Time

Week 9

AEM 2850 / 5850 : R for Business Analytics

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Spring 2023

Acknowledgements: Andrew Heiss

Announcements

Reminders:

- **Group project groups due this Friday (March 24)** (canvas link)
  - Form groups of 3
  - All students in each group must be in the same section (2850 or 5850)
  - If unable to form a group of 3, please state that in your submission
- **Group project due April 14** (full details to come in the next week)

Questions before we get started?

Plan for today

Prologue

Visualizing time

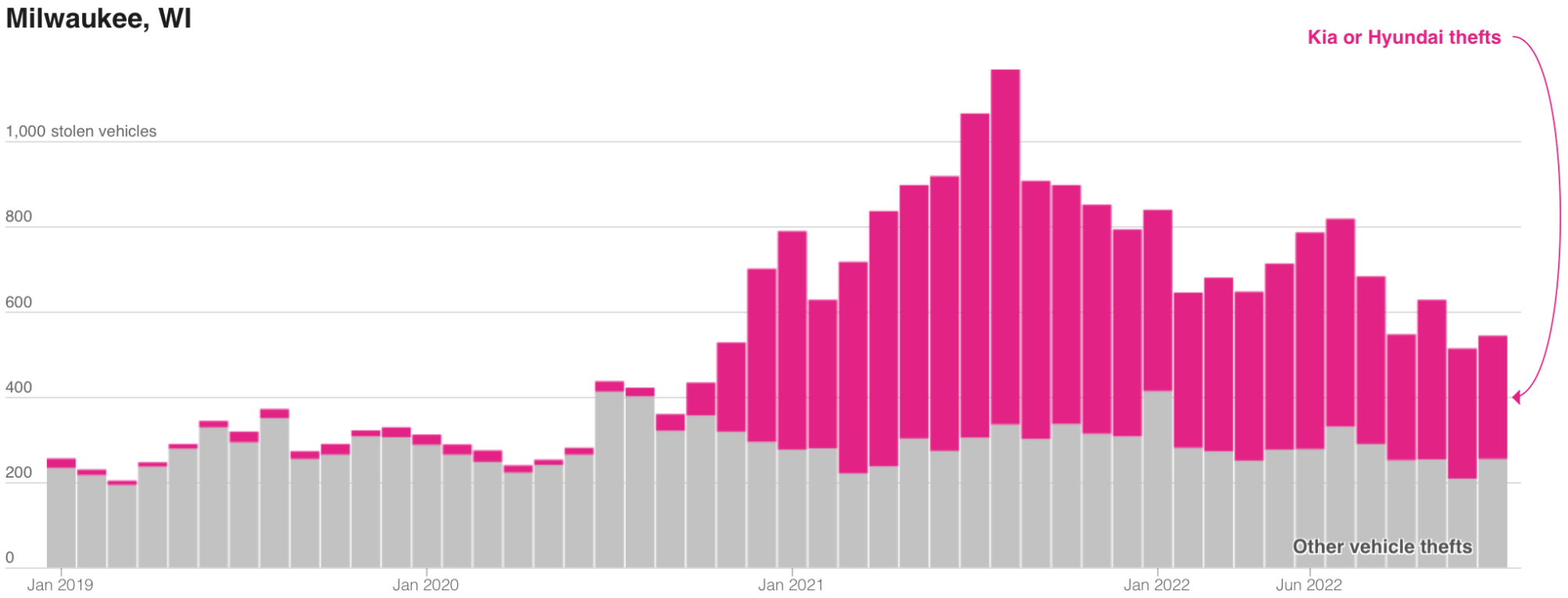
- Visualizing amounts over time
- Visualizing distributions over time
- Animating plots over time
- Faceting plots over time
- Connecting scatter plots over time

Starting, ending, and decomposing time

Dates and times in R

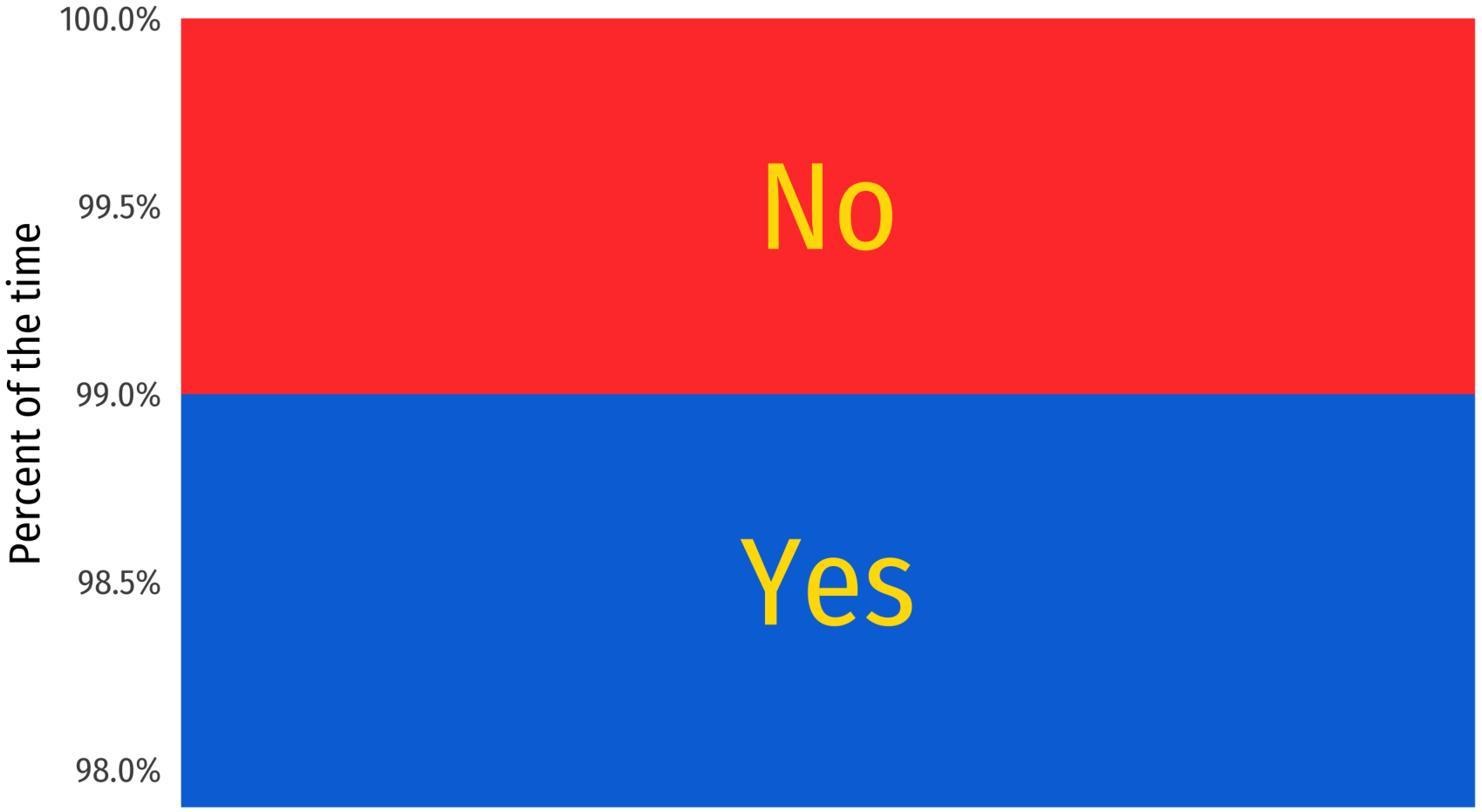
Prologue: In the news

Car thefts are rising. Is TikTok to blame?



Prologue: Axis issues (revisited)

Is truncating the y-axis misleading?



Don't be too extreme!

When discussing amounts, we said to never truncate the y-axis

But it is actually more legal to truncate the y-axis than you might think

When do you think it is okay to truncate?

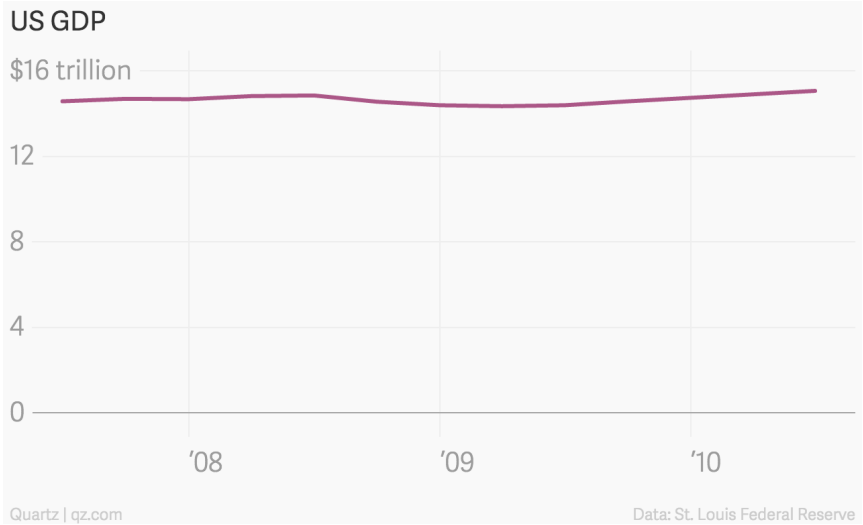
When small movements matter

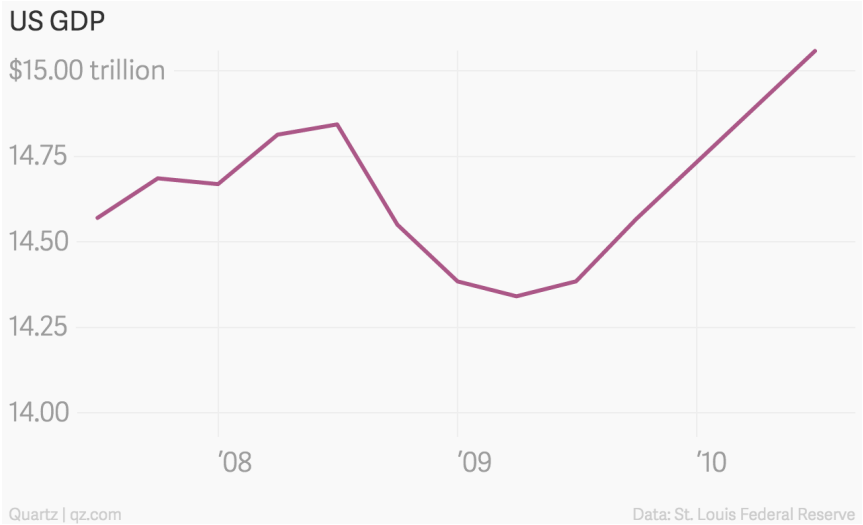
When the scale itself is distorted

When zero values are impossible

When is it okay to truncate?

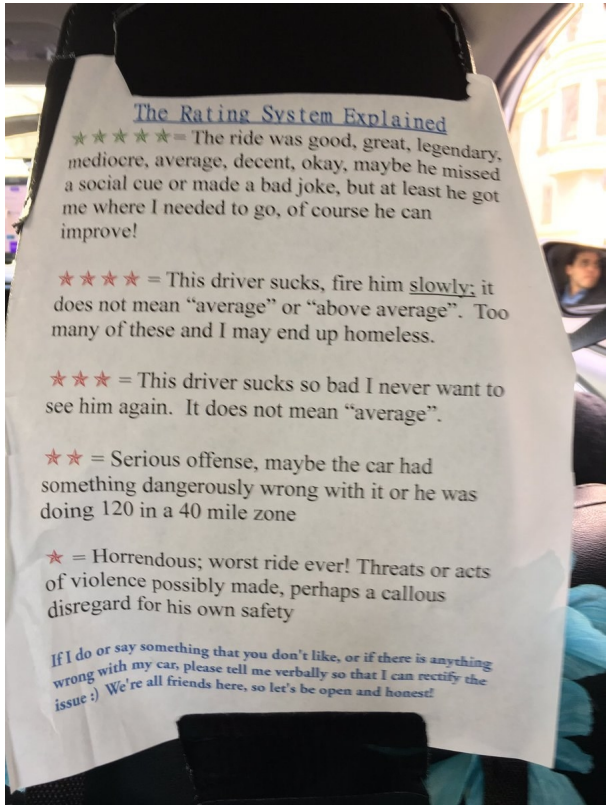
When small movements matter

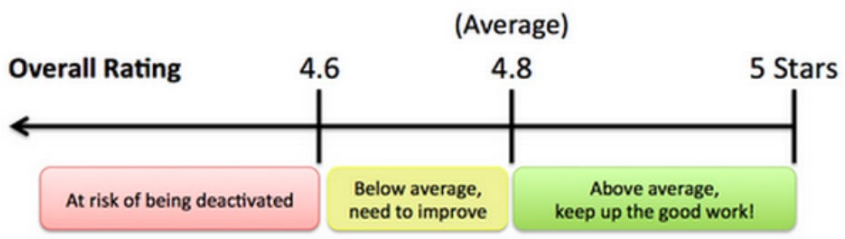




When is it okay to truncate?

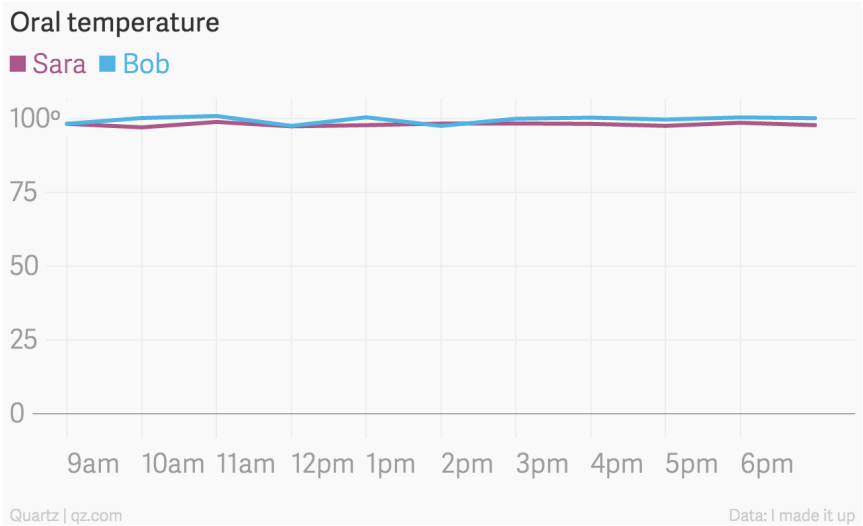
When the scale itself is distorted

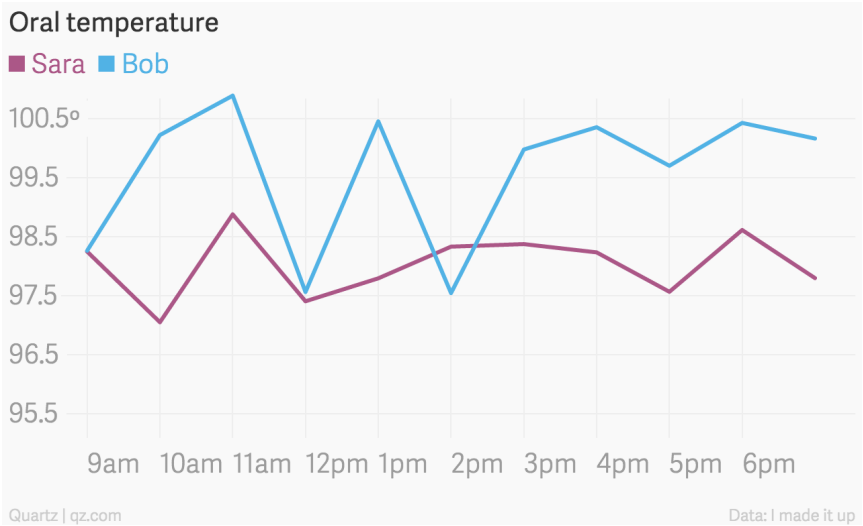




When is it okay to truncate?

When zero values are impossible



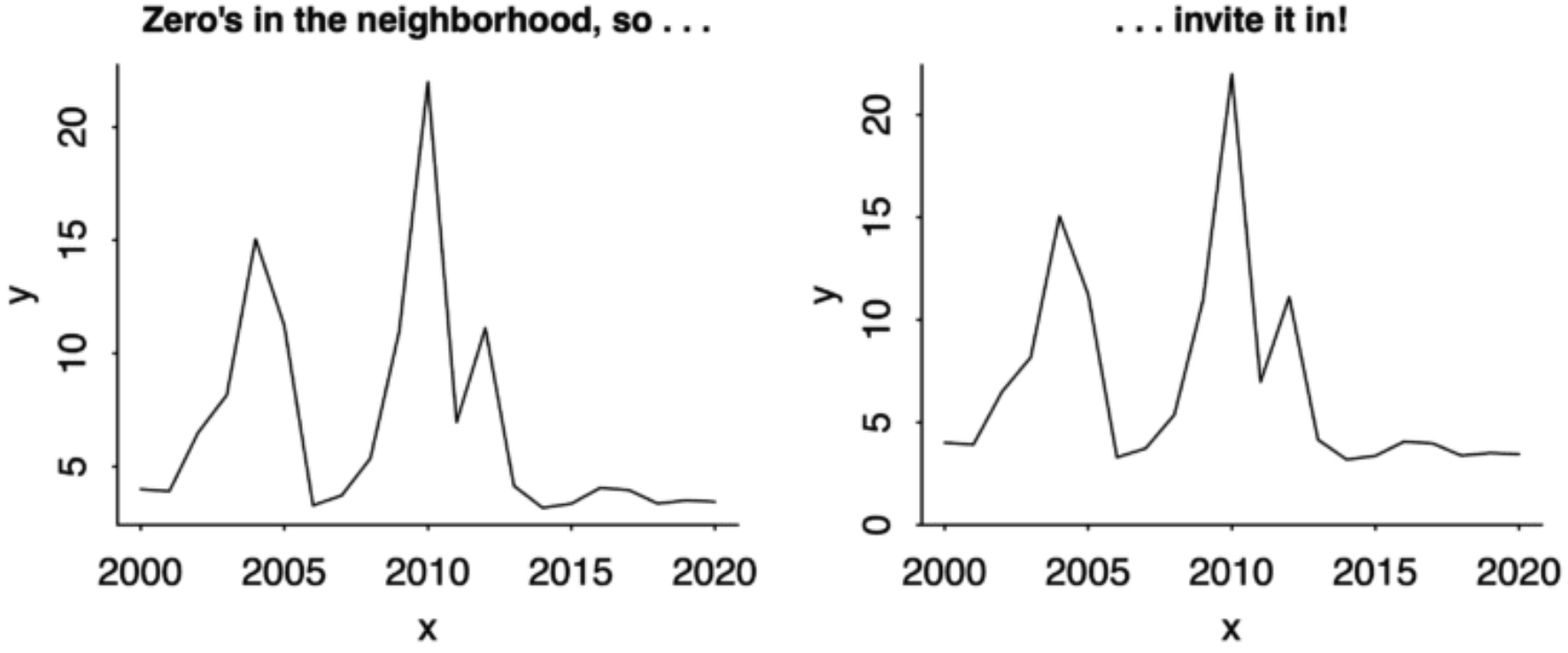


Never on bar charts

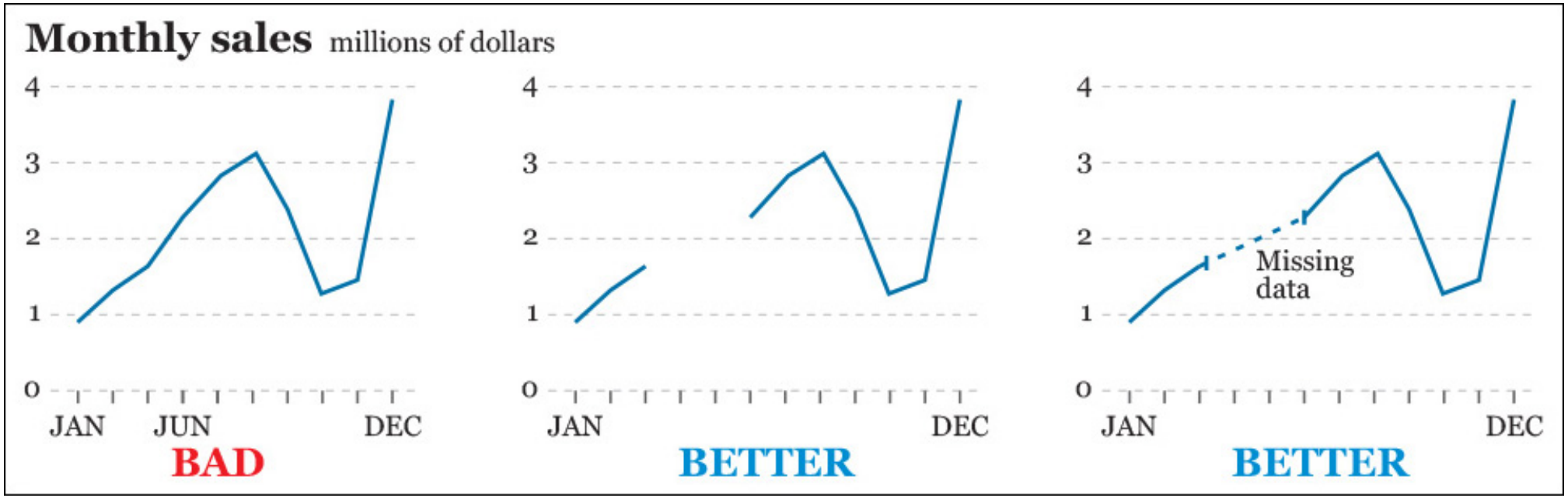
Zero is okay too!

Just because you don't *have to* start at 0 doesn't mean you should *never* start at 0

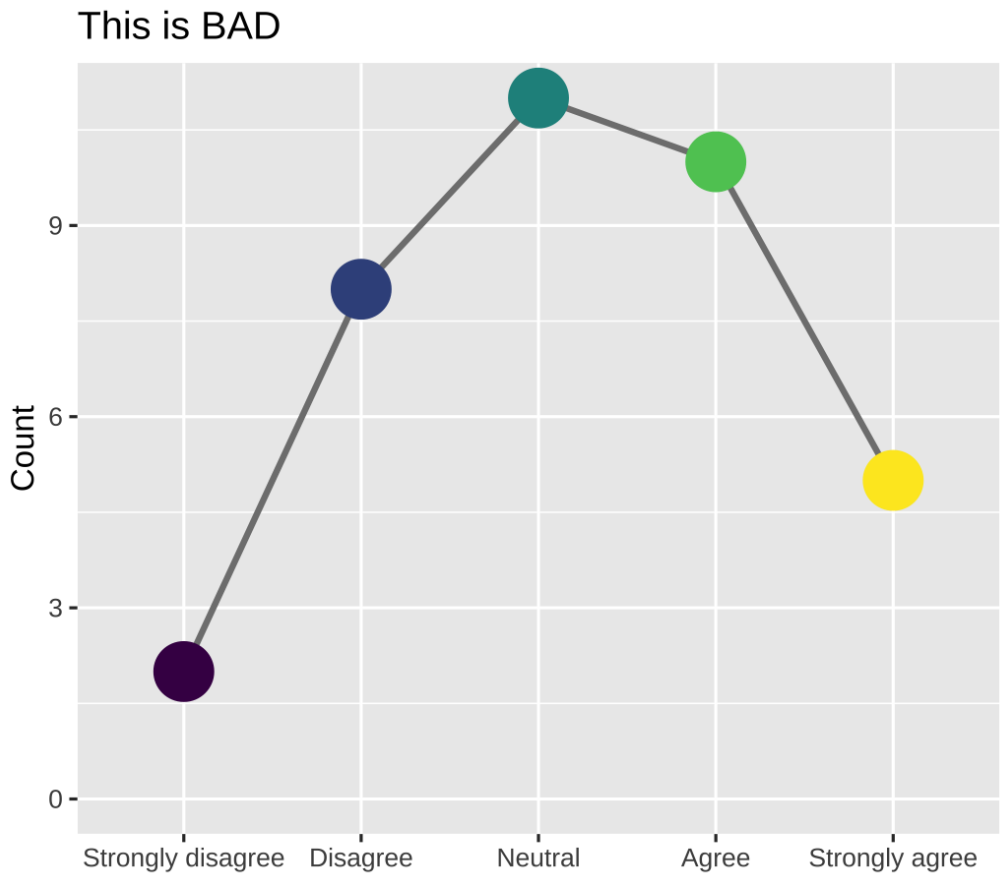
Andrew Gelman's heuristic: **"If zero is in the neighborhood, invite it in."**

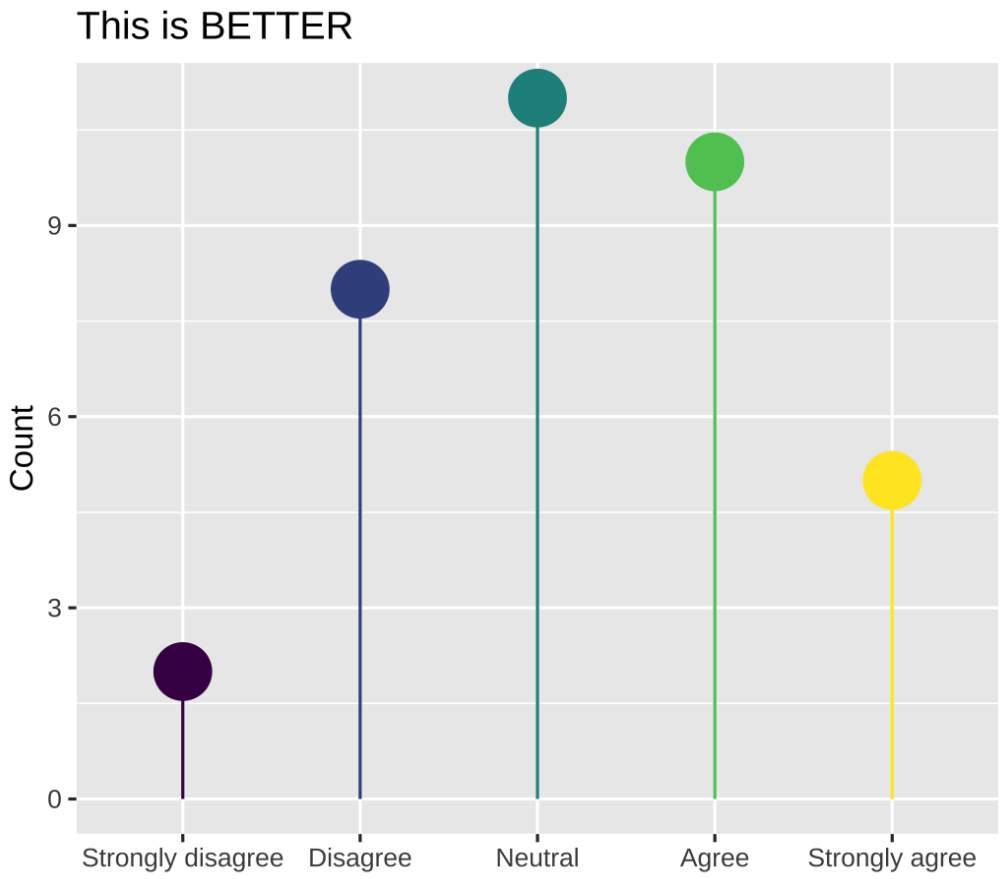


Also: keep scales consistent, flag missing data



Also: don't impute across categories





Visualizing time

Visualizing amounts over time

Time is just a variable that can be mapped to an aesthetic

Can be used as `x`, `y`, `color`, `fill`, `facet`, and even animation

Can use all sorts of `geom`s: lines, columns, points, heatmaps, densities, maps, etc.

In general, follow reading conventions to show time progression:

→ & ↓

Visualizing amounts over time using ggplot

Let's use GameStop share prices to make some plots:

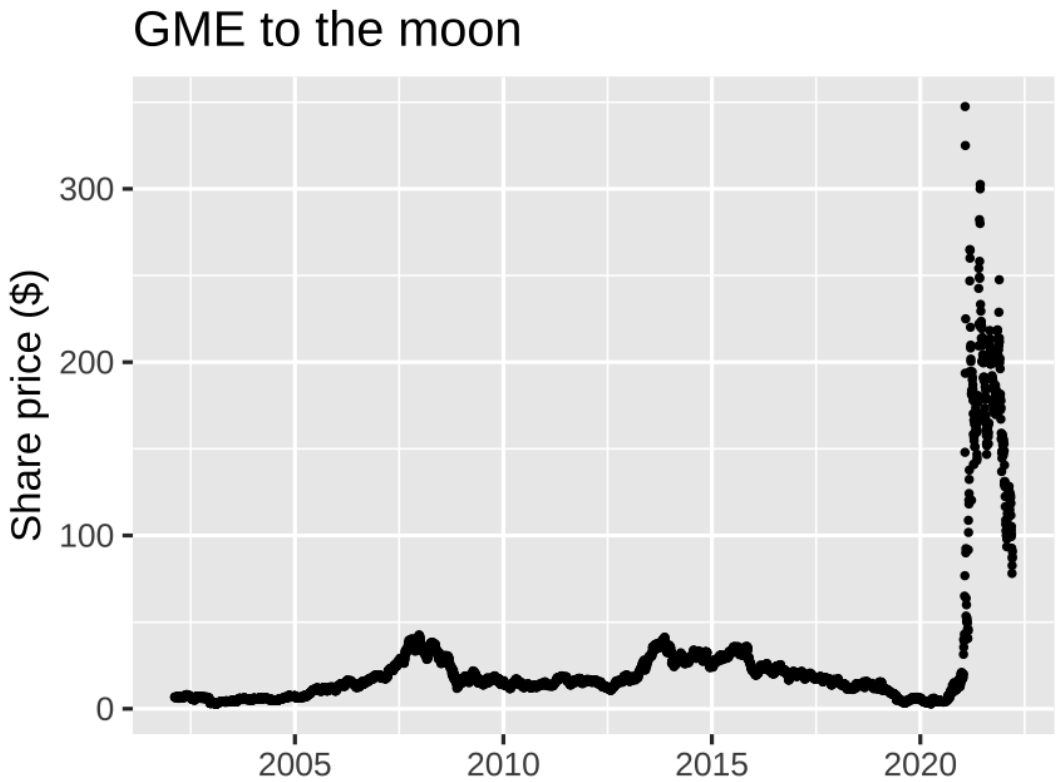
```
gme_prices
```

```
## # A tibble: 5,060 × 8
##    symbol date        open  high   low close   volume adjusted
##    <chr>  <date>     <dbl> <dbl> <dbl> <dbl>    <dbl>    <dbl>
##  1 GME    2002-02-13  9.62 10.1   9.52 10.0  19054000     6.77
##  2 GME    2002-02-14 10.2  10.2   9.93 10     2755400     6.73
##  3 GME    2002-02-15 10    10.0   9.85  9.95  2097400     6.70
##  4 GME    2002-02-19  9.9   9.9   9.38  9.55  1852600     6.43
##  5 GME    2002-02-20  9.6   9.88  9.52  9.88  1723200     6.65
##  6 GME    2002-02-21  9.84  9.93  9.75  9.85  1744200     6.63
##  7 GME    2002-02-22  9.93  9.93  9.6   9.68   881400     6.51
##  8 GME    2002-02-25  9.65  9.82  9.54  9.75   863400     6.56
##  9 GME    2002-02-26  9.7   9.85  9.54  9.75   690400     6.56
## 10 GME    2002-02-27  9.68  9.68  9.5   9.57  1022800     6.45
## # … with 5,050 more rows
```

Time on x-axis + `geom_point()`

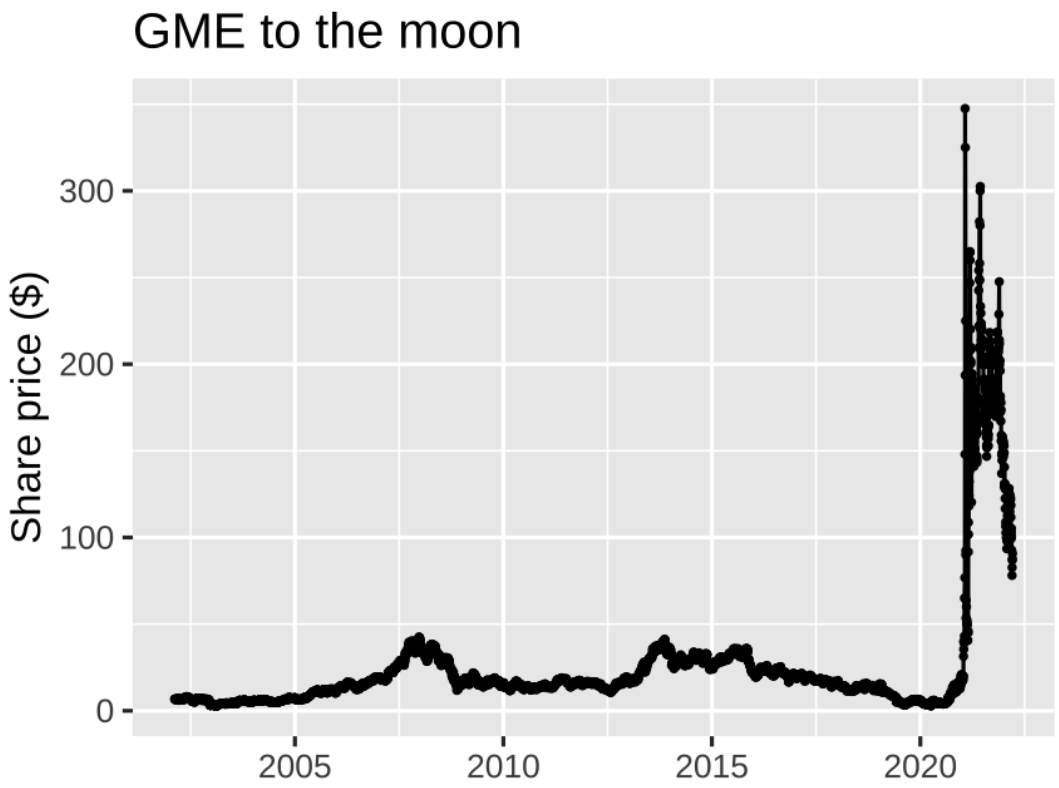
```
gme_prices |>
  ggplot(aes(x = date, y = adjusted)) +
  geom_point(size = 0.5) +
  labs(x = NULL, y = "Share price ($)",
       title = "GME to the moon")
```

How would you add a line to this?



Time on x-axis + `geom_point()`

```
gme_prices |>
  ggplot(aes(x = date, y = adjusted)) +
  geom_point(size = 0.5) +
  geom_line() +
  labs(x = NULL, y = "Share price ($)",
       title = "GME to the moon")
```



Time on x-axis: points vs lines

Points emphasize observations

Lines emphasize trends

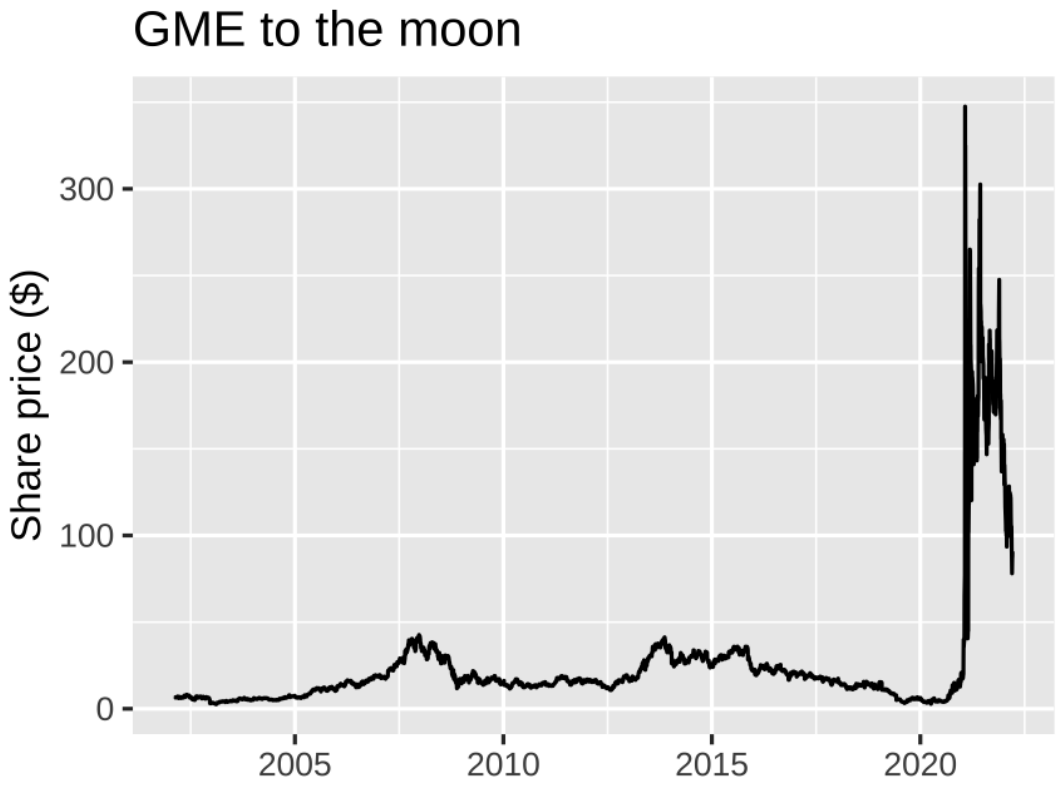
Using lines for time series is often fine since data are evenly spaced and usually complete

But lines are effectively made-up data, so be careful how you use them!

Time on x-axis + `geom_line/col()`

The GameStop share price plot is clearer without points:

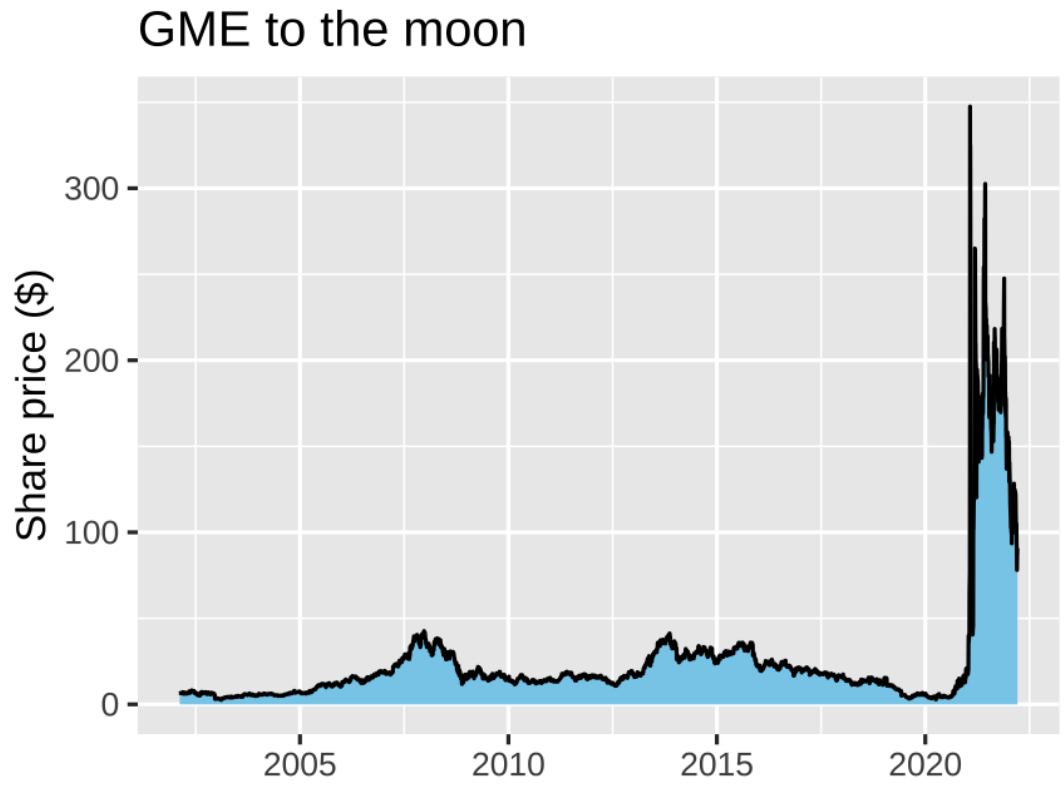
```
gme_prices |>
  ggplot(aes(x = date, y = adjusted)) +
  geom_line() +
  labs(x = NULL, y = "Share price ($)",
       title = "GME to the moon")
```



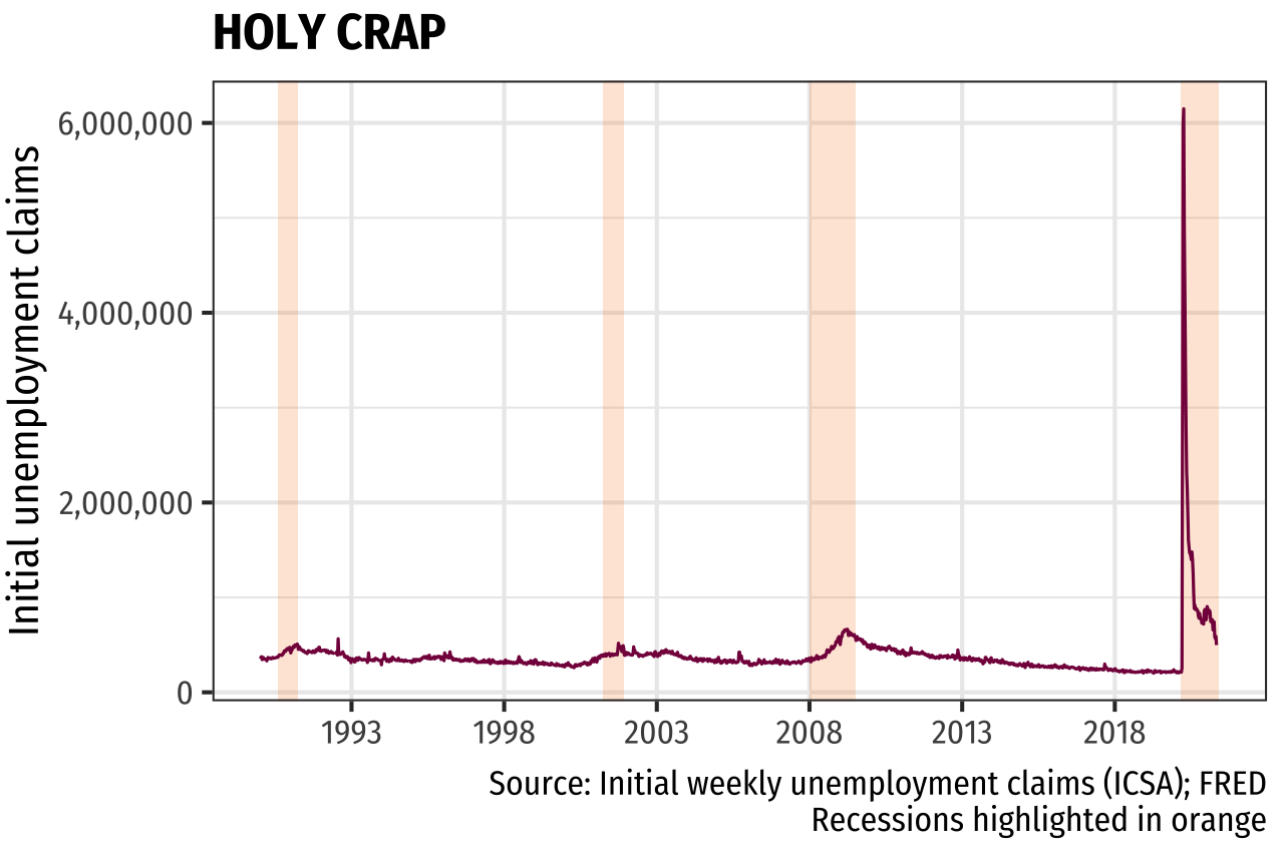
Time on x-axis + `geom_line/col()`

Can also use a fill for the area under a line, **as long as the y-axis starts at zero**

```
gme_prices |>
  ggplot(aes(x = date, y = adjusted)) +
  geom_area(fill = "skyblue", color = "black") +
  labs(x = NULL, y = "Share price ($)",
       title = "GME to the moon")
```

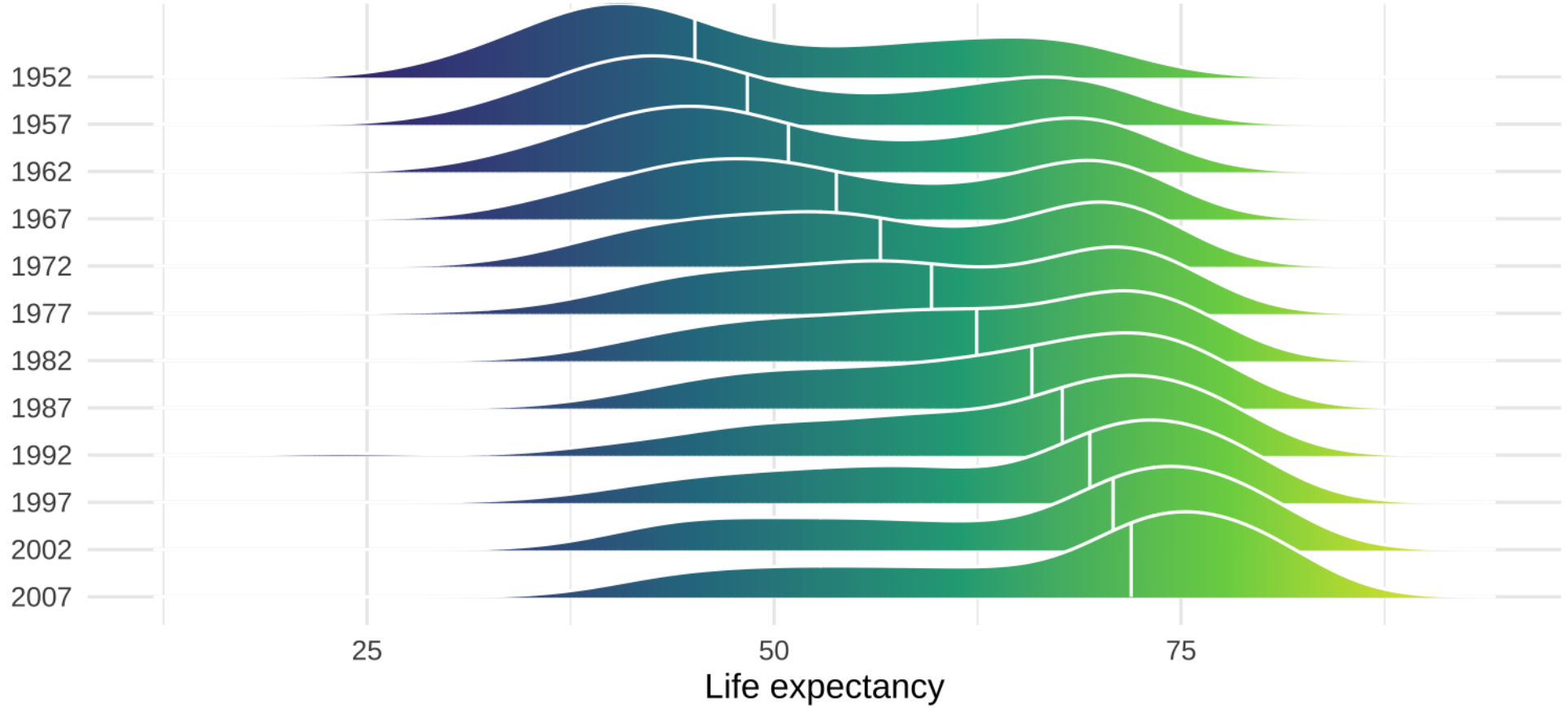


Line plots don't have to be boring



Visualizing distributions over time

We can also visualize how distributions evolve. How could you make this plot?

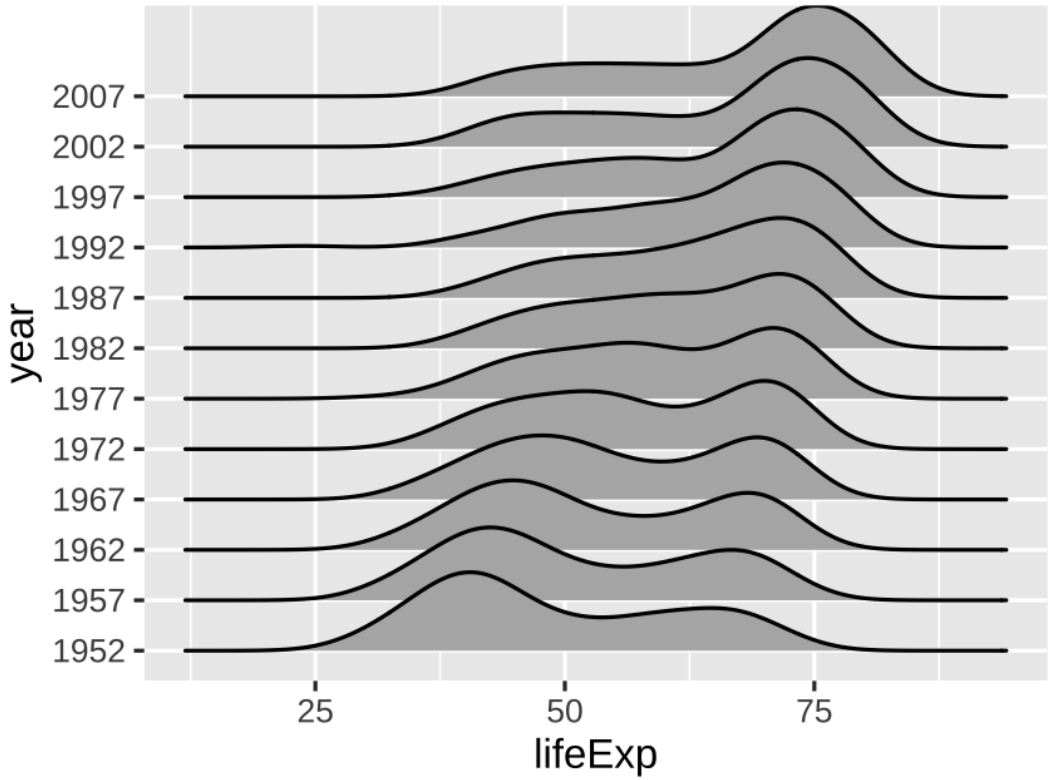


Let's start simple

```
library(ggridges) # for geom_density_ridges()

gapminder |>
    mutate(year = as_factor(year)) |>
    ggplot(
      aes(x = lifeExp,
          y = year) # map time to y
      ) +
    geom_density_ridges() # add geom
```

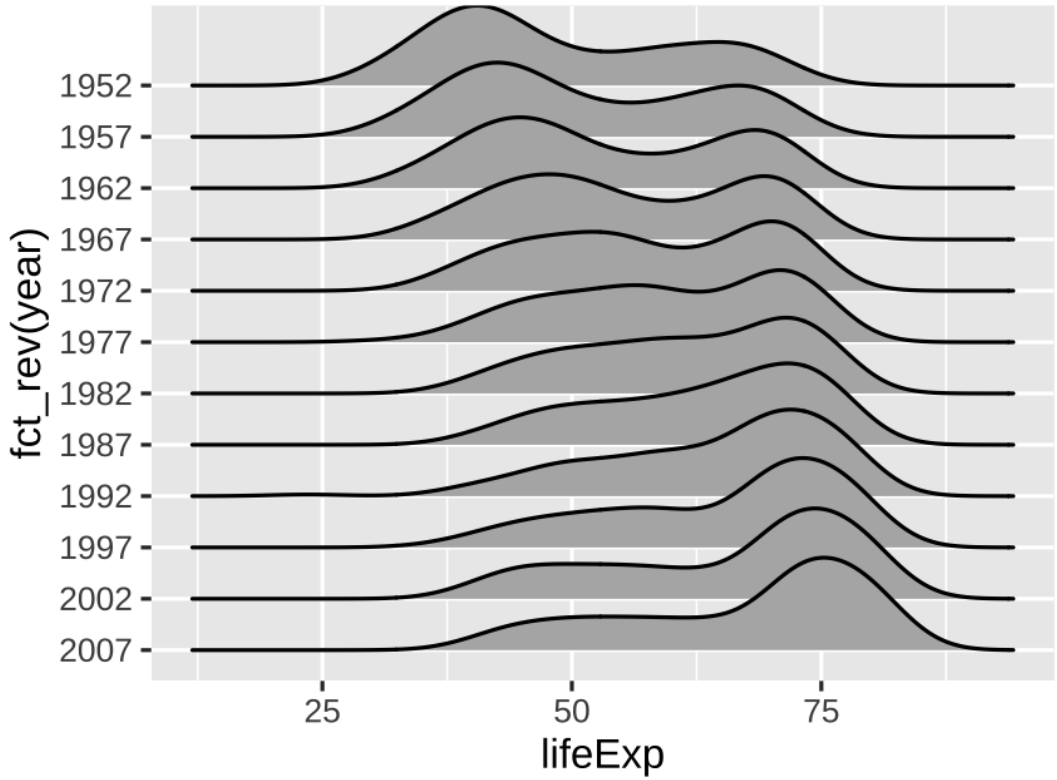
How could we modify this to follow ↓ convention for time?



Follow ↓ convention for time

```
gapminder |>
    mutate(year = as_factor(year)) |>
    ggplot(
      aes(x = lifeExp,
          y = fct_rev(year)) # reverse year
      ) +
    geom_density_ridges()
```

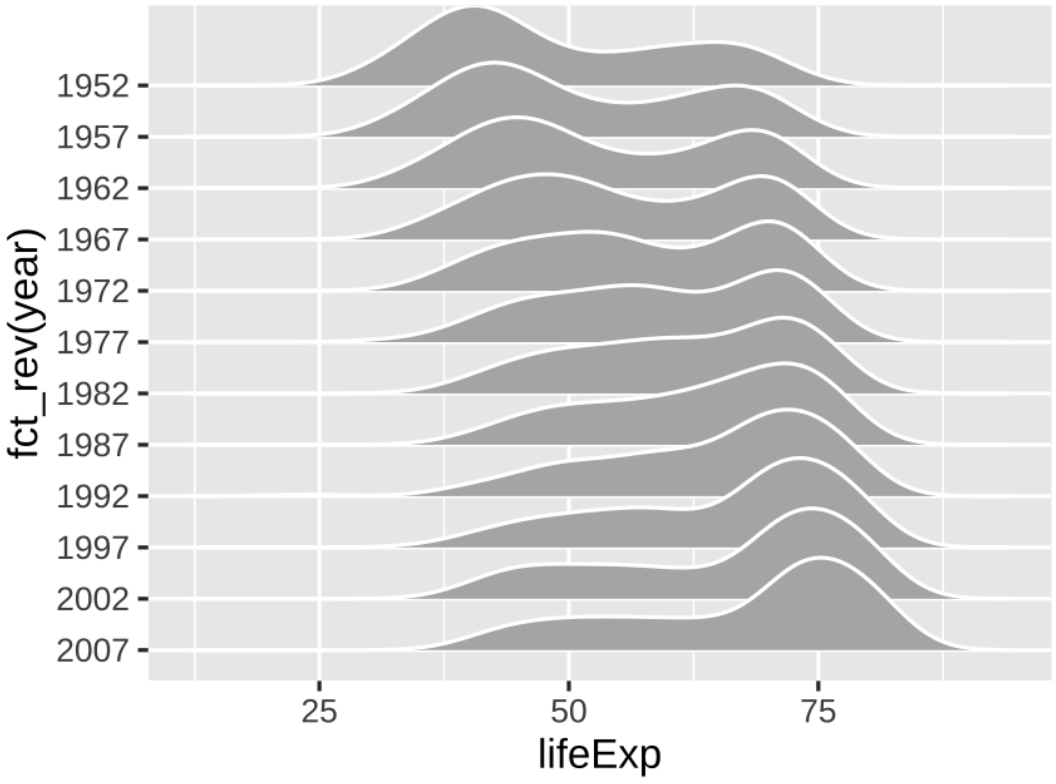
How could we make the lines white?



Add color to help visually separate densities

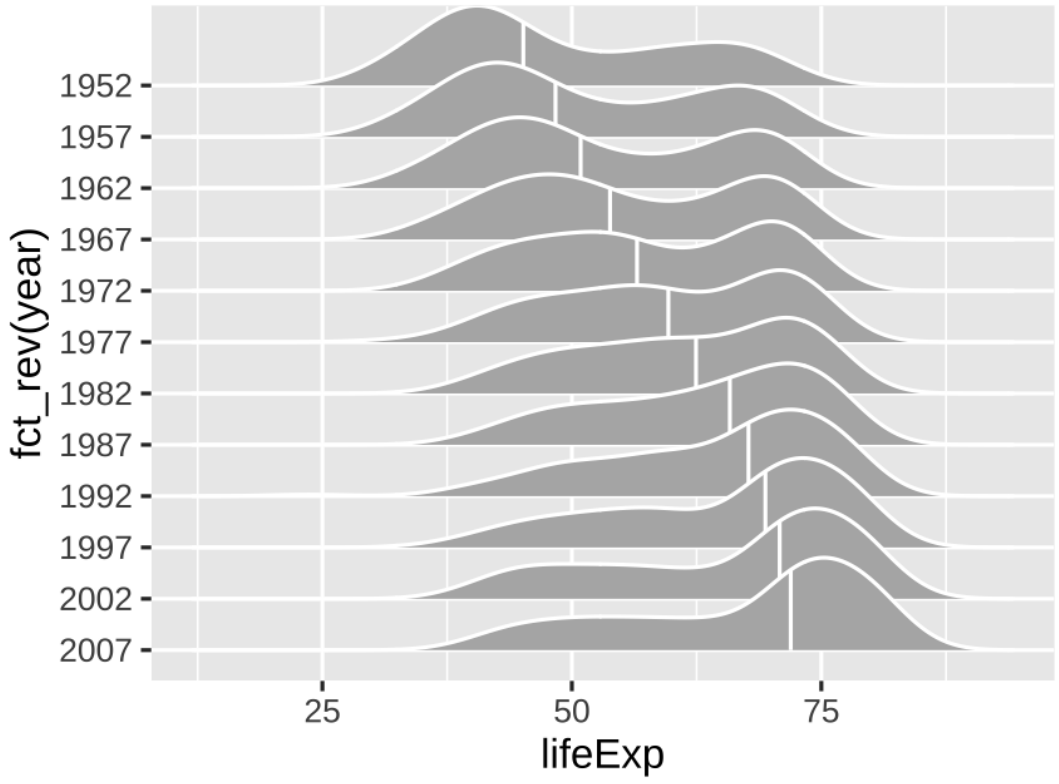
```
gapminder |>
    mutate(year = as_factor(year)) |>
    ggplot(
      aes(x = lifeExp,
          y = fct_rev(year))
      ) +
    geom_density_ridges(
      color = "white"  # separate densities
      )
```

How could we add a line at the median of each density?



Add a line at the median of each density

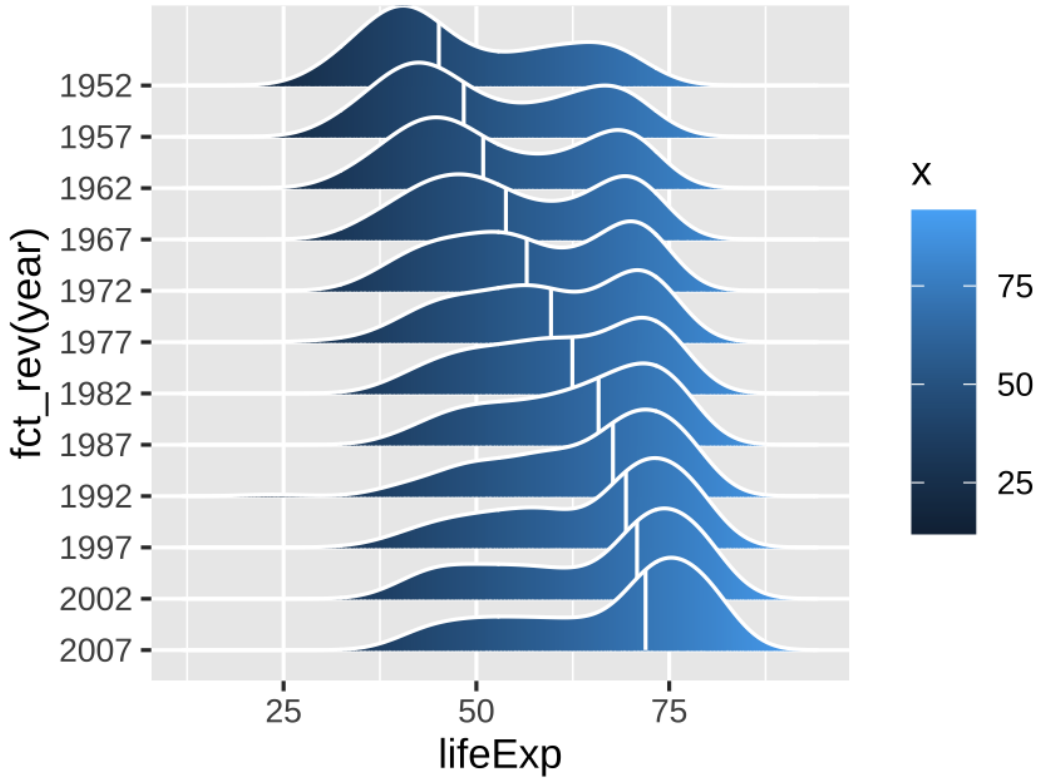
```
gapminder |>
    mutate(year = as_factor(year)) |>
    ggplot(
      aes(x = lifeExp,
          y = fct_rev(year))
      ) +
    geom_density_ridges(
      color = "white",
      quantile_lines = TRUE, # add lines
      quantiles = 2          # median
      )
```



How could we add a color gradient to the densities?

Fill the densities along the x axis

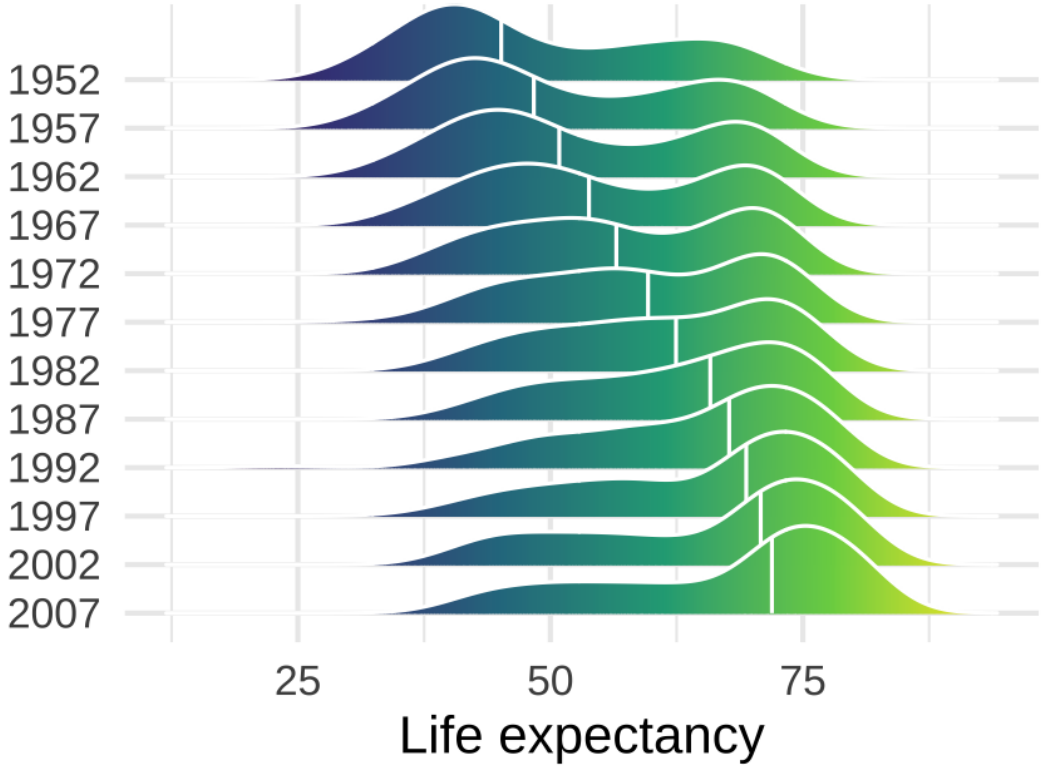
```
gapminder |>
    mutate(year = as_factor(year)) |>
    ggplot(
      aes(x = lifeExp,
          y = fct_rev(year),
          fill = after_stat(x)) # fill by x
      ) +
    geom_density_ridges_gradient(
      # this is a special geom to fill along x
      color = "white",
      quantile_lines = TRUE,
      quantiles = 2
      )
```



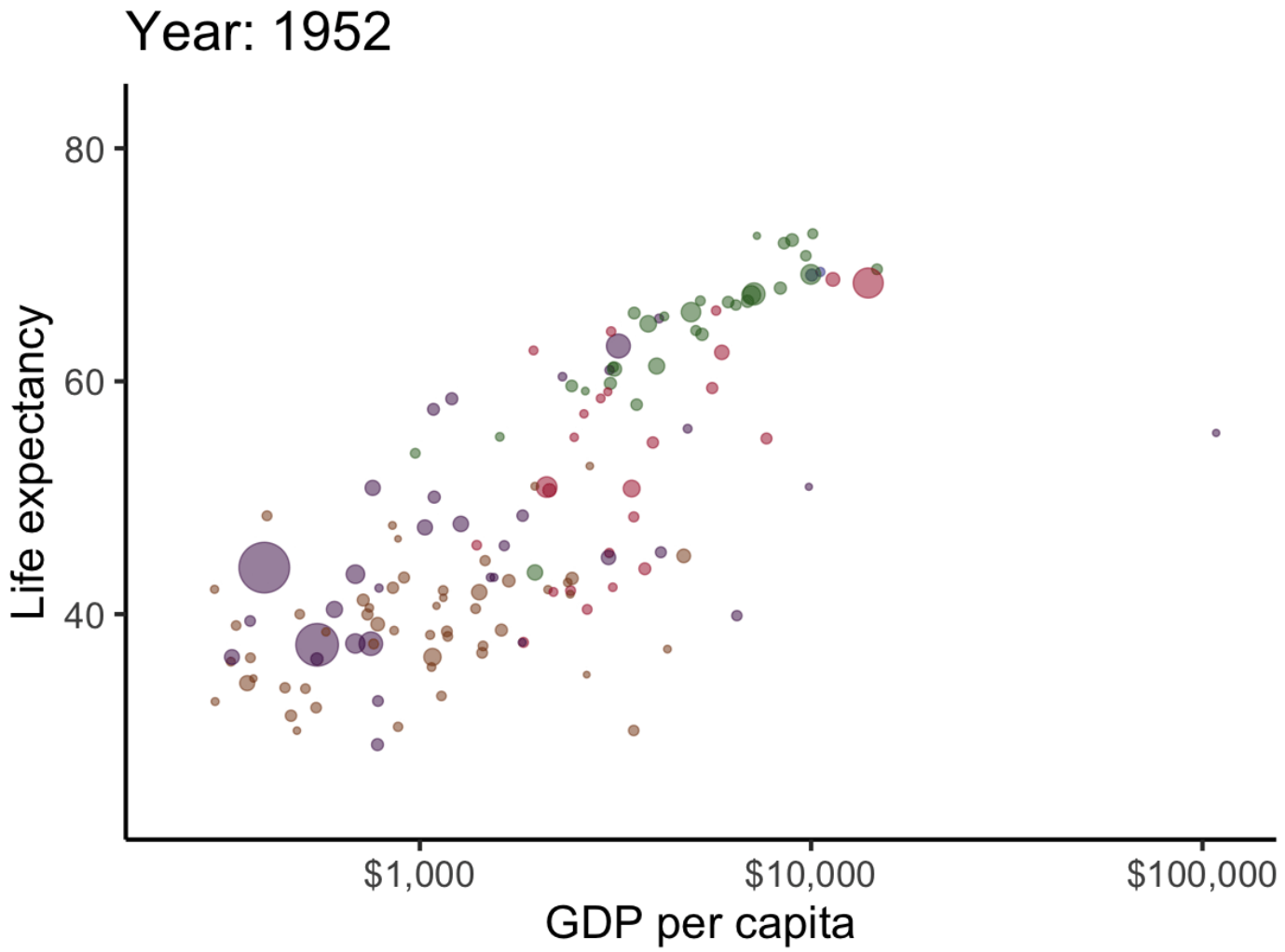
Use `after_stat(x)` to shade the *densities*, not the data itself

Finish by cleaning the plot up

```
gapminder |>
    mutate(year = as_factor(year)) |>
    ggplot(
      aes(x = lifeExp,
          y = fct_rev(year),
          fill = after_stat(x))
      ) +
    geom_density_ridges_gradient(
      color = "white",
      quantile_lines = TRUE,
      quantiles = 2
      ) +
    guides(fill = "none") +     # omit legend
    scale_fill_viridis_c() +    # nicer shading
    labs(x = "Life expectancy",# modify label
         y = NULL,              # omit labels
         fill = NULL) +         # omit labels
    theme_minimal(              # cleaner theme
      base_size = 14            # larger font
      )
```



Animating plots over time

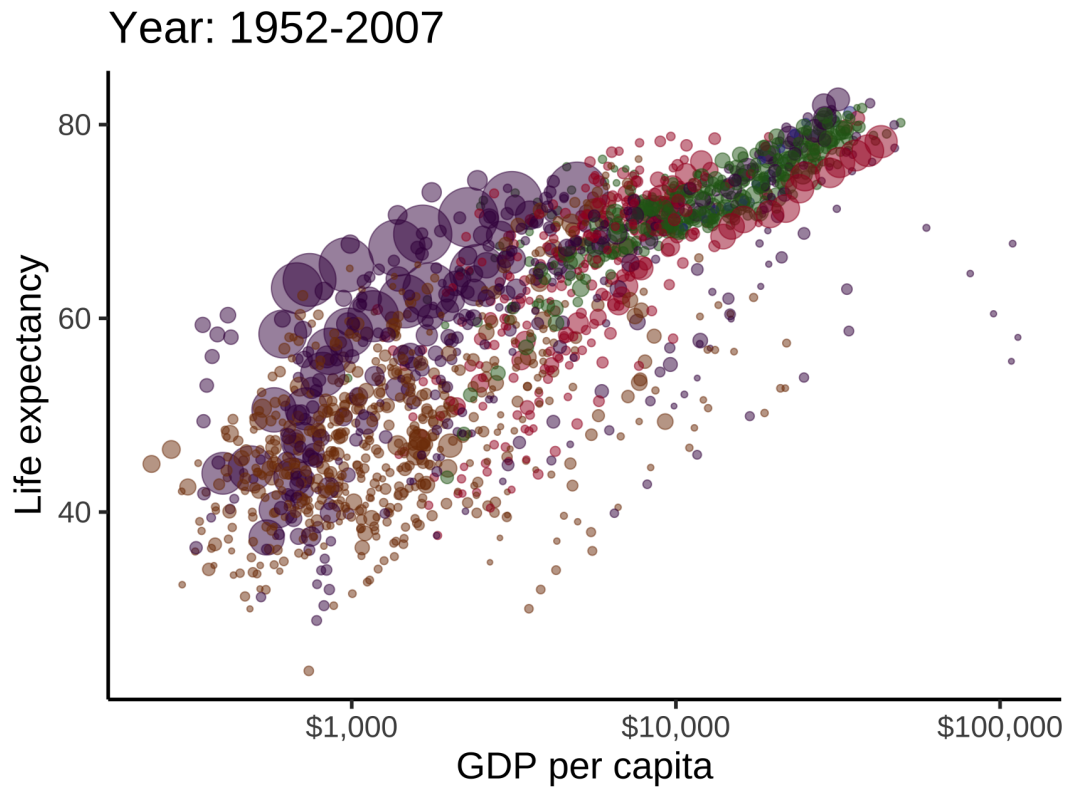


How can we make this animation in R?

First, how would we make a static plot of the data?

```
library(gapminder) # gapminder data

gapminder |>
  ggplot(aes(gdpPercap, lifeExp,
             size = pop, color = continent)) +
  geom_point(alpha = 0.5, show.legend = FALSE) +
  scale_color_manual(
    values = gapminder::continent_colors
    ) +
  scale_size_continuous(range = c(1, 15)) +
  scale_x_log10(labels = label_dollar()) +
  theme_classic(base_size = 20) +
  labs(x = "GDP per capita",
       y = "Life expectancy",
       title = "Year: 1952-2007")
```

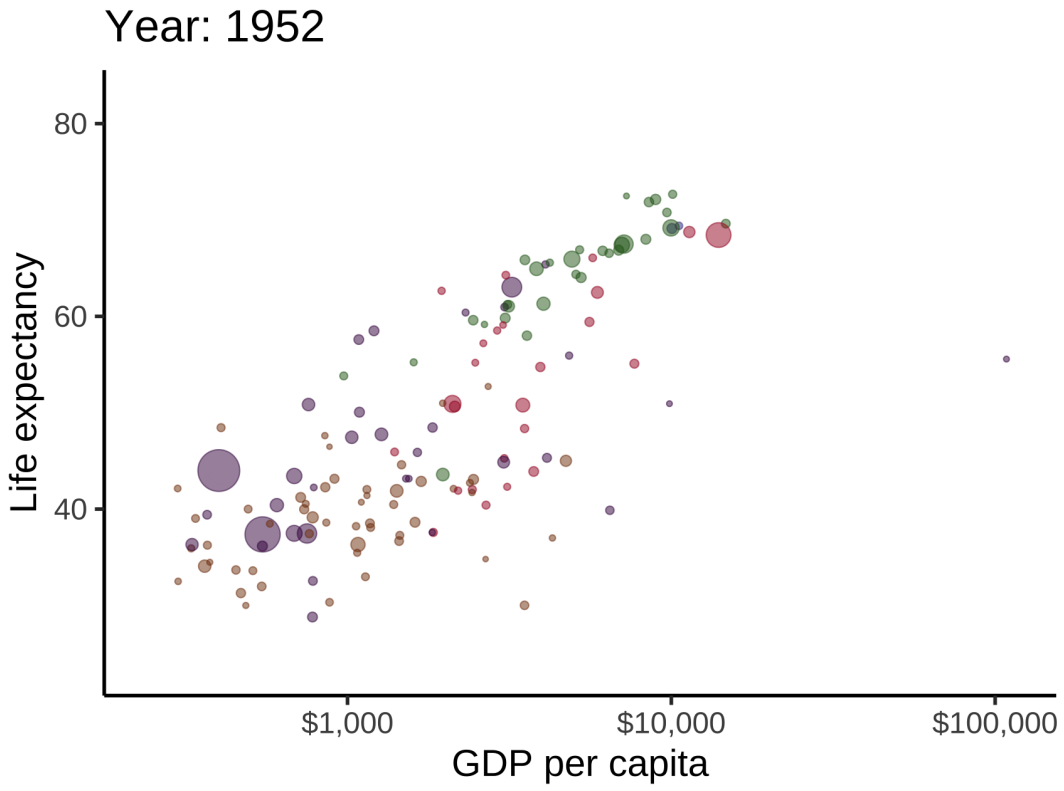


Converting a static plot to an animation

Second, let's use `gganimate` to visualize changes over time

```
library(gganimate) # plot animation package

gapminder |>
  ggplot(aes(gdpPercap, lifeExp,
             size = pop, color = continent)) +
  geom_point(alpha = 0.5, show.legend = FALSE) +
  scale_color_manual(
    values = gapminder::continent_colors
    ) +
  scale_size_continuous(range = c(1, 15)) +
  scale_x_log10(labels = label_dollar()) +
  theme_classic(base_size = 20) +
  labs(x = "GDP per capita",
       y = "Life expectancy",
       title = "Year: {frame_time}") +
  transition_time(year) +
  ease_aes('linear') # default progression
```



Saving gifs

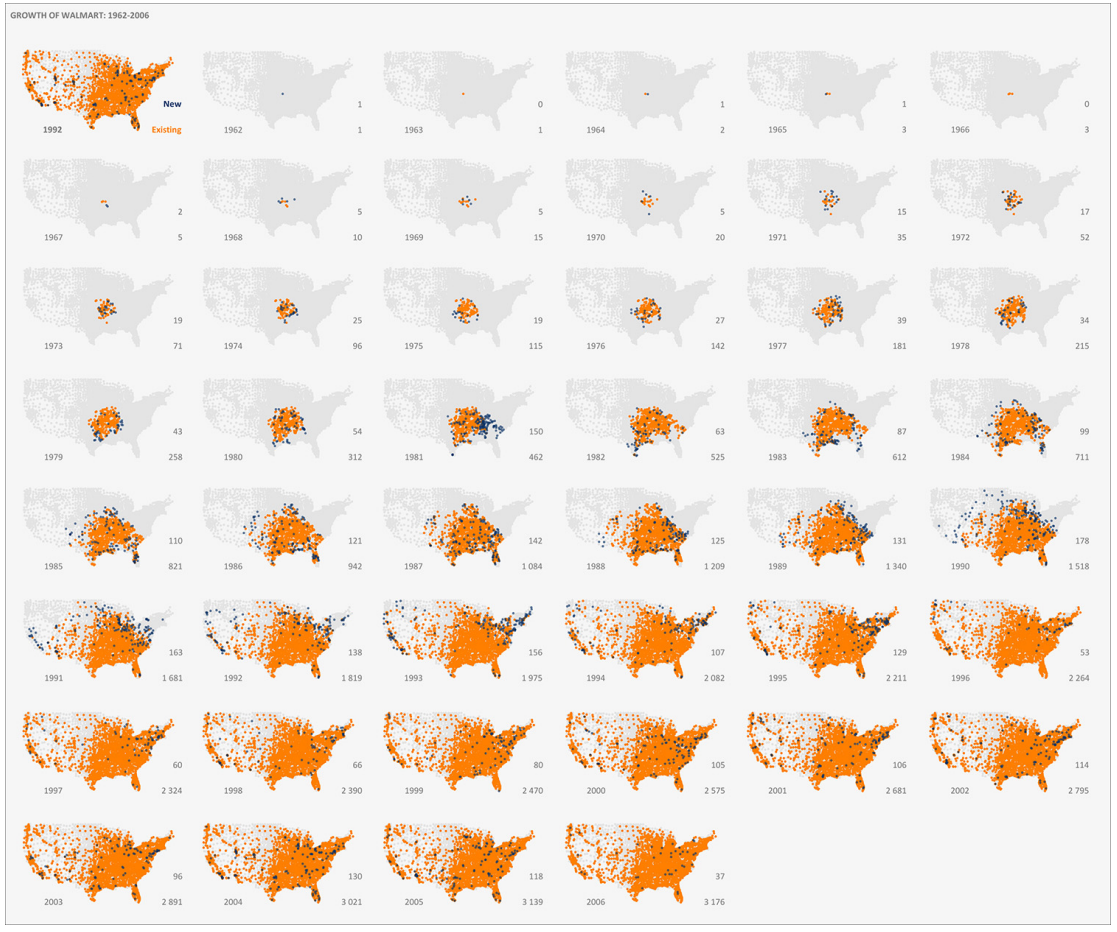
Third, use `anim_save()` to write a `.gif` that you can text to your mom

```
library(gganimate)
library(gifski)

my_gapminder_animation <- gapminder |>
  ggplot(aes(gdpPercap, lifeExp, size = pop, color = continent)) +
  geom_point(alpha = 0.5, show.legend = FALSE) +
  scale_color_manual(values = gapminder::continent_colors) +
  scale_size_continuous(range = c(1, 15)) +
  scale_x_log10(labels = label_dollar()) +
  theme_classic(base_size = 20) +
  labs(x = "GDP per capita",
       y = "Life expectancy",
       title = "Year: {frame_time}") +
  transition_time(year) +
  ease_aes('linear')

animate(my_gapminder_animation, renderer = gifski_renderer())
anim_save("content/slides/img/09/my-gapminder-animation.gif")
```

Faceting plots over time



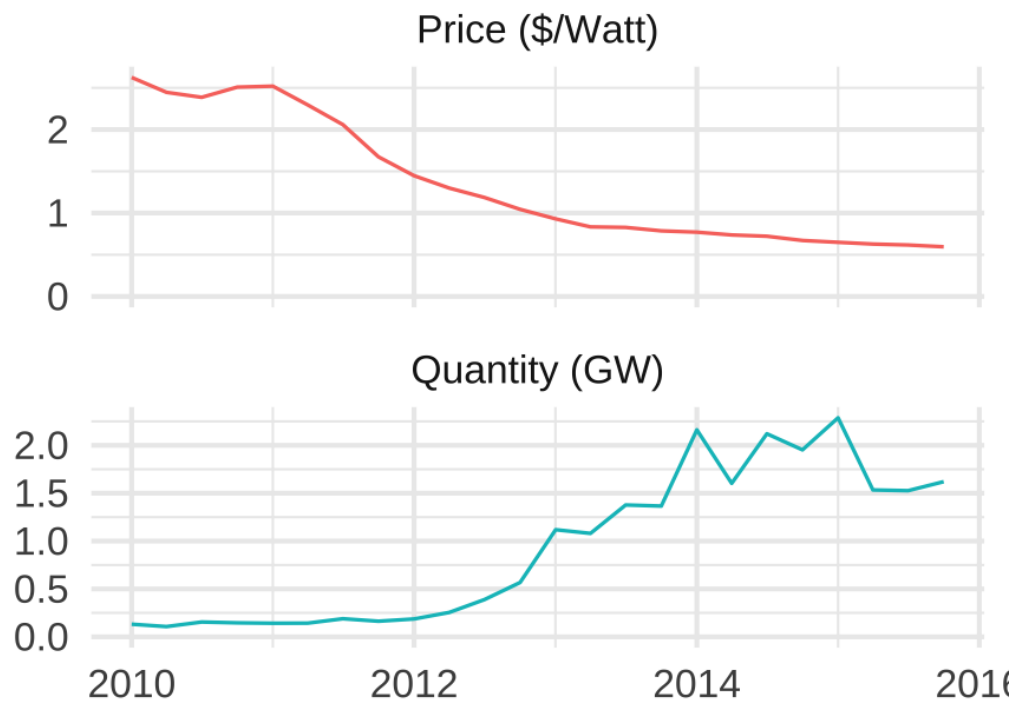
Map of the spread of Walmart by Jorge Camões

Connecting scatter plots over time

Sometimes connected scatter plots of time series data make sense

What is a connected scatter plot?

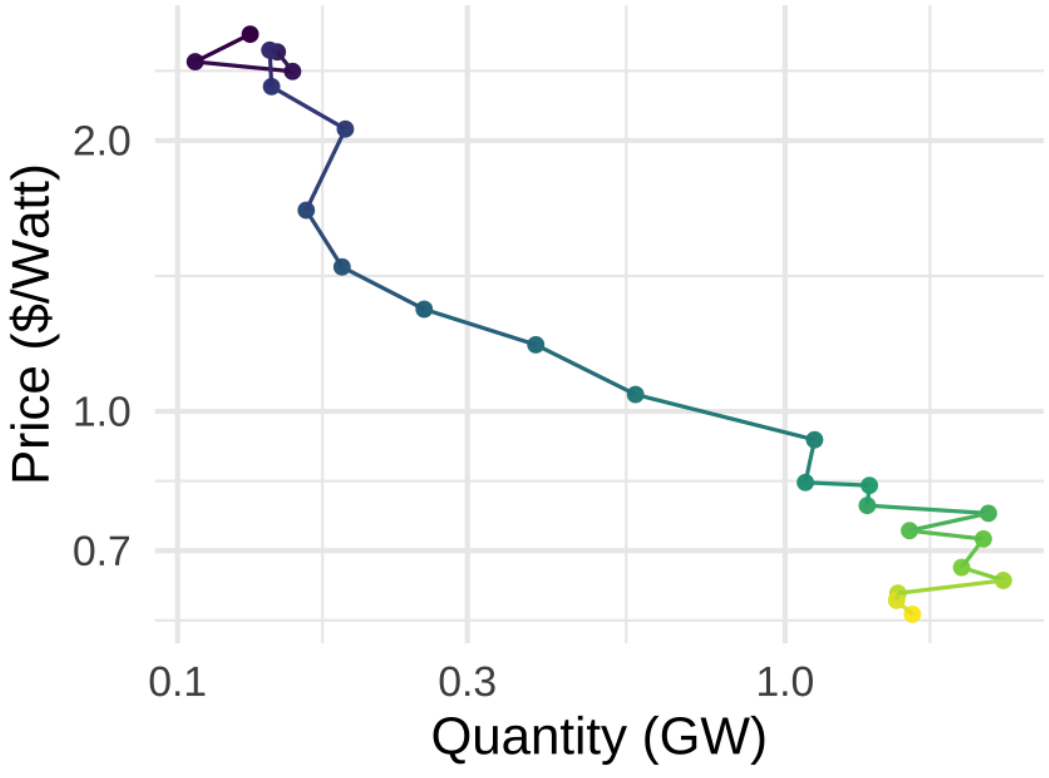
How would you make one using these data?



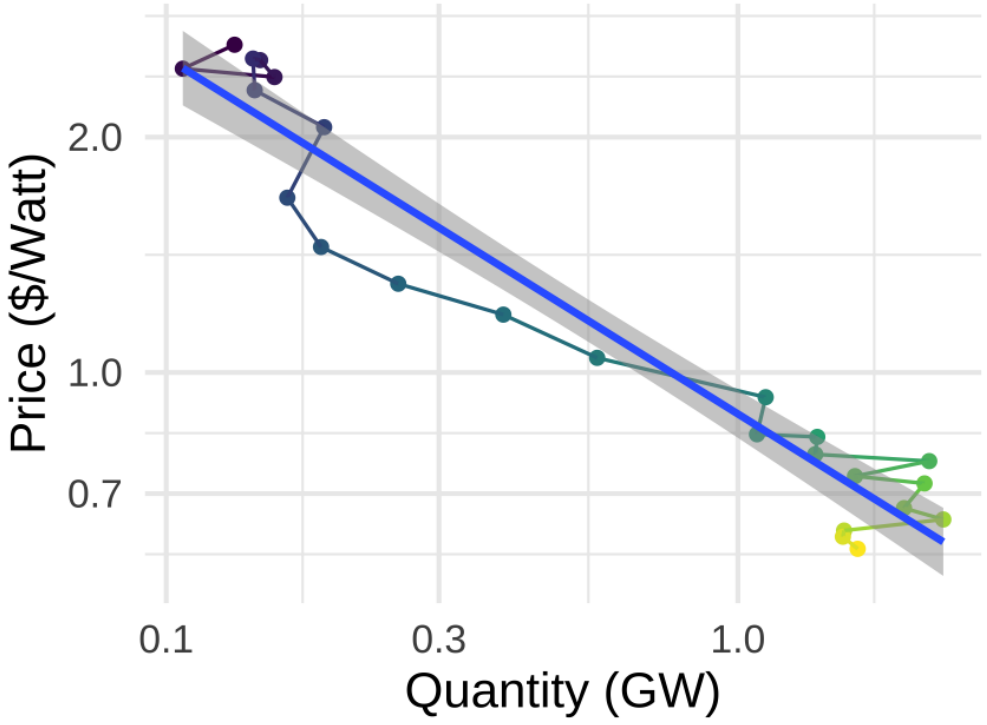
Connected scatter plots

```
solar_data |>
  ggplot(aes(x = `Quantity (GW)`,  # not time
             y = `Price ($/Watt)`, # not time
             color = date)) +      # time!
  geom_point() +
  geom_path() + # connect by time, not x
  scale_x_log10() +
  scale_y_log10() +
  scale_color_viridis_c() +
  guides(color = "none") +
  theme_minimal(base_size = 14)
```

Note the log axes



Is this a good use case?



Looks a lot like a demand curve!

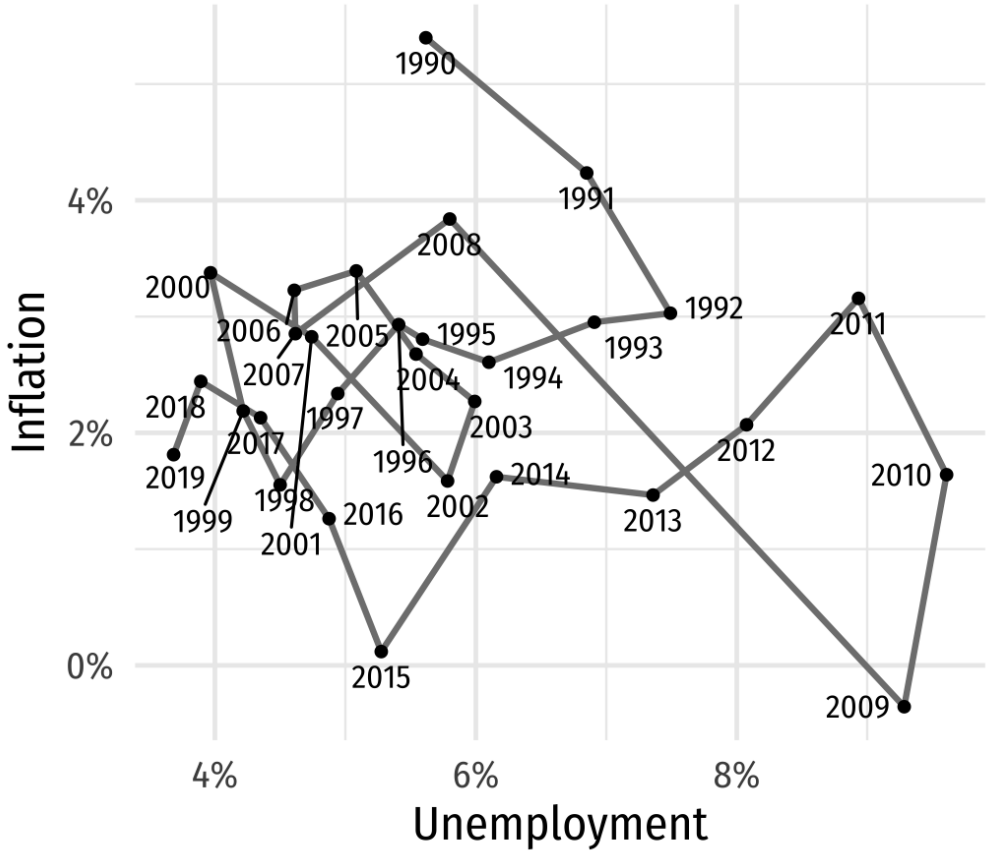
$$log(Q) = \alpha + \beta log(P) + \varepsilon$$

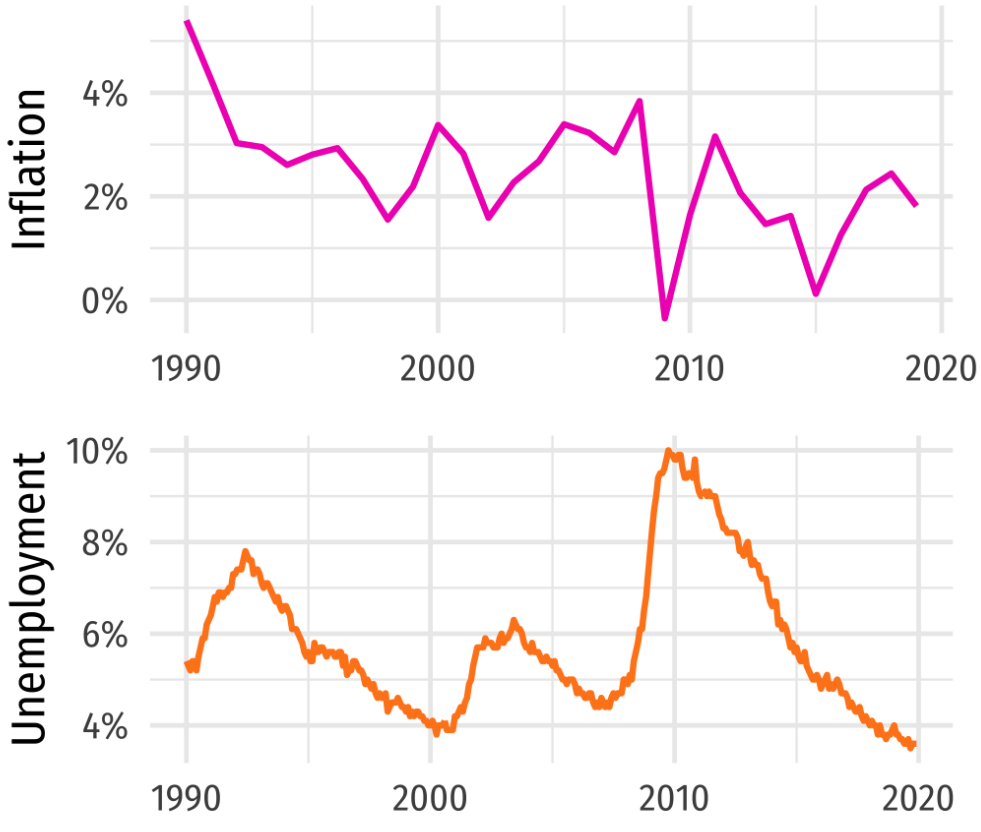
We could use regression to estimate β

How might we interpret β?

But even here, a regular (not connected) scatter plot would be better!

Often it's better to use multiple plots





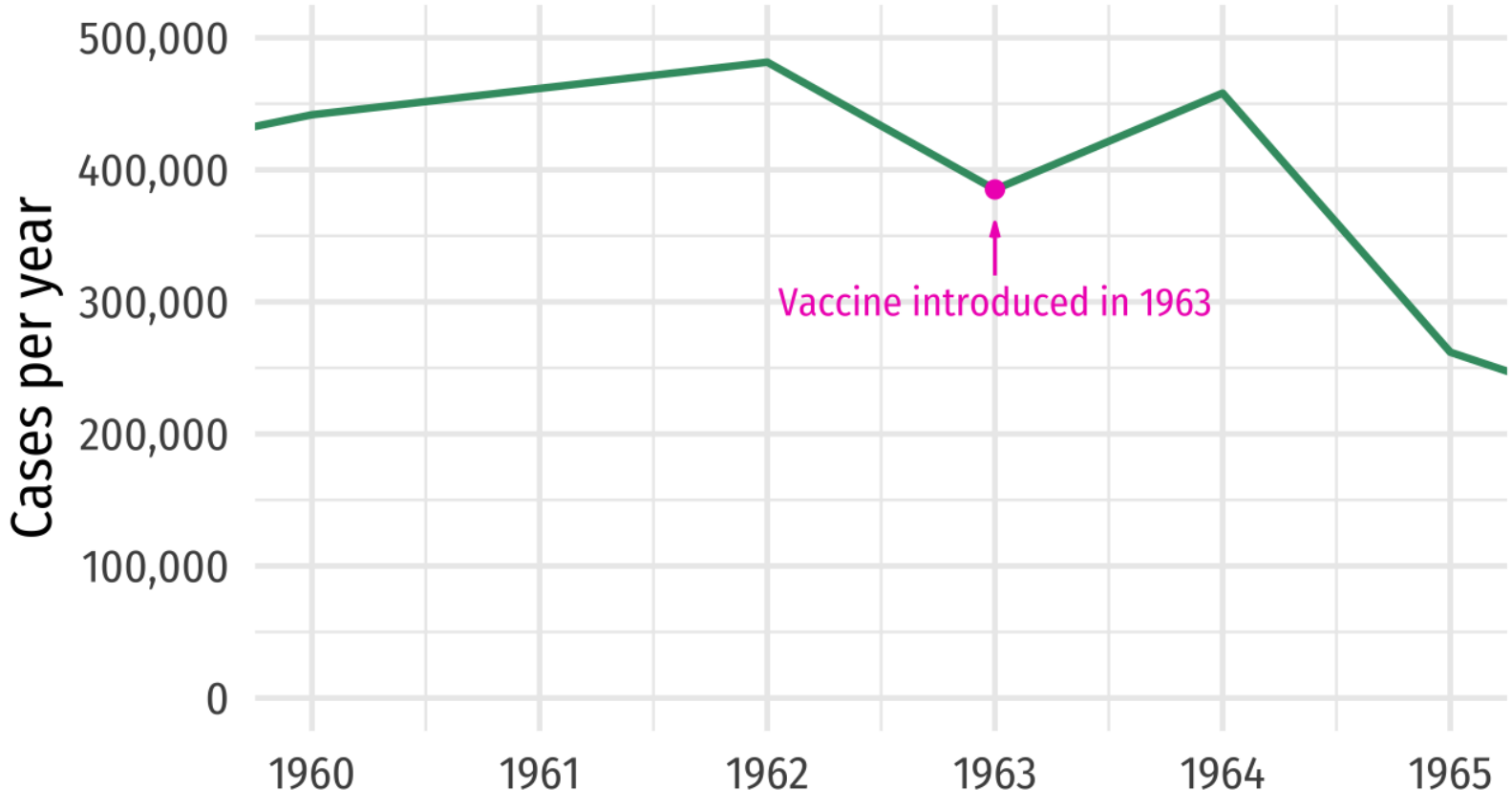
Starting, ending, and decomposing time

You have to start (and end) somewhere

You always have to choose start and end points

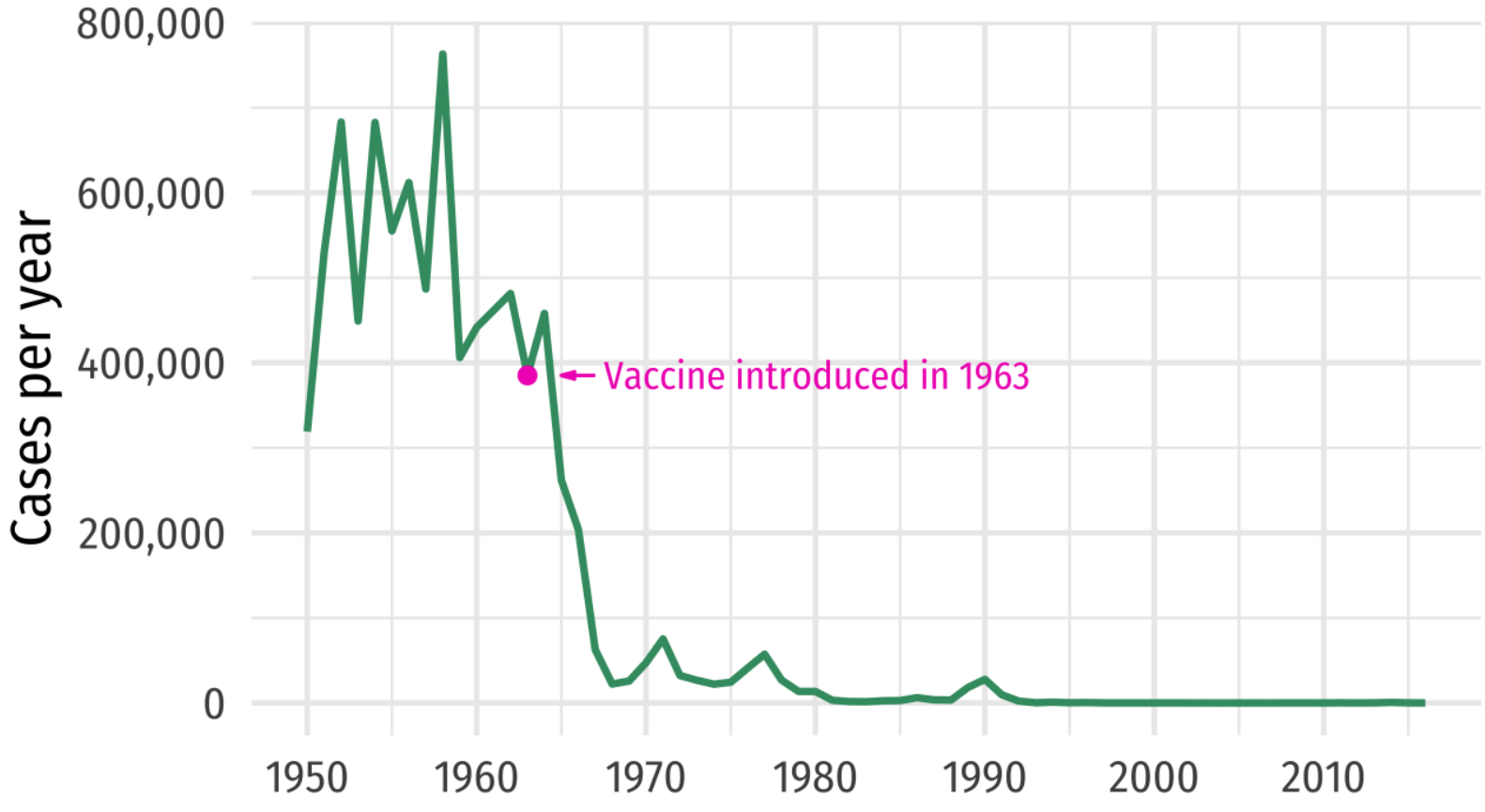
Start and end at reasonable times that help maintain the context of your story

Measles vaccine was pretty effective



Source: CDC, Epidemiology and Prevention of Vaccine-Preventable Diseases, 13th Edition

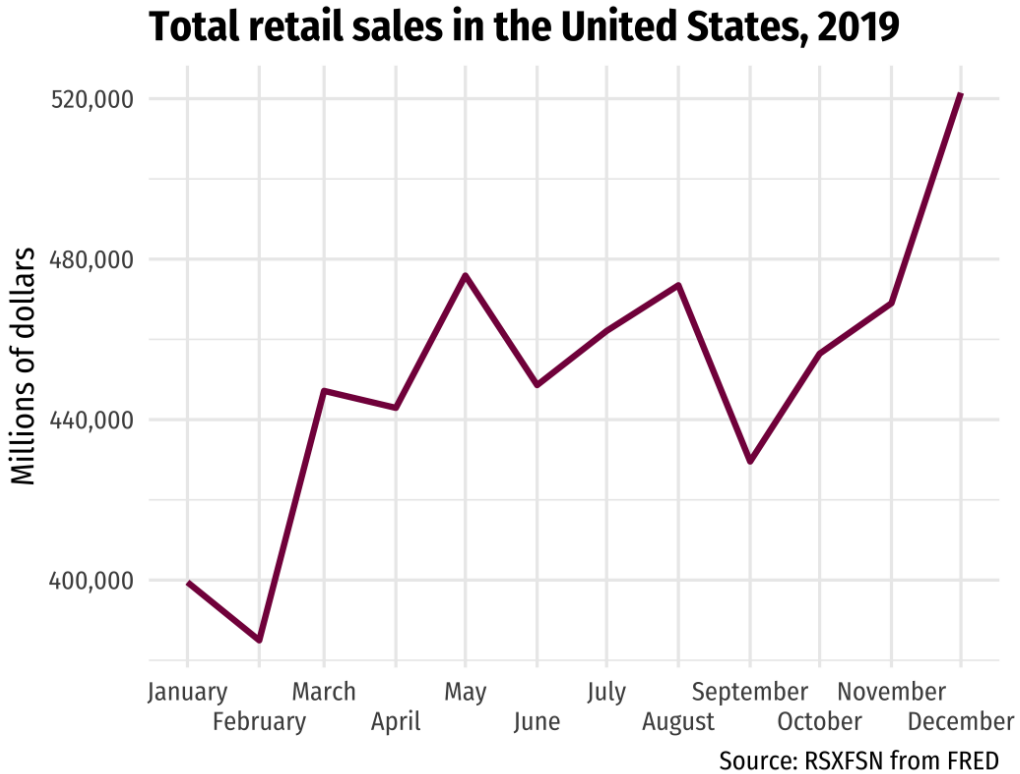
Measles vaccine was *incredible*!

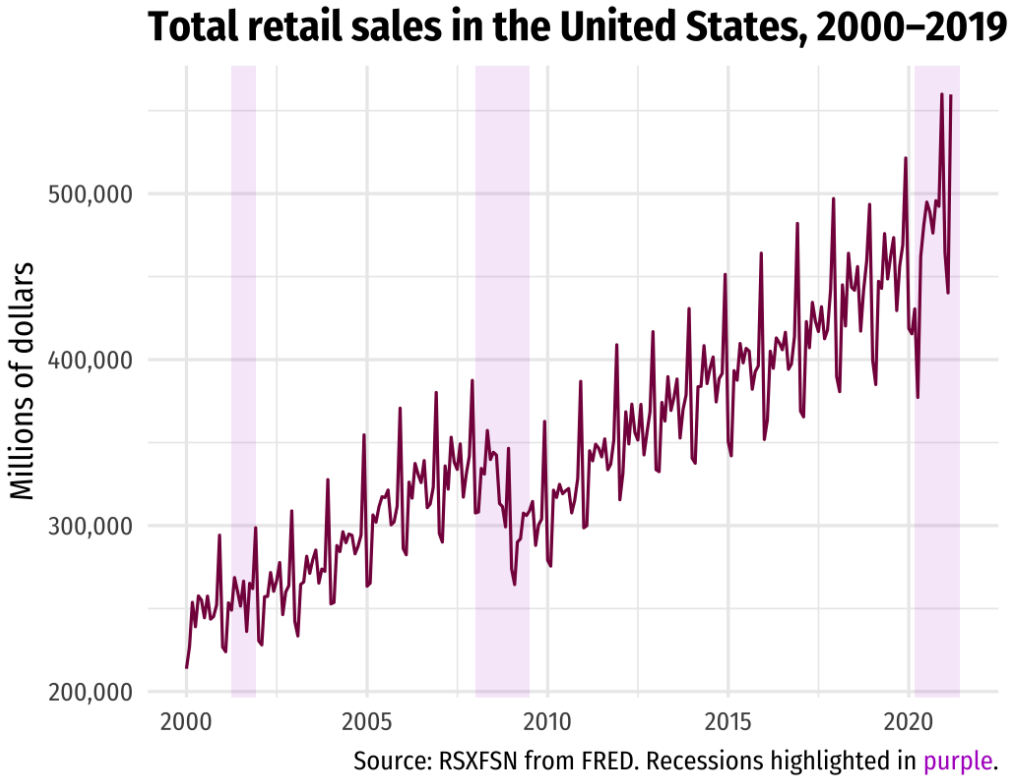


Source: CDC, Epidemiology and Prevention of Vaccine-Preventable Diseases, 13th Edition

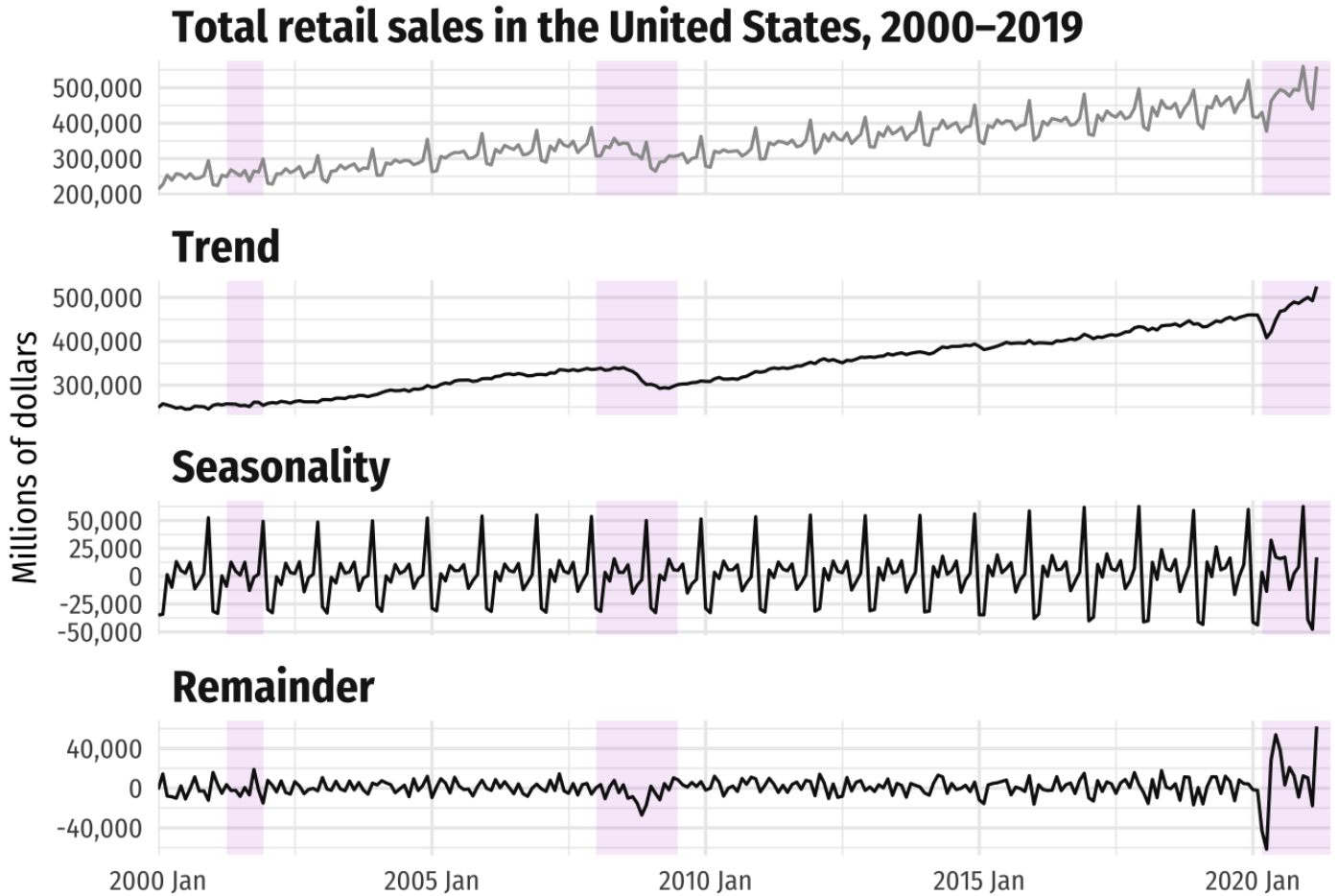
Seasonality

Don't mistake seasonality for actual trends



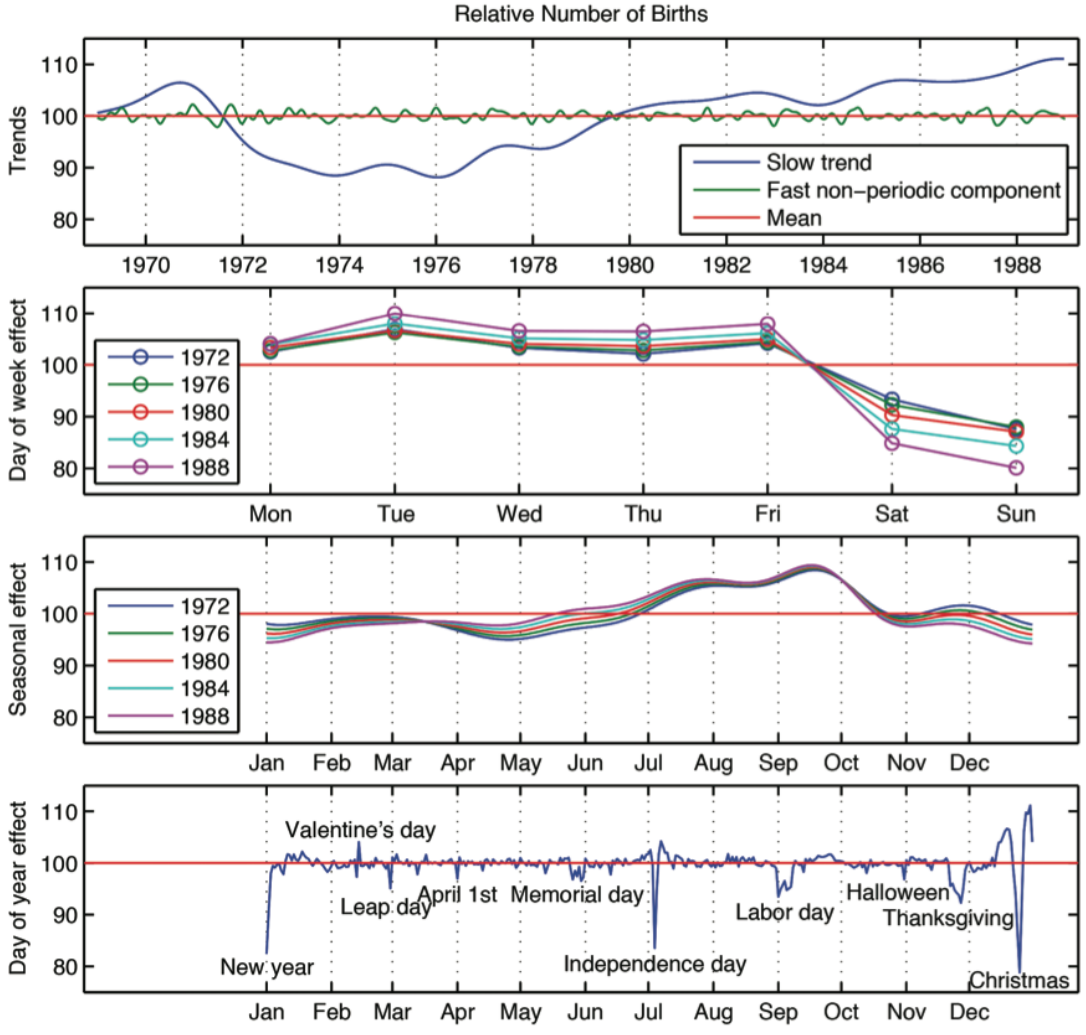


Seasonal adjustment



Source: RSXFSN from FRED. Recessions highlighted in purple.

Birthday decomposition



Dates and times in R

Are dates and times special?

We made a bunch of plots without really thinking about data types

We can map "dates" to x regardless of whether they are `date` or `numeric` objects

```
class(gme_prices$date)
```

```
## [1] "Date"
```

```
class(solar_data$date)
```

```
## [1] "Date"
```

```
class(measles$Year)
```

```
## [1] "numeric"
```

When do we need to pay attention to the details?

1. Converting from strings to dates
2. Getting components of date-time data
3. Computing time spans

Dates and times in R

R has "native" classes for storing calendar dates and times

- For background, see `?Dates` and `?DateTimeClasses`

The `lubridate` package offers convenient tools for working with dates and times

- Loaded automatically as part of the core tidyverse since tidyverse 2.0.0
- See `vignette("lubridate")` and Chapter 18 of R4DS (2e)

Converting from strings to dates

Use `lubridate::ymd` to parse dates with **y**ear, **m**onth, and **d**ay components

```
svb_failure <- ymd("2023-03-10")
svb_failure
```

```
## [1] "2023-03-10"
```

```
class(svb_failure)
```

```
## [1] "Date"
```

```
class("2023-03-10")
```

```
## [1] "character"
```

Converting from strings to dates

`lubridate` offers many other functions for parsing dates

For example, instead of `ymd` we could use `mdy`:

```
signature_failure <- mdy("March 12, 2023")
```

```
signature_failure
```

```
## [1] "2023-03-12"
```

```
class(signature_failure)
```

```
## [1] "Date"
```

Getting components of date-time data

What year did Silicon Valley Bank fail?

```
year(svb_failure)
```

```
## [1] 2023
```

What day of the week was that?

```
wday(svb_failure)
```

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

```
wday(svb_failure, label = TRUE)
```

```
## [1] Fri
## Levels: Sun < Mon < Tue < Wed < Thu < Fri < Sat
```

What month was that?

```
month(svb_failure)
```

```
## [1] 3
```

```
month(svb_failure, label = TRUE)
```

```
## [1] Mar
## 12 Levels: Jan < Feb < Mar < Apr < May < Jun < Jul
```

Computing time spans

How many days passed between independence and emancipation?

```
signature_failure - svb_failure
```

```
## Time difference of 2 days
```

How many days are left until classes end?

```
ymd(20230509) - today()
```

```
## Time difference of 51 days
```

These are **durations**

See Chapter 18 of R4DS (2e) for functions to compute **periods** and **intervals**