INSTITUTE
OF LAW,
POLITICS AND
DEVELOPMENT

Sant'Anna
School of Advanced Studies – Pisa

Data Analysis for the Social Sciences with R

Data Visualization

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Why visualization?

Data visualization

1. Visualization allows you to better understand data and to efficiently communicate results
2. Many important journals in Political Science require plots instead of tables for publication
3. Visual representations are easier to read than full tables

Today's class

1. The grammar of graphics in `ggplot2`

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2. Histograms, bar charts, and scatterplots

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1. The grammar of graphics in `ggplot2`
2. Histograms, bar charts, and scatterplots
3. Exercises

The grammar of graphics

ggplot2

The `ggplot2` package is part of the `tidyverse`. It provides a specific system of constructing plots.

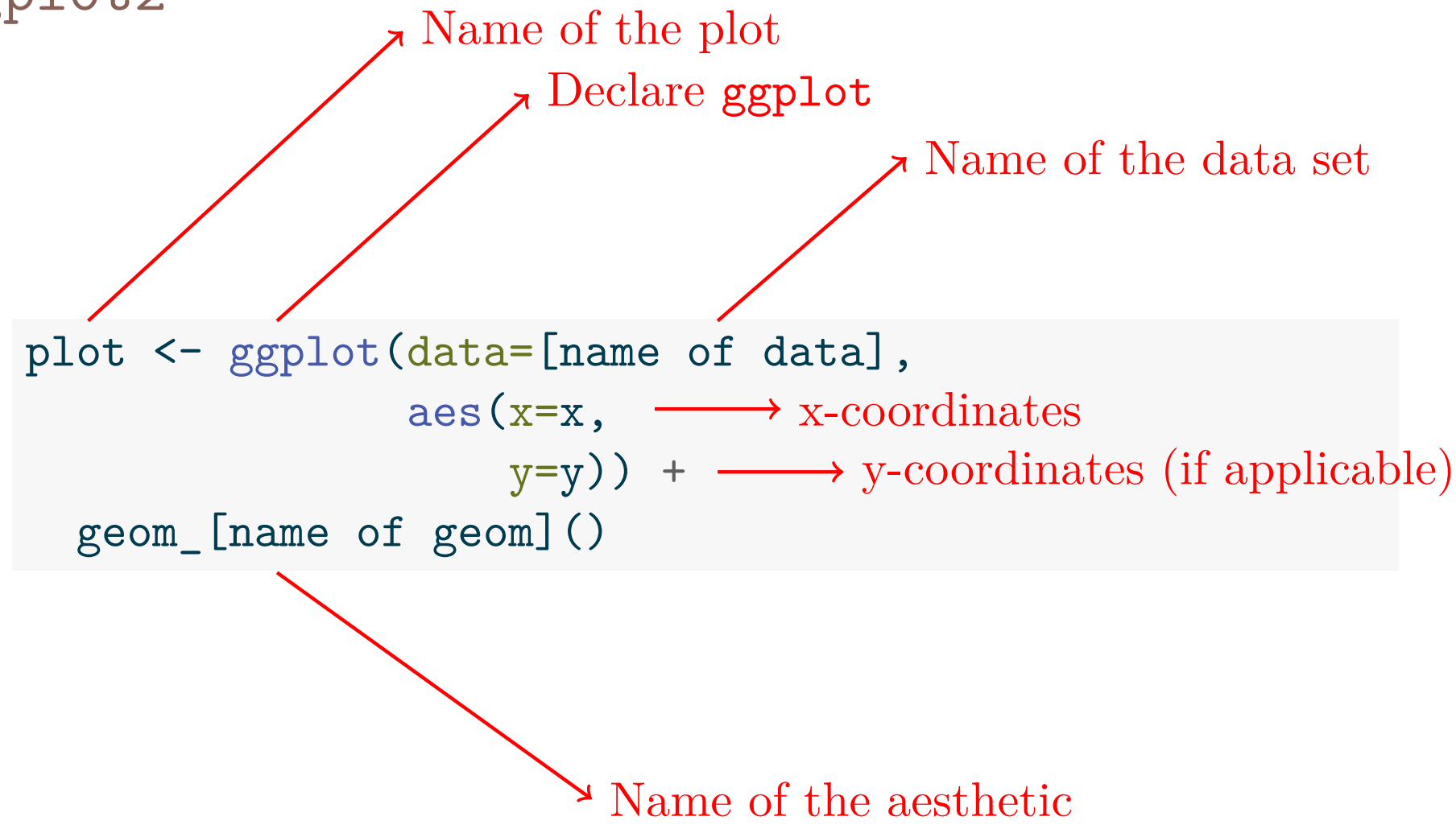
ggplot2

In `ggplot2`, plots consist of three basic components:

1. data
2. aesthetics
3. coordinate system

You can combine as many different aesthetic layers as you like.

ggplot2


Name of the plot
Declare ggplot
Name of the data set
plot <- ggplot(data=[name of data],
aes(x=x,
x-coordinates
y=y)) +
y-coordinates (if applicable)
geom_[name of geom]()
Name of the aesthetic

ggplot2

Data visualization with ggplot2 : : CHEATSHEET

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same components: a **data** set, a **coordinate system**, and **geoms**—visual marks that represent data points.

To display values, map variables in the data to visual properties of the geom (**aesthetics**) like **size**, **color**, and **x** and **y** locations.

Complete the template below to build a graph.

```
ggplot (data = <DATA>) +
<GEOM_FUNCTION>(mapping = aes(<MAPPINGS>),
 stat = <STAT>, position = <POSITION>) +
<COORDINATE_FUNCTION> +
<FACET_FUNCTION> +
<SCALE_FUNCTION> +
<THEME_FUNCTION>
```

required

Not required, sensible defaults supplied

ggplot(data = mpg, **aes(**x = cty, y = hwy**))** Begins a plot that you finish by adding layers to. Add one geom function per layer.

last_plot() Returns the last plot.

ggsave("plot.png", width = 5, height = 5**)** Saves last plot as 5' x 5' file named "plot.png" in working directory. Matches file type to file extension.

Aes

Common aesthetic values.

color and **fill** - string ("red", "#RRGGBB")

linetype - integer or string (0 = "blank", 1 = "solid", 2 = "dashed", 3 = "dotted", 4 = "dotdash", 5 = "longdash", 6 = "twodash")

size - integer (in mm for size of points and text)

linewidth - integer (in mm for widths of lines)

shape - integer/shape name or a single character ("a")

posit

Geoms

Use a geom function to represent data points, use the geom's aesthetic properties to represent variables. Each function returns a layer.

GRAPHICAL PRIMITIVES

```
a <- ggplot(economics, aes(date, unemploy))
b <- ggplot(seals, aes(x = long, y = lat))
```

a + geom_blank() and **a + expand_limits()** Ensure limits include values across all plots.

b + geom_curve(aes(yend = lat + 1, xend = long + 1), curvature = 1**)** - x, xend, y, yend, alpha, angle, color, curvature, linetype, size

a + geom_path(lineend = "butt", linejoin = "round", linemitre = 1**)** x, y, alpha, color, group, linetype, size

a + geom_polygon(aes(alpha = 50)**)** - x, y, alpha, color, fill, group, subgroup, linetype, size

b + geom_rect(aes(xmin = long, ymin = lat, xmax = long + 1, ymax = lat + 1)**)** - xmax, xmin, ymax, ymin, alpha, color, fill, linetype, size

a + geom_ribbon(aes(ymin = unemploy - 900, ymax = unemploy + 900)**)** - x, ymax, ymin, alpha, color, fill, group, linetype, size

LINE SEGMENTS

common aesthetics: x, y, alpha, color, linetype, size

b + geom_abline(aes(intercept = 0, slope = 1)**)**
b + geom_hline(aes(yintercept = lat)**)**
b + geom_vline(aes(xintercept = long)**)**

b + geom_segment(aes(yend = lat + 1, xend = long + 1)**)**
b + geom_spoke(aes(angle = 1:1155, radius = 1)**)**

ONE VARIABLE continuous

```
c <- ggplot(mpg, aes(hwy)); c2 <- ggplot(mpg)
```

c + geom_area(stat = "bin"**)** x, y, alpha, color, fill, linetype, size

c + geom_density(kernel = "gaussian"**)** x, y, alpha, color, fill, group, linetype, size, weight

c + geom_dotplot() x, y, alpha, color, fill

c + geom_freqpoly() x, y, alpha, color, group, linetype, size

c + geom_histogram(binwidth = 5**)** x, y, alpha, color, fill, linetype, size, weight

c2 + geom_qq(aes(sample = hwy)**)** x, y, alpha, color, fill, linetype, size, weight

discrete

```
d <- ggplot(mpg, aes(fl))
```

d + geom_bar() x, alpha, color, fill, linetype, size, weight

TWO VARIABLES both continuous

```
e <- ggplot(mpg, aes(cty, hwy))
```

e + geom_label(aes(label = cty), nudge_x = 1, nudge_y = 1**)** - x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

e + geom_point() x, y, alpha, color, fill, shape, size, stroke

e + geom_quantile() x, y, alpha, color, group, linetype, size, weight

e + geom_rug(sides = "bl"**)** x, y, alpha, color, linetype, size

e + geom_smooth(method = lm**)** x, y, alpha, color, fill, group, linetype, size, weight

e + geom_text(aes(label = cty), nudge_x = 1, nudge_y = 1**)** - x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

one discrete, one continuous

```
f <- ggplot(mpg, aes(class, hwy))
```

f + geom_col() x, y, alpha, color, fill, group, linetype, size

f + geom_boxplot() x, y, lower, middle, upper, ymax, ymin, alpha, color, fill, group, linetype, shape, size, weight

f + geom_dotplot(binaxis = "y", stackdir = "center"**)** x, y, alpha, color, fill, group

f + geom_violin(scale = "area"**)** x, y, alpha, color, fill, group, linetype, size, weight

both discrete

```
g <- ggplot(diamonds, aes(cut, color))
```

g + geom_count() x, y, alpha, color, fill, shape, size, stroke

e + geom_jitter(height = 2, width = 2**)** x, y, alpha, color, fill, shape, size

THREE VARIABLES

```
seals$z <- with(seals, sqrt(delta_long^2 + delta_lat^2)); l <- ggplot(seals, aes(long, lat))
```

l + geom_contour(aes(z = z)**)** x, y, z, alpha, color, group, linetype, size, weight

l + geom_contour_filled(aes(fill = z)**)** x, y, alpha, color, fill, group, linetype, size, subgroup

continuous bivariate distribution

```
h <- ggplot(diamonds, aes(carat, price))
```

h + geom_bin2d(binwidth = c(0.25, 500)**)** x, y, alpha, color, fill, linetype, size, weight

h + geom_density_2d() x, y, alpha, color, group, linetype, size

h + geom_hex() x, y, alpha, color, fill, size

continuous function

```
i <- ggplot(economics, aes(date, unemploy))
```

i + geom_area() x, y, alpha, color, fill, linetype, size

i + geom_line() x, y, alpha, color, group, linetype, size

i + geom_step(direction = "hv"**)** x, y, alpha, color, group, linetype, size

visualizing error

```
df <- data.frame(grp = c("A", "B"), fit = 4:5, se = 1:2)
j <- ggplot(df, aes(grp, fit, ymin = fit - se, ymax = fit + se))
```

j + geom_crossbar(fatten = 2**)** - x, y, ymax, ymin, alpha, color, fill, group, linetype, size

j + geom_errorbar() - x, ymax, ymin, alpha, color, group, linetype, size, width Also **geom_errorbarh()**.

j + geom_linerange() x, ymin, ymax, alpha, color, group, linetype, size

j + geom_pointrange() - x, y, ymin, ymax, alpha, color, fill, group, linetype, shape, size

maps

Draw the appropriate geometric object depending on the simple features present in the data. aes() arguments: map_id, alpha, color, fill, linetype, linewidth.

```
nc <- sf::st_read(system.file("shape/nc.shp", package = "sf"))
ggplot(nc) +
  geom_sf(aes(fill = AREA))
```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Plotting a single variable

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  - Box plots (for interval-scaled variables)

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  - Histograms (for interval-scaled variables)
  - Density plots (for interval-scaled variables)
  - Box plots (for interval-scaled variables)
  - Bar charts (for categorical variables)

Let's plot the distribution of respondents' age in the Tunisia survey

Histograms

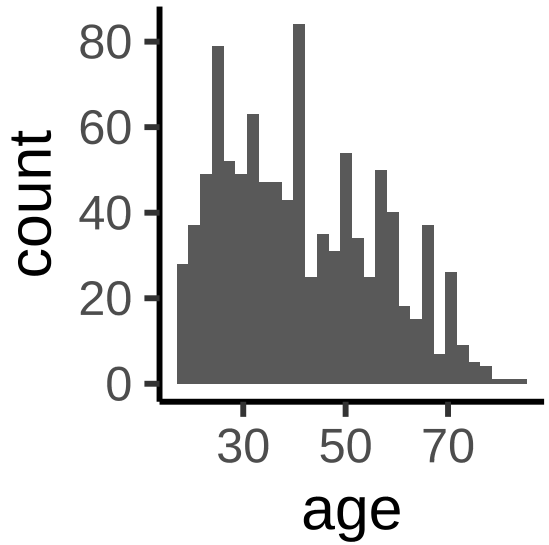
- A **histogram** is a type of chart representing the distribution of a single numerical variable.
- In histograms, the x-axis is divided into **bins** which represent ranges of the variable.
- The height of the bars represent **how many observations** fall within a bin.

In `ggplot2`, histograms layers can be produced with `geom_histogram()`.

Write code for a histogram of age.

Histograms

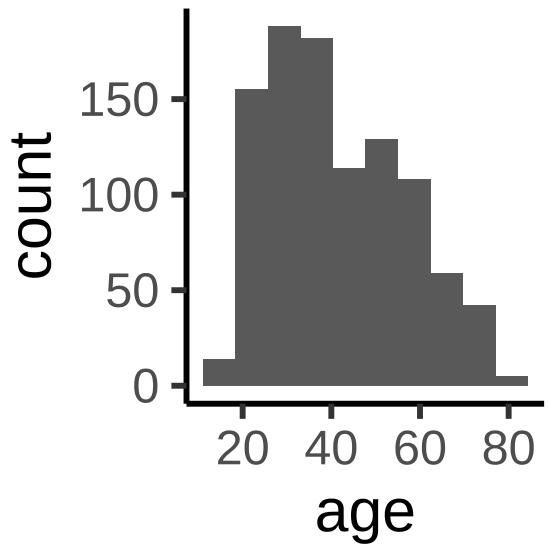
```
plot <- ggplot(data=tun22,
                aes(x=age)) +
  geom_histogram() +
  theme_classic()
plot
```



Histograms

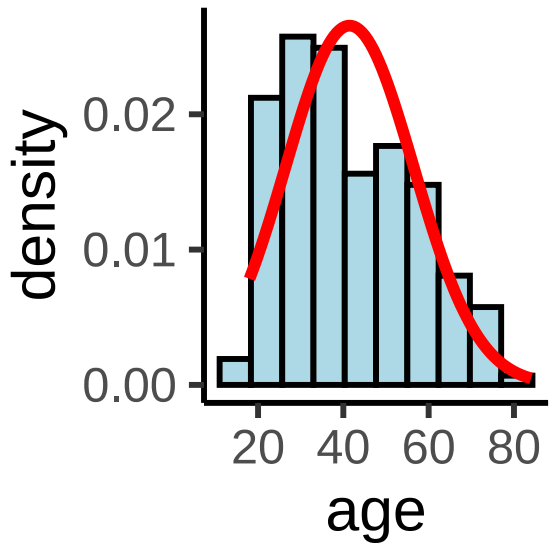
You can set the number of bins with the `bin` option (the default is 30):

```
plot1 <- ggplot(data=tun22,
                aes(x=age)) +
  geom_histogram(bins = 10) +
  theme_classic()
plot1
```



Histograms

We frequently want to check whether a variable aligns with the normal distribution. We can graphically check this by overlaying a normal distribution with the same mean and standard deviation.



Histograms

Here is the code:

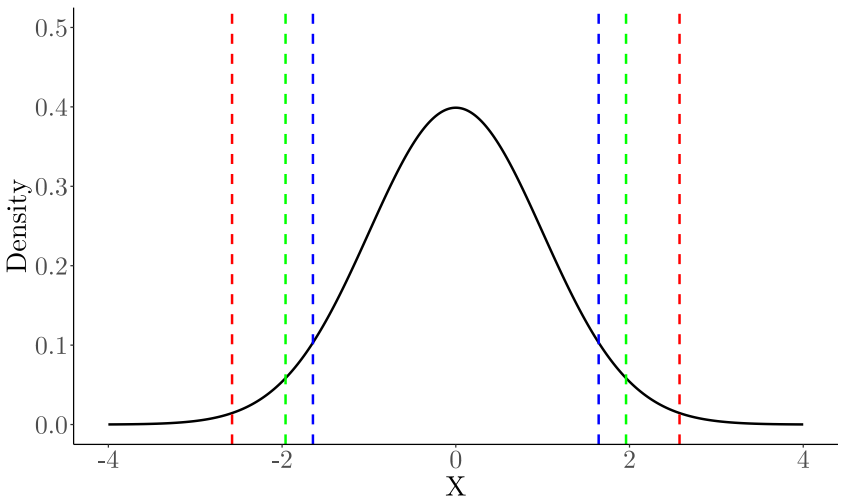
We now plot **density**, not counts

```
plot <- ggplot(data=tun22,
                aes(x=age)) +
  geom_histogram(aes(y=..density..),
                 bins = 10,
                 fill="lightblue",
                 color="black") +
  stat_function(fun = dnorm,
                args = list(mean = mean(tun22$age, na.rm=T),
                            sd = sd(tun22$age, na.rm=T)),
                color = "red", size = 1) +
  theme_classic()
plot
```

Quick detour: What is density?

- **Density** refers to the **probability density function (PDF)**.
- It shows how likely a variable is to take a specific value.
- The total area under the density curve (or histogram) equals **1**.

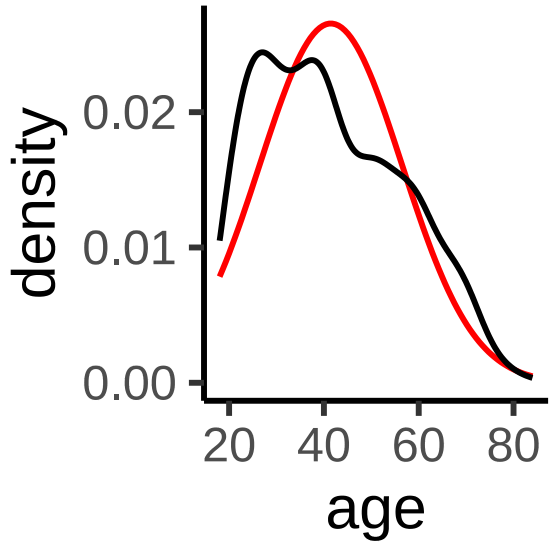
The normal distribution



- 90% of observations fall into the area between the blue lines
- 95% of observations fall into the area between the green lines
- 99% of observations fall into the area between the red lines

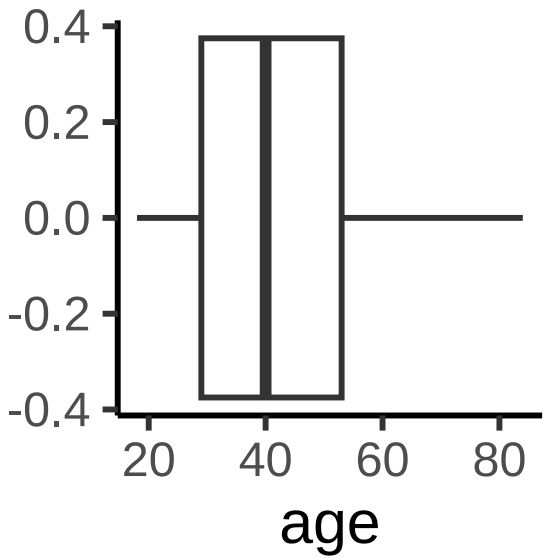
Density plots

```
plot2 <- ggplot(data=tun22,
                aes(x=age)) +
   stat_function(fun = dnorm,
                 args = list(mean = mean(tun22$age, na.rm=T),
                             sd = sd(tun22$age, na.rm=T)),
                 color = "red") +
  geom_density() +
  theme_classic()
plot2
```

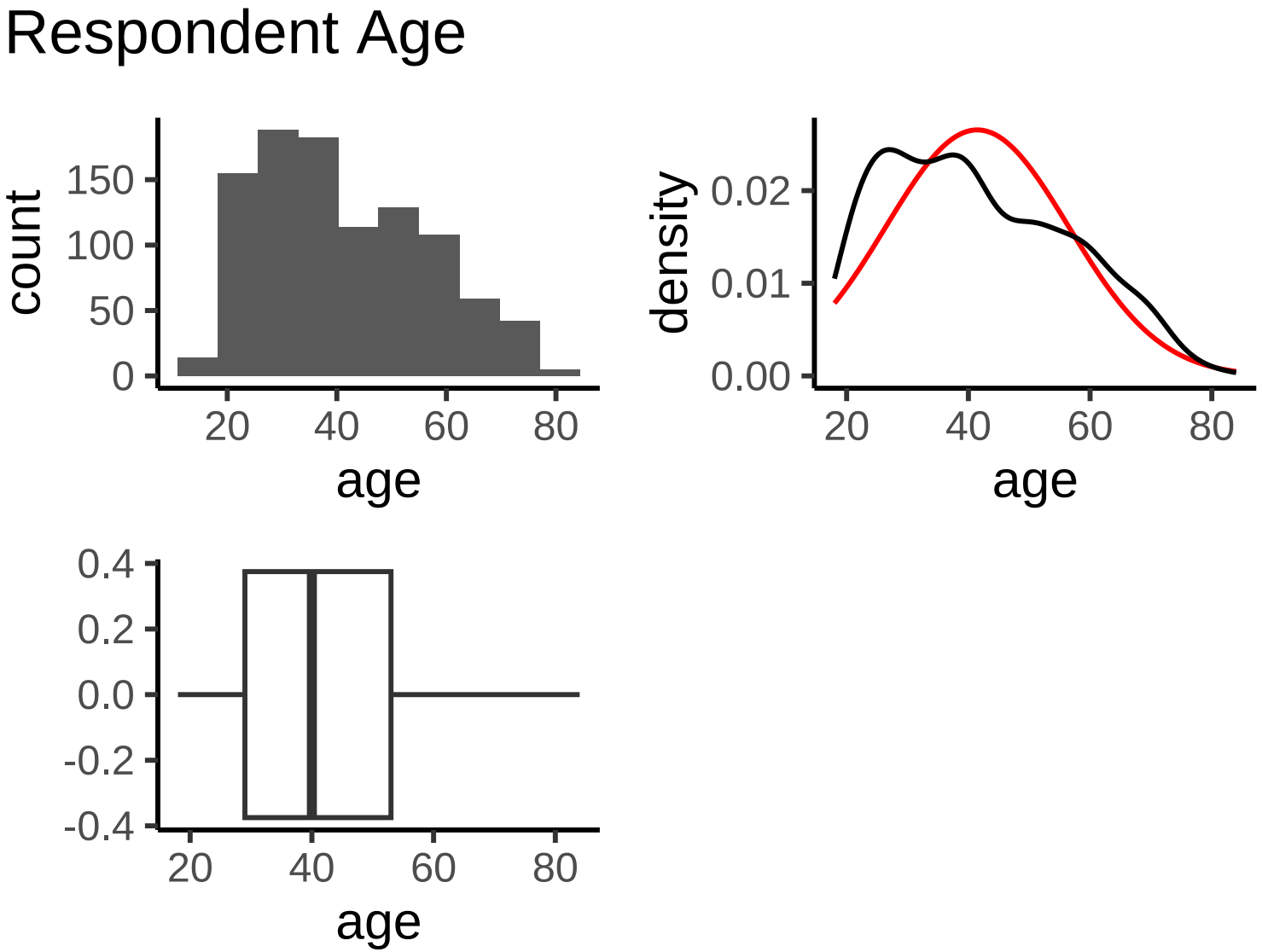


Boxplots

```
plot3 <- ggplot(data=tun22,
                aes(x=age)) +
  geom_boxplot() +
  theme_classic()
plot3
```



Summary


Respondent Age
count
150
100
50
0
20
40
60
80
age
density
0.02
0.01
0.00
20
40
60
80
age
0.4
0.2
0.0
-0.2
-0.4
20
40
60
80
age

ggplot2

We can combine `ggplot` with `tidyverse` data manipulation:

```
tun22 %>%
  group_by(region) %>%
  summarize(n = n()) %>%
  ggplot() +
  geom_bar(
    aes(x = region, y = n),
    stat = "identity"
  ) +
  labs(x="",
       y="") +
  theme_classic() +
  theme(axis.text.x = element_text(angle = 90))
```

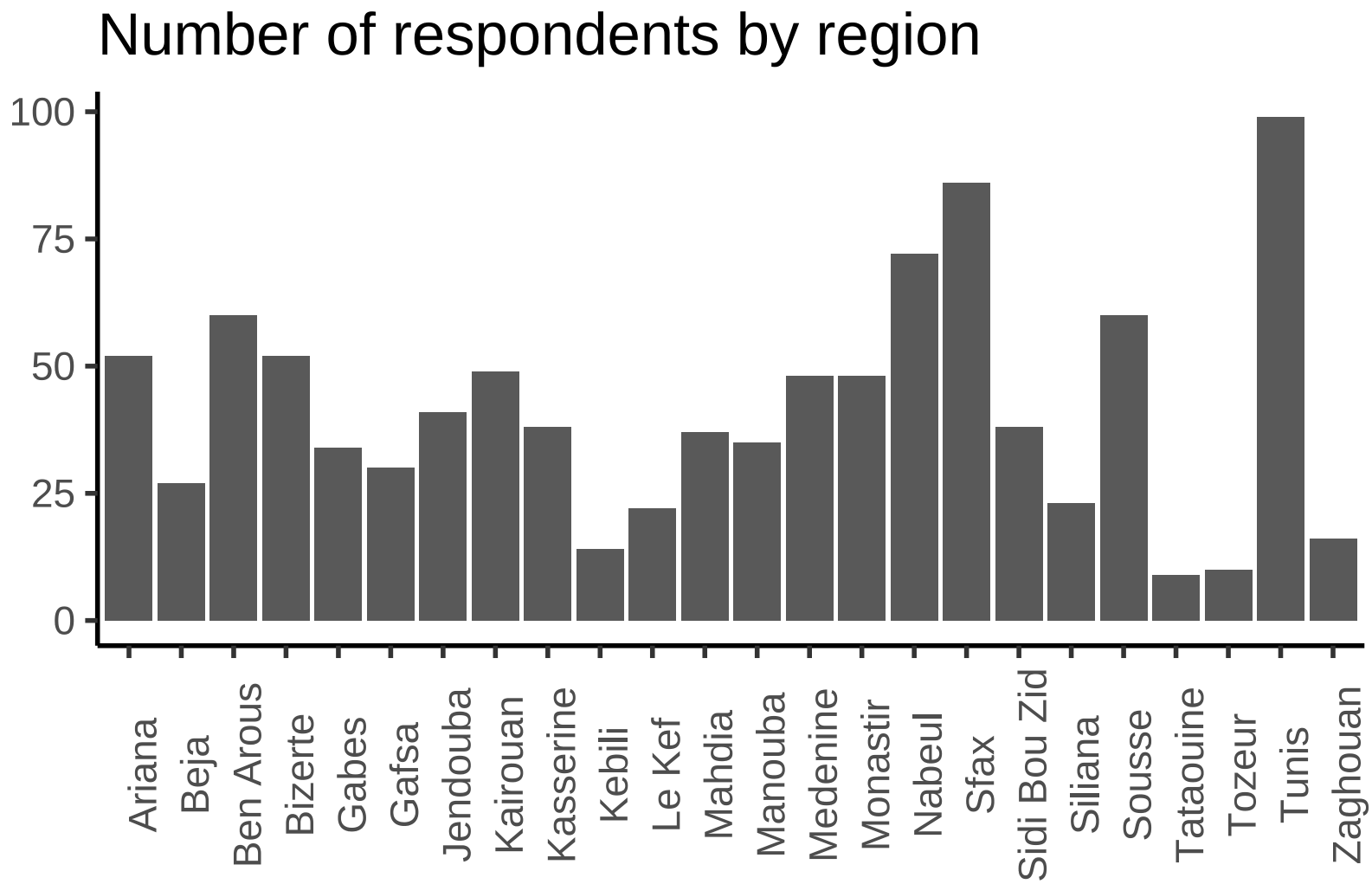
ggplot2

We can combine `ggplot` with `tidyverse` data manipulation:

```
tun22 %>%
  group_by(region) %>%
  summarize(n = n()) %>%
  ggplot() +
  geom_bar(
    aes(x = region, y = n),
    stat = "identity"
  ) +
  labs(x="",
       y="",
       title="Number of respondents by region") +
  theme_classic() +
  theme(axis.text.x = element_text(angle = 90))
```

What will this graph look like?

Bar charts

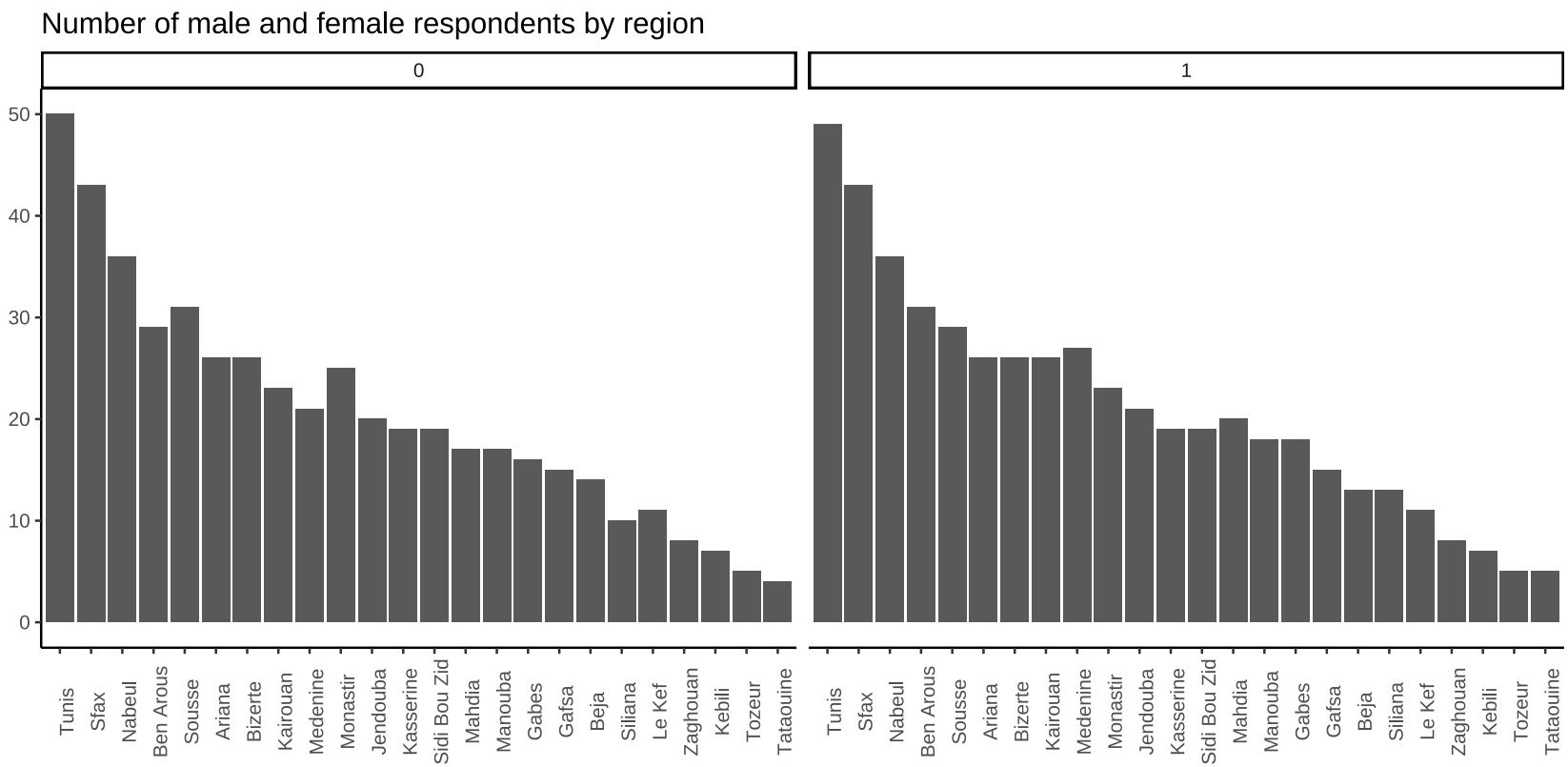

Number of respondents by region
100
75
50
25
0
Ariana
Beja
Ben Arous
Bizerte
Gabes
Gafsa
Jendouba
Kairouan
Kasserine
Kebili
Le Kef
Mahdia
Manouba
Medenine
Monastir
Nabeul
Sfax
Sidi Bou Zid
Siliana
Sousse
Tataouine
Tozeur
Tunis
Zaghouan

ggplot2

We can also produce different plots by group using the `facet()` layer

```
tun22 %>%
  group_by(region,female) %>%
  summarize(n = n()) %>%
  ggplot() +
  geom_bar(
    aes(x = reorder(region,-n), y = n), stat = "identity") +
  labs(x="",
       y="",
       title="Number of male and female respondents by region") +
  theme_classic() +
  theme(axis.text.x = element_text(angle = 90)) +
  facet_wrap(~female)
```

ggplot2


Number of male and female respondents by region
0
1
50
40
30
20
10
0
Tunis
Sfax
Nabeul
Ben Arous
Sousse
Ariana
Bizerte
Kairouan
Medenine
Monastir
Jendouba
Kasserine
Sidi Bou Zid
Mahdia
Manouba
Gabes
Gafsa
Beja
Siliana
Le Kef
Zaghouan
Kebili
Tozeur
Tataouine

Plotting two variables

Scatterplots

- **Scatterplots** are plots displaying the relationship between two numerical variables.
- The variables are plotted on the x and y-axis, each dot represents one observation (or case).

V-Dem data

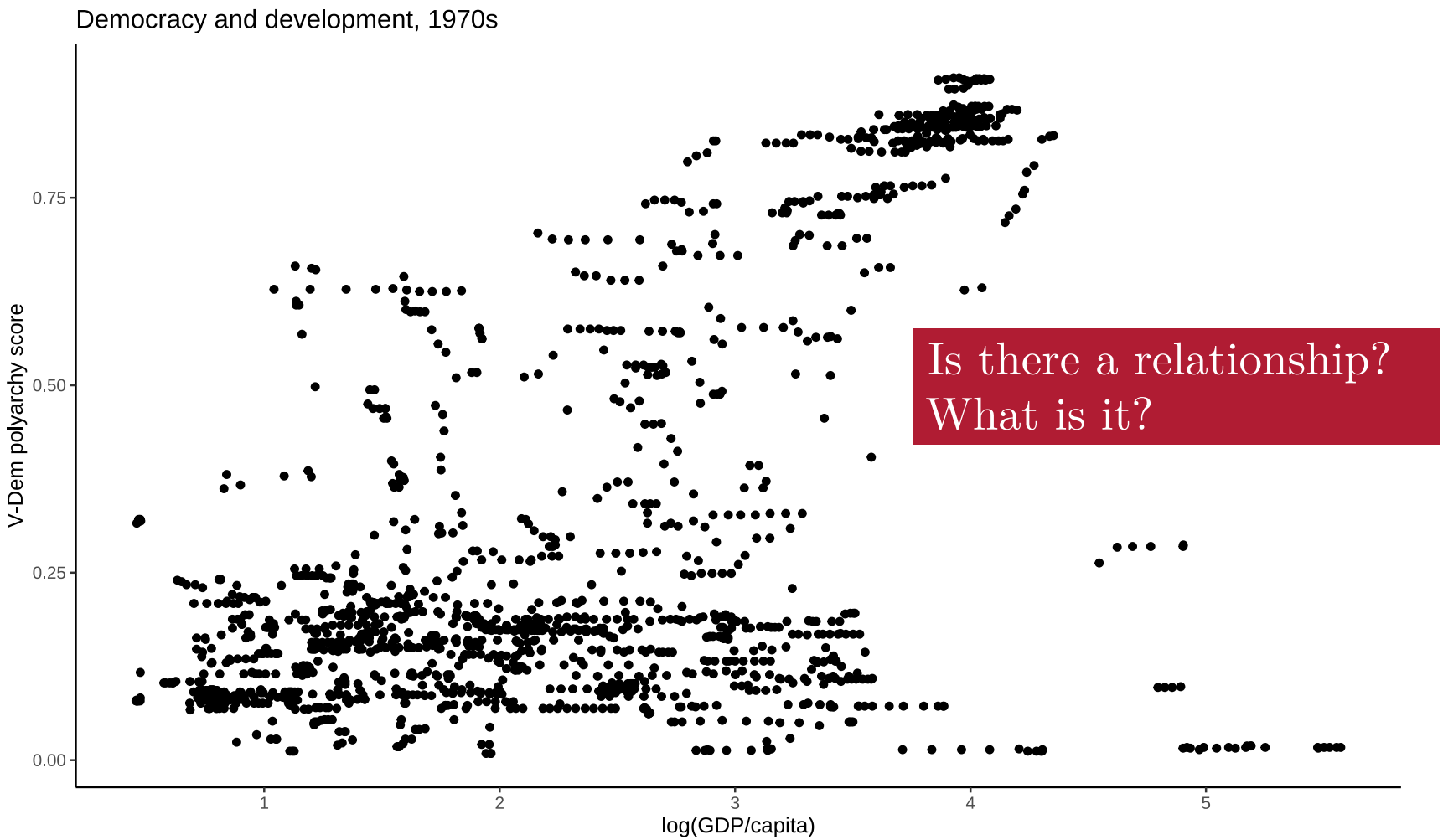
Download the V-Dem data:

```
# First, you need to have the devtools package installed
install.packages("devtools")
# now, install the vdemdata package directly from GitHub
devtools::install_github("vdeminstitute/vdemdata")
# Now load the package
library(vdemdata)

data <- vdem

data <- data %>%
  dplyr::select(v2x_polyarchy,
                e_gdppc,year,
                country_name,
                e_regionpol)
```

Let's create a scatterplot showing the relationship between log GDP/capita and the polyarchy score for the 1970s

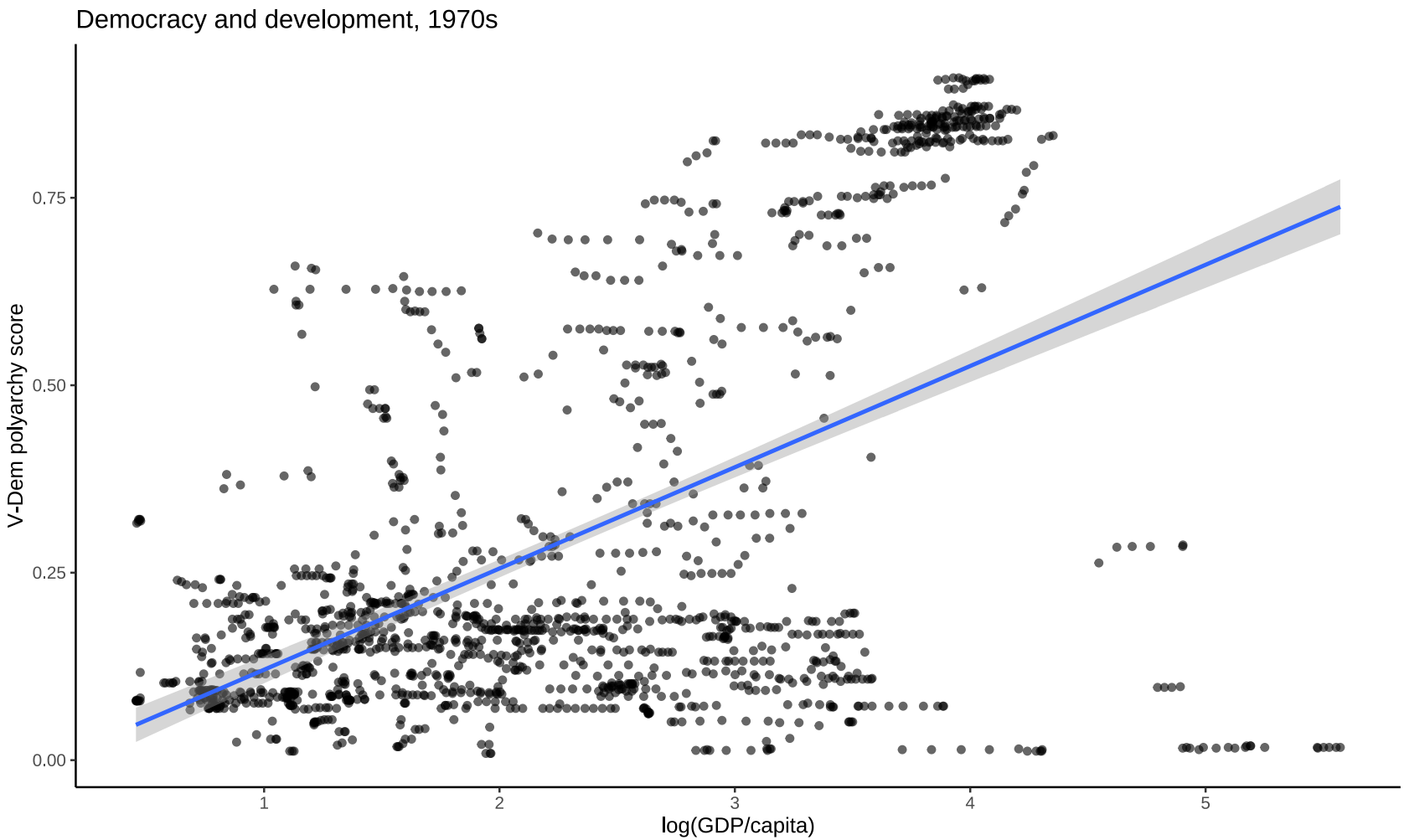
Scatterplots

Scatterplots



Is there a relationship?
What is it?

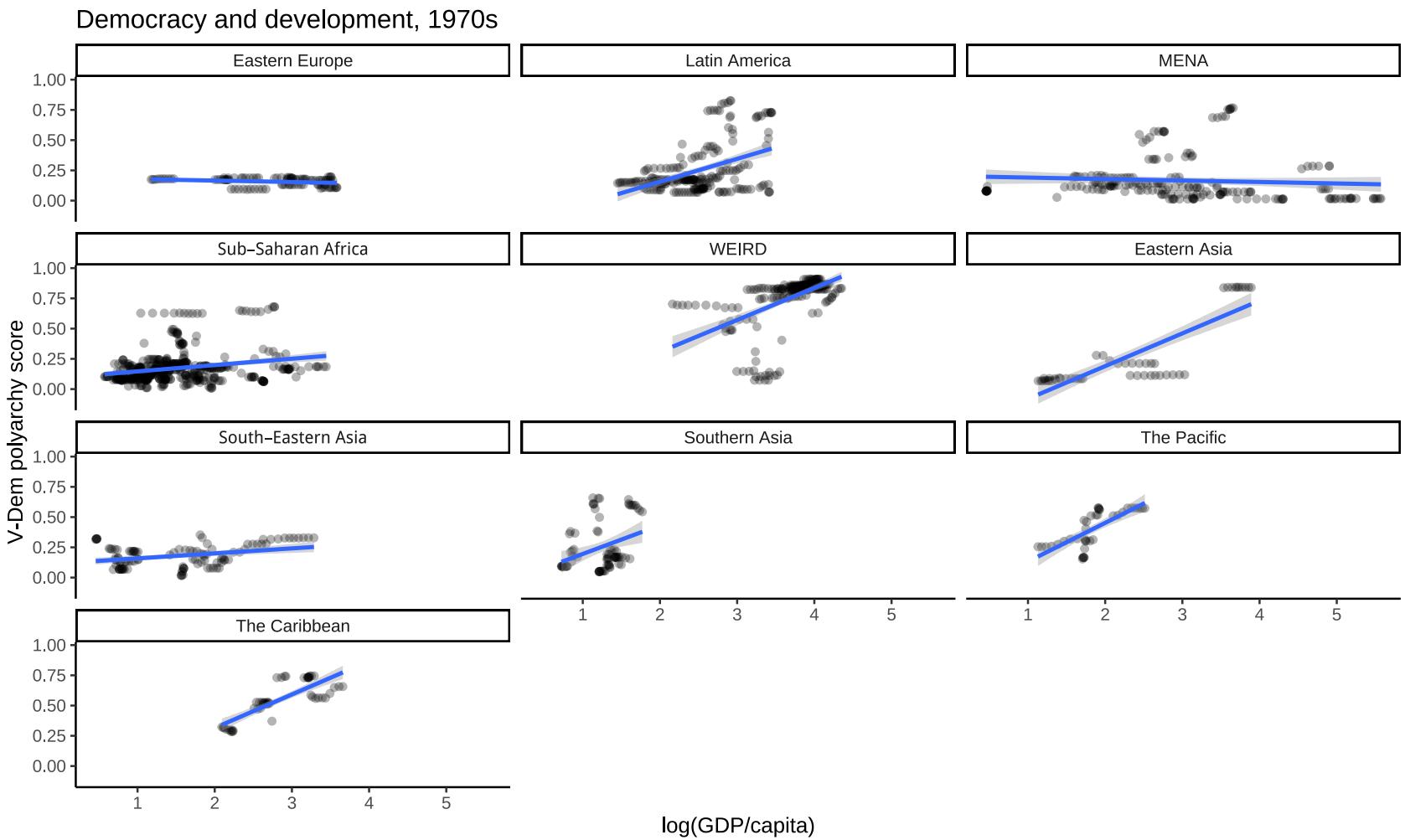
Scatterplots



Scatterplots

```
plot1 <- data %>%
  filter(year>1969 & year<1980) %>%
  rename(democracy=v2x_polyarchy) %>%
  mutate(gdp=log(e_gdppc)) %>%
  ggplot(aes(x=gdp,
             y=democracy)) +
  geom_point(alpha=0.6) +
  geom_smooth(method = "lm") +
  theme_classic() +
  labs(x="log(GDP/capita)",
       y="V-Dem polyarchy score",
       title = "Democracy and development, 1970s")
```

By the way


Democracy and development, 1970s
Eastern Europe
Latin America
MENA
Sub–Saharan Africa
WEIRD
Eastern Asia
South–Eastern Asia
Southern Asia
The Pacific
The Caribbean
V-Dem polyarchy score
1.00
0.75
0.50
0.25
0.00
1
2
3
4
5
log(GDP/capita)

Combining graphs with the patchwork package

```
plot1 <- data %>%
  filter(year>1969 & year<1980) %>%
  rename(democracy=v2x_polyarchy) %>%
  mutate(gdp=log(e_gdppc)) %>%
  ggplot() +
  geom_point(aes(
    x=gdp,
    y=democracy
  ), alpha=0.6, size=1) +
  geom_smooth(aes(
    x=gdp,
    y=democracy),
    method = "lm") +
  theme_classic() +
  labs(x="log(GDP/capita)",
       y="V-Dem polyarchy score",
       title = "All countries")
```

Plot 1

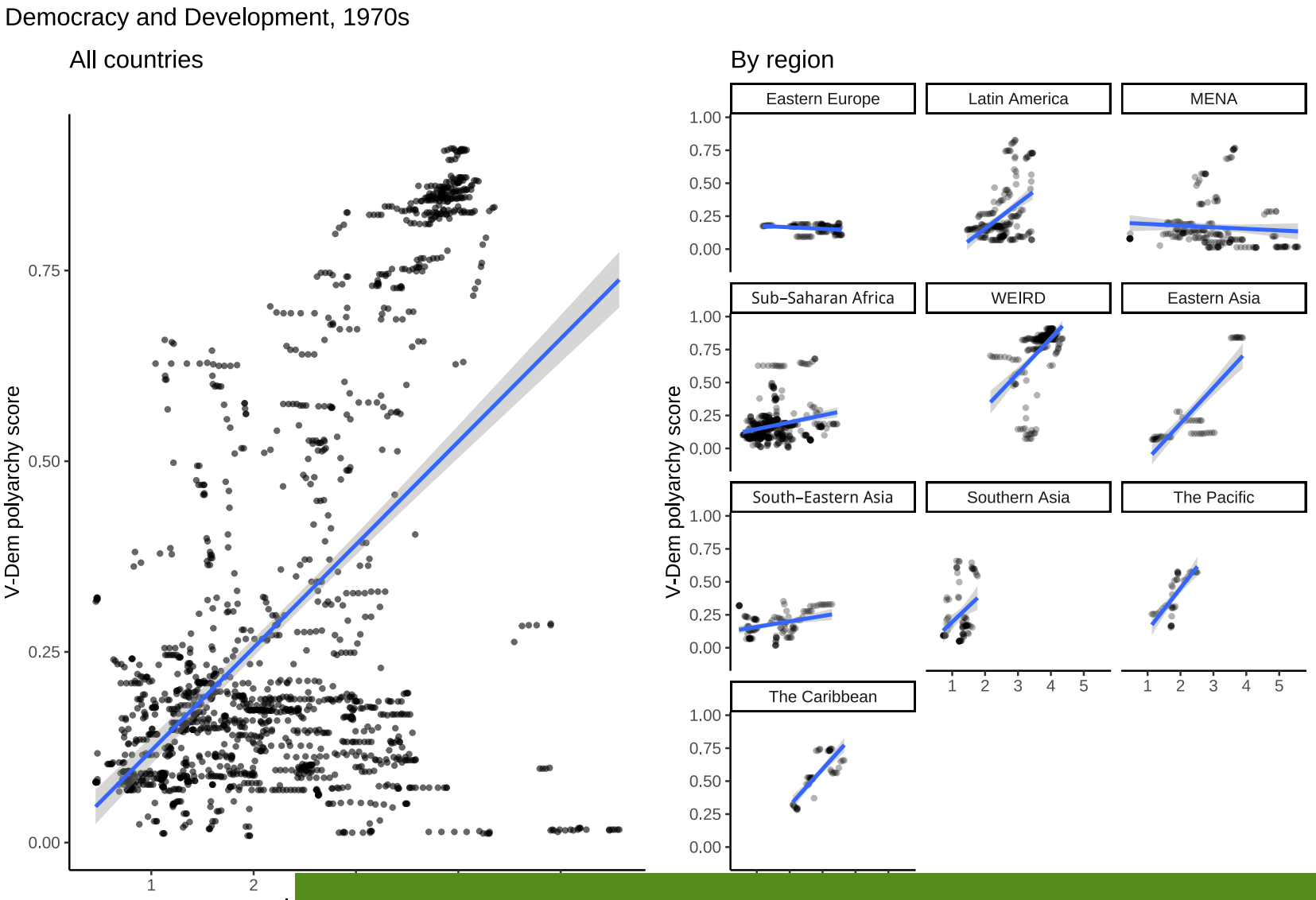
```
library(patchwork)
all_plots <- plot1 + plot2
all_plots + plot_annotation(
  title = "Democracy and Development,
  1970s"
)
```

Combine

```
plot2 <- data %>%
  mutate(region = factor(e_regionpol,
                         levels = 1:10,
                         labels = c("Eastern Europe",
                                    "Latin America",
                                    "MENA",
                                    "Sub-Saharan Africa",
                                    "WEIRD",
                                    "Eastern Asia",
                                    "South-Eastern Asia",
                                    "Southern Asia",
                                    "The Pacific",
                                    "The Caribbean"))) %>%
  filter(year > 1969 & year < 1980) %>%
  rename(democracy = v2x_polyarchy) %>%
  mutate(gdp = log(e_gdppc)) %>%
  ggplot(aes(x = gdp, y = democracy)) +
  geom_point(alpha=0.3, size=1, show.legend = F) +
  geom_smooth(method = "lm", show.legend = FALSE) +
  theme_classic() +
  labs(
    x = "log(GDP/capita)",
    y = "V-Dem polyarchy score",
    title = "By region"
  ) +
  facet_wrap(~ region, ncol = 3)
```

Plot 2

Combining graphs with the `patchwork` package



Exercises

Exercises

Recreate the plots on the GitHub page.