 3 Afghanistan 2004 summer    0      0      0   24.72669  7.978512
## 4 Afghanistan 2006 winter    0      0      0   26.43306  9.349917
## 5 Afghanistan 2008 summer    0      0      1   27.72228 11.060389
## 6 Afghanistan 2010 winter    0      0      0   29.18551 15.354605
```

- First we write the data set name, then the pipe operator (%>%), and then the select() function.
- In the select() function I list the variables I want to keep (. . . there are other ways to do this)
- this smaller data is saved as `olympics2` in the environment

Filtering Data

You may want to limit your data to certain rows.

Create a new dataset `us_olympics` that only contains observations for the United States, using the `filter` function

```
us_olympics<-olympics2 %>% filter(country == "United States")
head(us_olympics)
```

```
##         country year   type gold silver bronze population      gdp
## 1 United States 2000 summer   37     24     32   284.9690 13754.30
## 2 United States 2002 winter   10     13     11   287.6252 14121.05
## 3 United States 2004 summer   36     39     26   292.8053 15075.14
## 4 United States 2006 winter    9      9      7   298.3799 16034.37
## 5 United States 2008 summer   36     39     37   304.0940 16376.73
## 6 United States 2010 winter    9     15     13   309.3271 16383.04
```

- First we write the data set name, then the pipe operator (%>%), and then the `filter()` function.
- The `filter()` function takes a logical statement. In this case country == "United States". `country` is the variable we are filtering on, == is a logical operator, "United States" is a value.

Variable types

String variable:

- Country is a string variable: to select rows we write "United States" in quotation marks
- Main logical operators: == (is equal to) and != (is not equal to)

Numeric variables:

- Year is a numeric variable: no need for quotation marks.
  - With numeric variables we can use additional logical operators
    - < Less than and > Greater than
    - <= Less than or equal to and >= Greater than or equal to
    - %in% is in a particular vector (more about vectors later

Factor variables:

- variable is a set of numeric codes
- the numeric value does not matter, it just defines a category

Filtering Data

Filter the United States at Summer Olympics since 2010

```
uss10_olympics<-olympics2 %>% filter(country == "United States" & type == "summer" & year >= 2010)
head(uss10_olympics)
```

```
##         country year   type gold silver bronze population      gdp
## 1 United States 2012 summer   47     27     30   313.8777 17016.39
## 2 United States 2016 summer   46     37     38   323.0718 18509.60
## 3 United States 2020 summer   39     41     33   331.5011 19247.06
```

- We can combine multiple conditions using the & operator.
- If we want to use or, we can use | (that is a vertical line not a capital I)

Filtering Data

Filter observations with more than 10 silver medals or more than 4 gold medals.

```
olympics_SG<-olympics2 %>% filter(silver > 10 | gold > 4)
head(olympics_SG)
```

```
##     country year   type gold silver bronze population       gdp
## 1 Australia 2000 summer   16     25     17   19.41300  872.5868
## 2 Australia 2004 summer   17     16     17   20.12740  995.0810
## 3 Australia 2008 summer   14     15     17   21.24920 1133.4026
## 4 Australia 2012 summer    8     15     12   22.73346 1256.1287
## 5 Australia 2016 summer    8     11     10   24.19091 1387.5610
## 6 Australia 2020 summer   17      7     22   25.69327 1490.9678
```

Filtering Data

Filter observations from Argentina, Colombia, Brazil, Mexico.

```
olympics_LA<-olympics2 %>% filter(country %in% c("Argentina", "Colombia", "Brazil", "Mexico"))
```

- Use `%in%` operator
- `c( , , , )` defines a vector
- we are telling R to keep observations where the variable `country` is the same as one of the strings in the given vector

Missing values

- Missing values in R are indicated with `NA`
- Being aware of missing values in a variable is important since they tend to mess things up. We'll talk more about this later.

We can filter on rows where none of the population values of a variable are missing.

```
olympics_nomiss <- olympics2 %>% filter(!is.na(population))
head(olympics_nomiss)
```

```
##       country year   type gold silver bronze population       gdp
## 1 Afghanistan 2000 summer    0      0      0   21.60699        NA
## 2 Afghanistan 2002 winter    0      0      0   22.60077  7.228792
## 3 Afghanistan 2004 summer    0      0      0   24.72669  7.978512
## 4 Afghanistan 2006 winter    0      0      0   26.43306  9.349917
## 5 Afghanistan 2008 summer    0      0      1   27.72228 11.060389
## 6 Afghanistan 2010 winter    0      0      0   29.18551 15.354605
```

Create New Variables

Create a new variable called total that is the sum of all medals

```
#method 1: use the mutate function in dplyr
olympics2 <- olympics2 %>% mutate(total = gold + silver + bronze)

#method 2: using base R
olympics2$total2<-olympics2$gold+olympics2$silver+olympics2$bronze
head(olympics2)
```

```
##       country year   type gold silver bronze population       gdp total total2
## 1 Afghanistan 2000 summer    0      0      0   21.60699        NA     0      0
## 2 Afghanistan 2002 winter    0      0      0   22.60077  7.228792     0      0
## 3 Afghanistan 2004 summer    0      0      0   24.72669  7.978512     0      0
## 4 Afghanistan 2006 winter    0      0      0   26.43306  9.349917     0      0
## 5 Afghanistan 2008 summer    0      0      1   27.72228 11.060389     1      1
## 6 Afghanistan 2010 winter    0      0      0   29.18551 15.354605     0      0
```

- I store my output using the same name. This overwrites the original data set.
- Here I use only a single = sign. This is not a logical statement but rather a formula.
- to call a variable in base R: `dataset_name$variable_name`

Summarize Data

To summarize data, we combine group_by() and summarize().

Get the total count of medals by country and season for all years

```
olympics_totals<-olympics2 %>% group_by(country, type) %>% summarize(total_medals = sum(total))

head(olympics_totals)
```

```
## # A tibble: 6 x 3
## # Groups:   country [3]
##   country     type   total_medals
##   <chr>       <chr>         <dbl>
## 1 Afghanistan summer            2
## 2 Afghanistan winter            0
## 3 Algeria     summer           10
## 4 Algeria     winter            0
## 5 Argentina   summer           27
## 6 Argentina   winter            0
```

- We divided the data into groups and got the sum of each group.
- The groups are defined by country and season so we write group_by(country, type).
- summarize took the sum of the variable total and stored it in a variable called total_medals.
- Other `summarize` operations: mean(), median(), sd(), min(), max()...

Multiple operations

Now let's put it all together. Calculate a country's average score at the summer olympics.

```
olympics_sumavg<-olympics2 %>% filter(type == "summer")%>%
  group_by(country) %>%
  summarize(avg_total = mean(total))

head(olympics_sumavg)
```

```
## # A tibble: 6 x 2
##   country     avg_total
##   <chr>           <dbl>
## 1 Afghanistan     0.333
## 2 Algeria         1.67
## 3 Argentina       4.5
## 4 Armenia         2.67
## 5 Australia      44
## 6 Austria         3.5
```

This is the beauty of dplyr.

GGplot2

A great tool to visualize, and learn about, your data

First we will need to load ggplot

```
# Install GGplot2
# install.packages("ggplot2")

# Load  GGplot2
library(ggplot2)
```

Step 1: Prepare the data

Before working with ggplot, you need to prepare your data for graphing.

- Is there a relationship between population and medals in the summer olympics?

```
olympics_plot1<-olympics2 %>% filter(type == "summer" & !is.na(population))

head(olympics_plot1)
```

```
##       country year   type gold silver bronze population       gdp total total2
## 1 Afghanistan 2000 summer    0      0      0   21.60699        NA     0      0
## 2 Afghanistan 2004 summer    0      0      0   24.72669  7.978512     0      0
## 3 Afghanistan 2008 summer    0      0      1   27.72228 11.060389     1      1
## 4 Afghanistan 2012 summer    0      0      1   31.16138 17.386481     1      1
## 5 Afghanistan 2016 summer    0      0      0   35.38303 19.566705     0      0
## 6 Afghanistan 2020 summer    0      0      0   38.92834 20.621946     0      0
```

Step 2: Understand your data

It is wise to look at the summary statistics of variables.

```
summary(olympics_plot1$population)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
##    0.0278    3.7227   10.3255   49.5113   34.7306 1411.1000
```

```
sd(olympics_plot1$population)
```

```
## [1] 167.3171
```

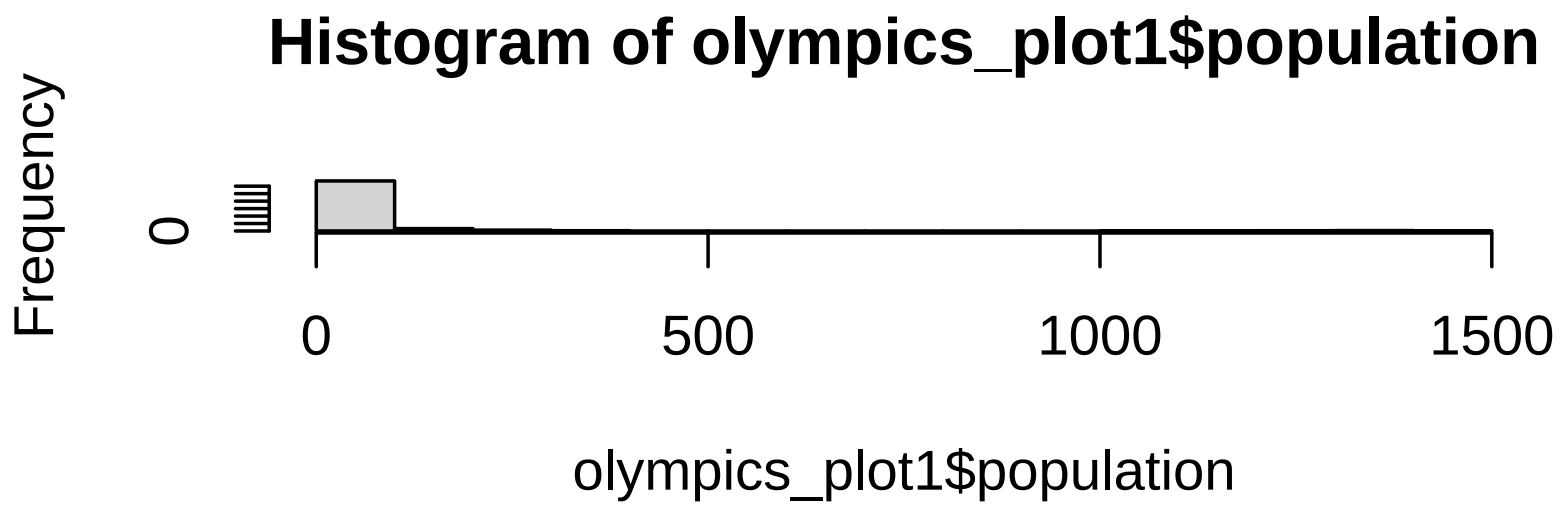
Step 2: Understand your data

Histograms can be particularly informative to get a sense of your data.

- Here I use a simple command but could also use ggplot

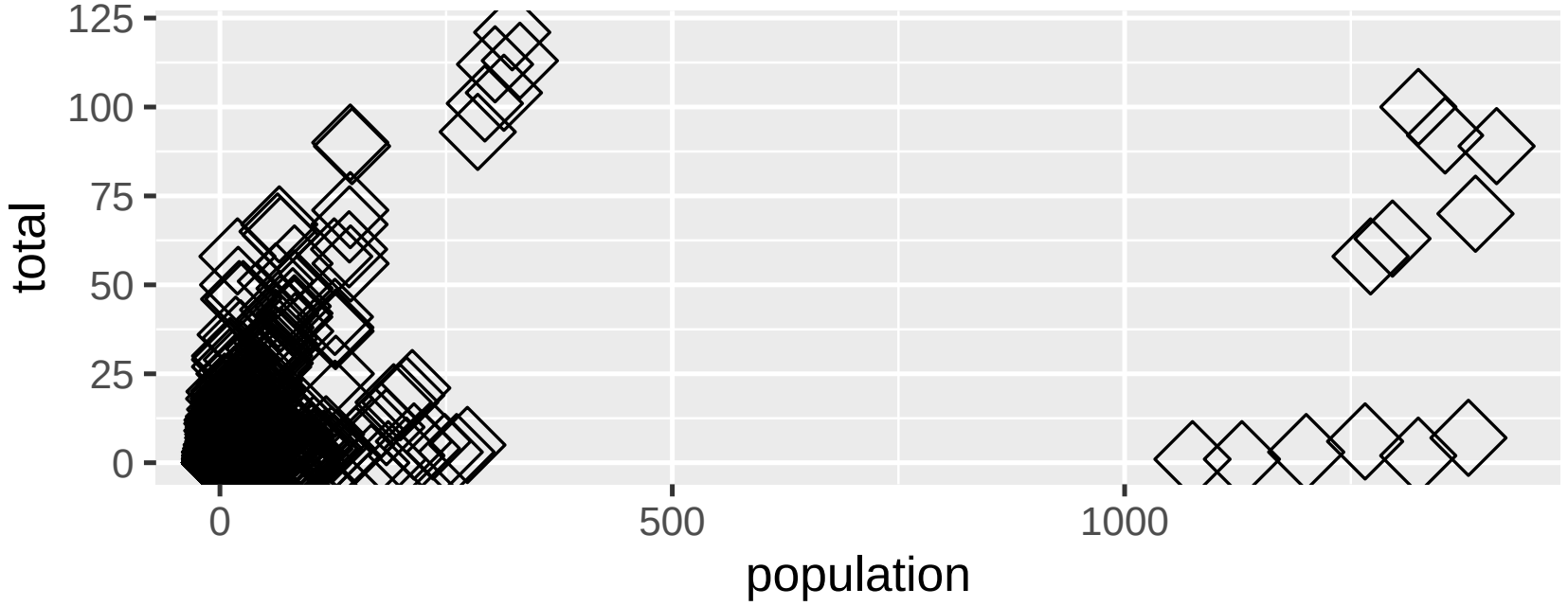
Looks like there are some big outliers. . .

```
hist(olympics_plot1$population)
```



Step 3: Build your figure

```
my_plot1<-ggplot(data = olympics_plot1, aes(x = population, y = total))+
  geom_point(size=6, shape=23)
my_plot1
```



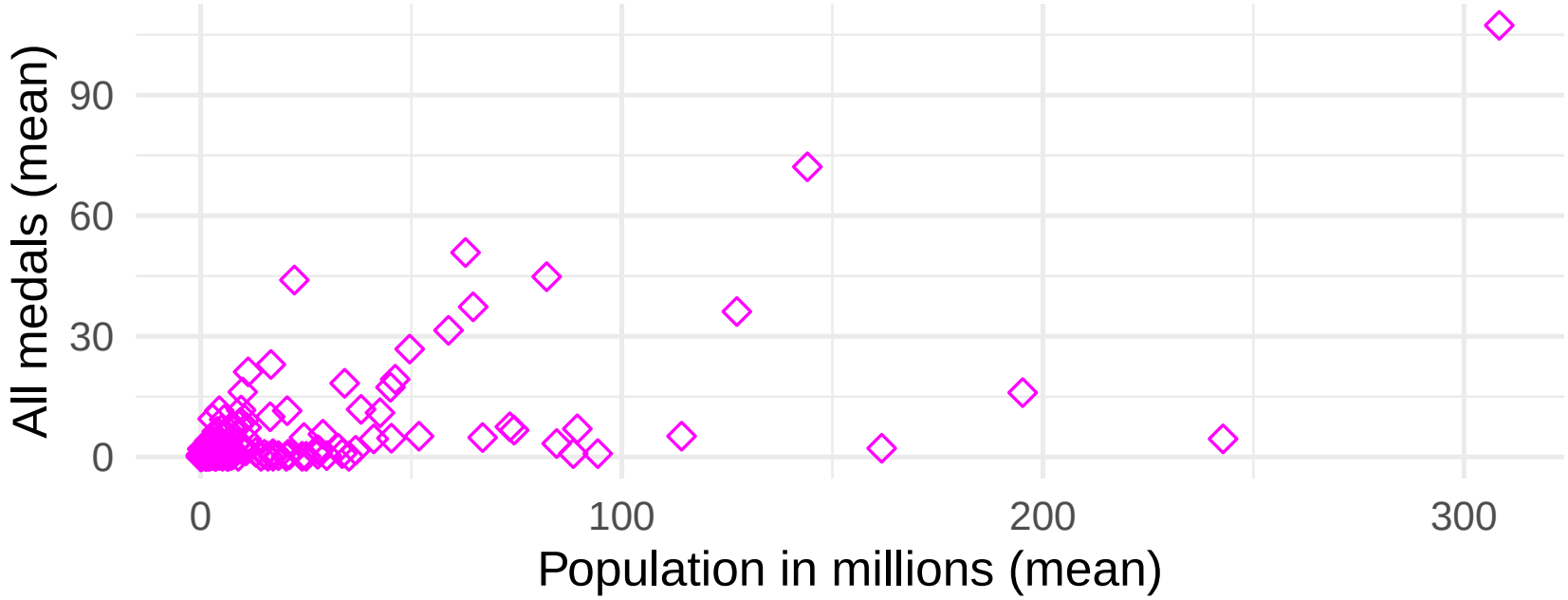
Step 5: Critiquing our figure

Not bad BUT...

- kind of ugly
- can't see much where the action is (bottom left)
- have multiple observations for each country. Maybe averages over this time period would be better?

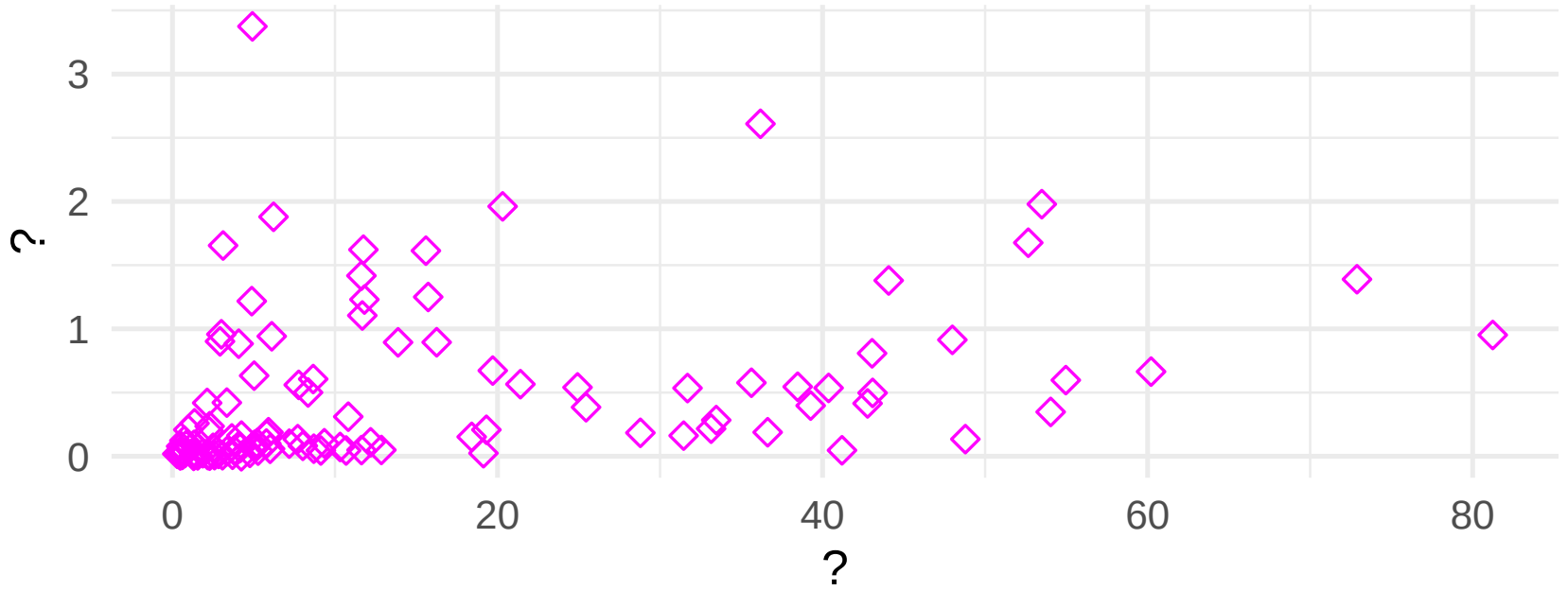
Step 6: Improve your figure

```
olympics_plot2<-olympics2 %>%
  filter(type == "summer" & !is.na(population)& population<400)%>%
  group_by(country)%>%
  mutate(total = gold + silver + bronze) %>%
  summarize(avg_total = mean(total), avg_pop=mean(population))

my_plot2<-ggplot(data = olympics_plot2, aes(x =avg_pop, y = avg_total))+
  geom_point(size=2,shape=23, color="magenta1")+
  labs(x = "Population in millions (mean)", y = "All medals (mean)")+
  theme_minimal()
my_plot2
```



A more interesting figure

```
olympics_plot3<-olympics2 %>%
  filter(type == "summer" & !is.na(population)& !is.na(gdp))%>%
  group_by(country)%>%
  mutate(total = gold + silver + bronze) %>%
  summarize(avg_total = mean(total), avg_pop=mean(population), avg_gdp=mean(gdp))%>%
  mutate(avg_total_cap=avg_total/avg_pop, avg_gdp_cap=avg_gdp/avg_pop)%>%
  filter(avg_pop>=1)

my_plot3<-ggplot(data = olympics_plot3, aes(x =avg_gdp_cap, y =avg_total_cap ))+
  geom_point(size=2,shape=23, color="magenta1")+
  labs(x = "?", y = "?")+
  theme_minimal()
my_plot3
```



Top Hat question

How should I label the axes?

$\Rightarrow$ Top Hat

GGplot basics

- Always prepare your data before making a graph.
- We start a ggplot with the ggplot() function, typically with two arguments:
  - data: this is the name of your dataset
  - aes: this controls how your data relates to the graph.
    - x: the variable on the x-axis
    - y: the variable on the y-axis
- ggplot() only creates the chart area. To add layers we use the + operator. Here we added a
- geom_point() layer (the dots)
- labs() layer (defines the axis labels)
- the theme_minimal() layer (sets the background colors/format)

There are many (MANY!) options with ggplot with lots (LOTS!) of online example to help you make great figures

Regressions in R

- Can use the `lm()` function
- for more advanced regressions we will be running use `felm()` which is part of the lfe package (same syntax)

```
reg<-felm(avg_total_cap~avg_gdp_cap, olympics_plot3)
summary(reg)
```

```
##
## Call:
##    felm(formula = avg_total_cap ~ avg_gdp_cap, data = olympics_plot3)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.71306 -0.30524 -0.25759  0.09904  3.02881
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 0.289600   0.073164   3.958 0.000135 ***
## avg_gdp_cap 0.011413   0.003102   3.680 0.000365 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.5836 on 109 degrees of freedom
## Multiple R-squared(full model): 0.1105   Adjusted R-squared: 0.1023
## Multiple R-squared(proj model): 0.1105   Adjusted R-squared: 0.1023
## F-statistic(full model):13.54 on 1 and 109 DF, p-value: 0.0003647
## F-statistic(proj model): 13.54 on 1 and 109 DF, p-value: 0.0003647
```

Stargazer

Lets make the regression results more presentable.

```
reg<-felm(avg_total_cap~avg_gdp_cap, olympics_plot3)
stargazer(reg, type = "latex",  header=FALSE)
```

Table 1:

	Dependent variable:
	avg_total_cap
avg_gdp_cap	0.011^{***}
	(0.003)
Constant	0.290^{***}
	(0.073)
Observations	111
R^2	0.110
Adjusted R^2	0.102
Residual Std. Error	0.584 (df = 109)
Note:	*p<0.1; **p<0.05; ***p<0.01

Stargazer

Stargazer is like the table version of ggplot.

- It will help you generate nice presentable table
- has lots (LOTS!) of options to customize your presentation
- for the table to render you need to add the chunk option: `results='asis'` in the chunk header
- you should specify output type "latex"
- there are lots of example online of how to format stargazer tables.
- you might need to install a latex editor (https://miktex.org/download)

R resources for troubleshooting

Help function:

- The help() function will bring up the documentation for a given function
- Let's look at the documentation for rnorm

```
#help(rnorm)
```

Web search:

- Half of coding is knowing how to Google your questions.
- **stackoverflow.com**: A particularly helpful website

GGplot image web search:

- Describe the kind of figure you want +ggplot and look at image results. Sometimes the code for the image is given
- Lots of tutorial websites on ggplot visualizations