Visualizing Data

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R graphics Package

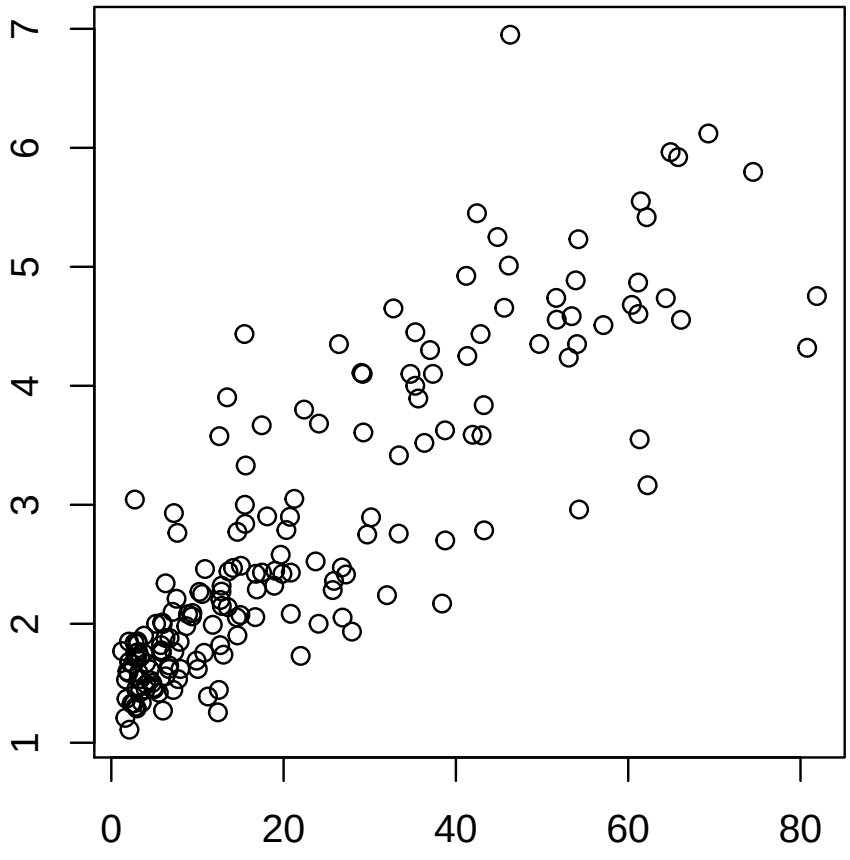
- R has fantastic graphic capabilities.
  - There are many approaches and packages designed for this specific task.
  - The `graphics` package (loaded when start R) has many plotting functions.
  - Simple look, may not be consistent across different types of plots

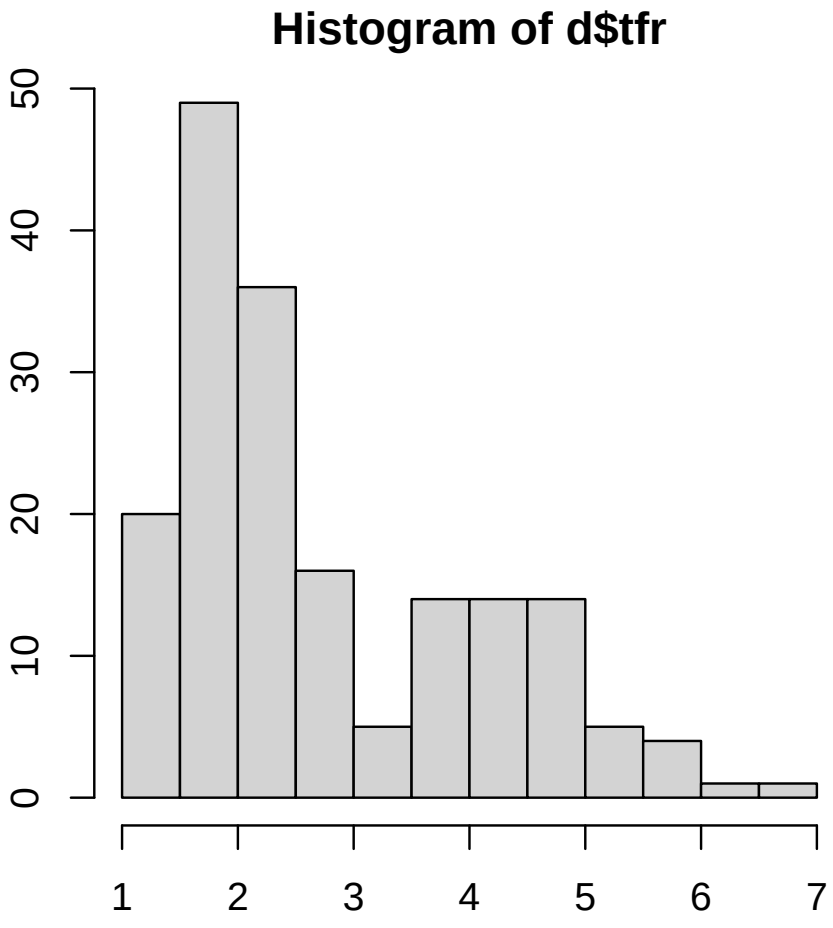
R graphics Package

```
> d
# A tibble: 179 x 8
   name      region_name  area_name   imr   tfr sex_ratio developed growth_policy
   <chr>     <chr>        <chr>     <dbl> <dbl>     <dbl> <chr>     <chr>
 1 Burundi   Eastern Afr~ Africa     42.4  5.45      1.03 Less      Lower
 2 Comoros   Eastern Afr~ Africa     53.1  4.24      1.05 Less      Lower
 3 Djibouti  Eastern Afr~ Africa     33.4  2.76      1.04 Less      Lower
 4 Eritrea   Eastern Afr~ Africa     34.7  4.1       1.05 Less      Lower
 5 Ethiopia  Eastern Afr~ Africa     37    4.3       1.04 Less      Lower
 6 Kenya     Eastern Afr~ Africa     36.3  3.52      1.03 Less      Lower
 7 Madagas~  Eastern Afr~ Africa     29.0  4.11      1.03 Less      Lower
 8 Malawi    Eastern Afr~ Africa     41.3  4.25      1.03 Less      Lower
 9 Mauriti~  Eastern Afr~ Africa     11.2  1.39      1.04 Less      Maintain
10 Mozambi~  Eastern Afr~ Africa     53.9  4.89      1.02 Less      Lower
# ... with 169 more rows
```

R graphics Package

```
> # left
> plot(x = d$imr, y = d$tfr)
> # right
> hist(x = d$tfr)
```



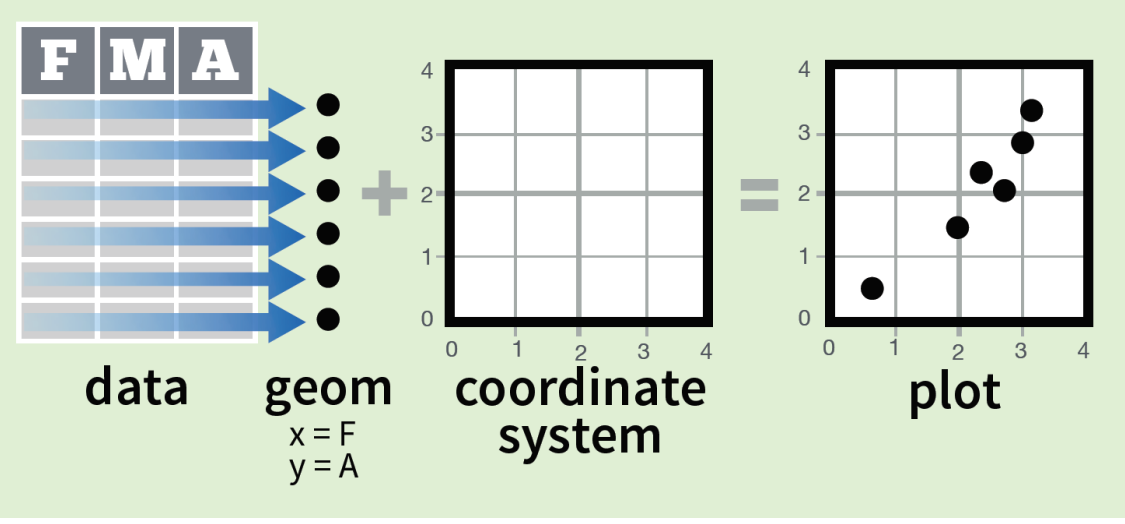


Grammar of Graphics

- The `ggplot2` package by Hadley Wickham implements the grammar of graphics, a coherent system for describing and building graphs.
  - One of the most beautiful and most versatile.
  - Flexible and consistent approach across different plots
  - Do more faster as a single learning one system for all plots types that you can apply in many data situations.
- Included in the tidyverse package (more on tidyverse later)
  - `library(tidyverse)` loads `ggplot2` along with other useful packages

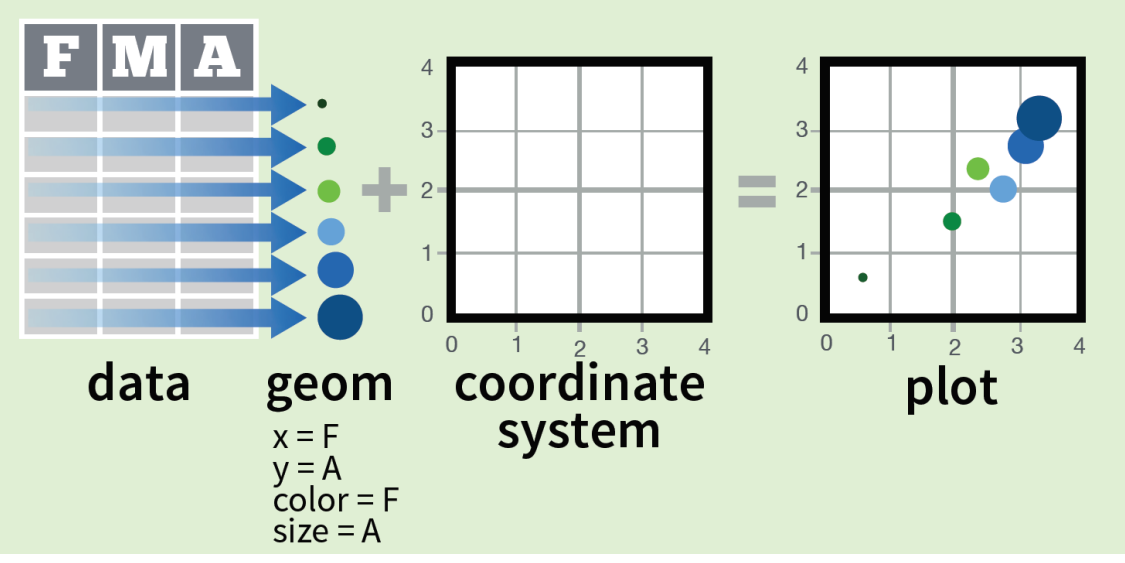
Grammar of Graphics

- The grammar of graphics builds every graph from the same components:
  - data set
  - coordinate system
  - geoms (visual marks that represent data points)



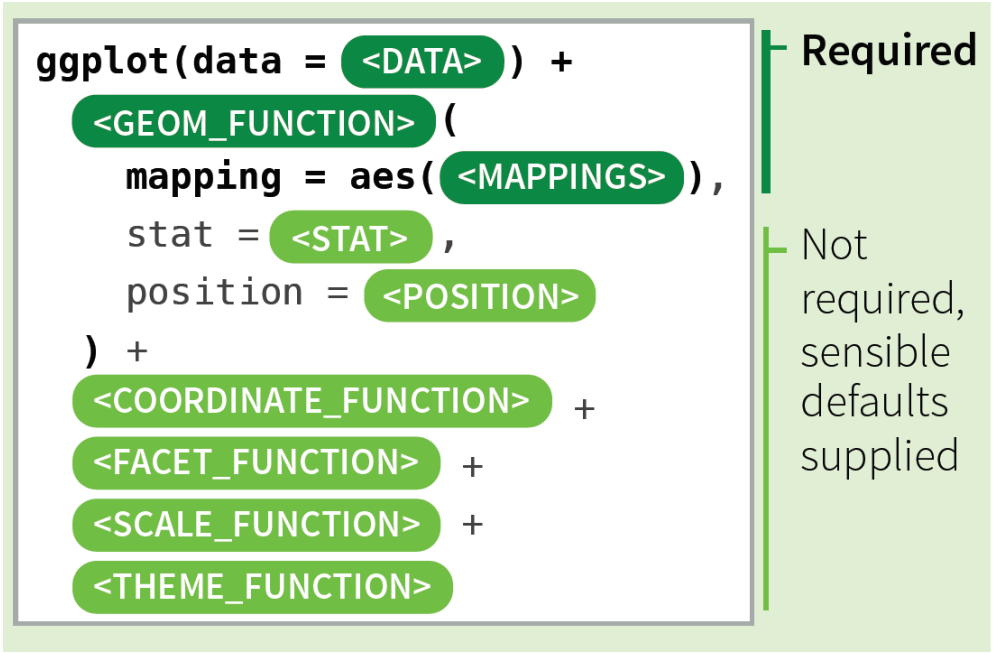
Grammar of Graphics

- When variables are mapped to data they can take different visual properties of the geom (aesthetics) like size, color, and x and y locations.
  - Aesthetics meaning something you can see.



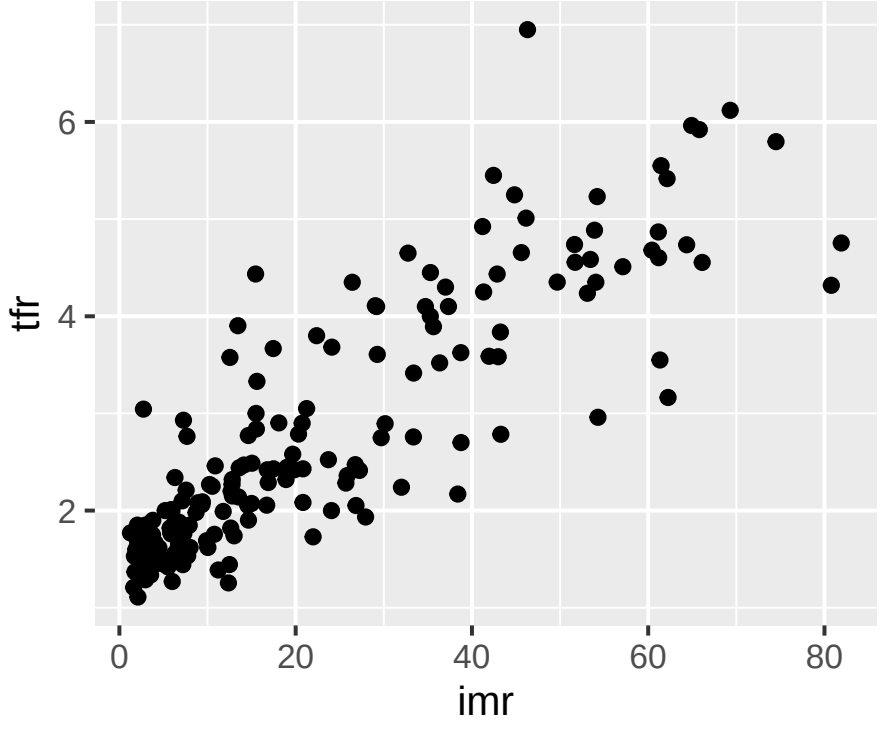
Grammar of Graphics

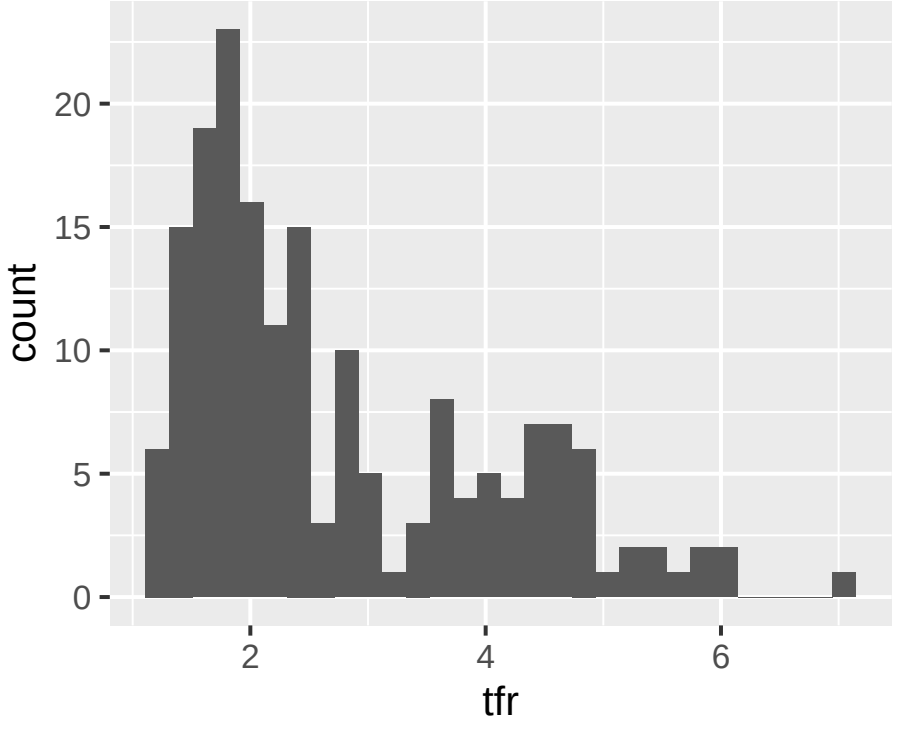
- The R code follows a common template



Grammar of Graphics

```
> library(tidyverse)
> # left
> ggplot(data = d, mapping = aes(x = imr, y = tfr)) +
+   geom_point()
> # right
> ggplot(data = d, mapping = aes(x = tfr)) +
+   geom_histogram()
```





Grammar of Graphics

- The function `ggplot()` creates a coordinate system to add layers onto.
- The first argument of `ggplot()` is the data set used to graph
  - For example, `ggplot(data = swiss)` creates an empty graph that will use the `swiss` data set.
  - Can then build on the empty graphs by adding one or more layers to `ggplot()`.
- The geom functions adds a layer of points to your plot.
  - The `ggplot2` library comes with many geom functions
  - Each add a different type of layer to a plot.
  - Each geom function in ggplot2 takes a `mapping` argument.
- The `mapping` argument explains where your points should go
  - Set in the `mapping` argument with a call to the `aes()` function.
  - For example the `x` and `y` arguments of `aes()` explain which variables to map to the x- and y-axes of your plot.
  - The `ggplot()` function looks for those variables in your data set.
  - The `mapping` arguments are different for each geom function

Geom

- The ggplot2 package provides over 30 geom functions
  - Further packages provide even more.
- Each geom function is suitable for visualizing a certain type of data or relationship.
  - Listed on the first page of the ggplot cheat sheet.
  - Next to geom is a visual representation of the geom.
  - Beneath geom is a list of aesthetics that apply to the geom.
  - Required aesthetics are in bold.

Geoms

GRAPHICAL PRIMITIVES

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

a + geom_blank()
(Useful for expanding limits)

b + geom_curve(aes(yend = lat + 1, xend=long+1,curvature=z)**)** - 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(group = group)**)**
x, y, alpha, color, fill, group, 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)

TWO VARIABLES

continuous x , continuous y

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

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

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

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, check_overlap = TRUE**)**, x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

discrete x , continuous y

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

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_density2d()
x, y, alpha, colour, group, linetype, size

h + geom_hex()
x, y, alpha, colour, 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()**)

i + geom_linerange()

Geoms

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

discrete x , continuous y

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

discrete x , discrete y

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

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

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

data <- data.frame(murder = USArrests$Murder,
state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))

k + geom_map(aes(map_id = state), map = map)
+ expand_limits(x = map$long, y = map$lat),
map_id, alpha, color, fill, linetype, size

THREE VARIABLES

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

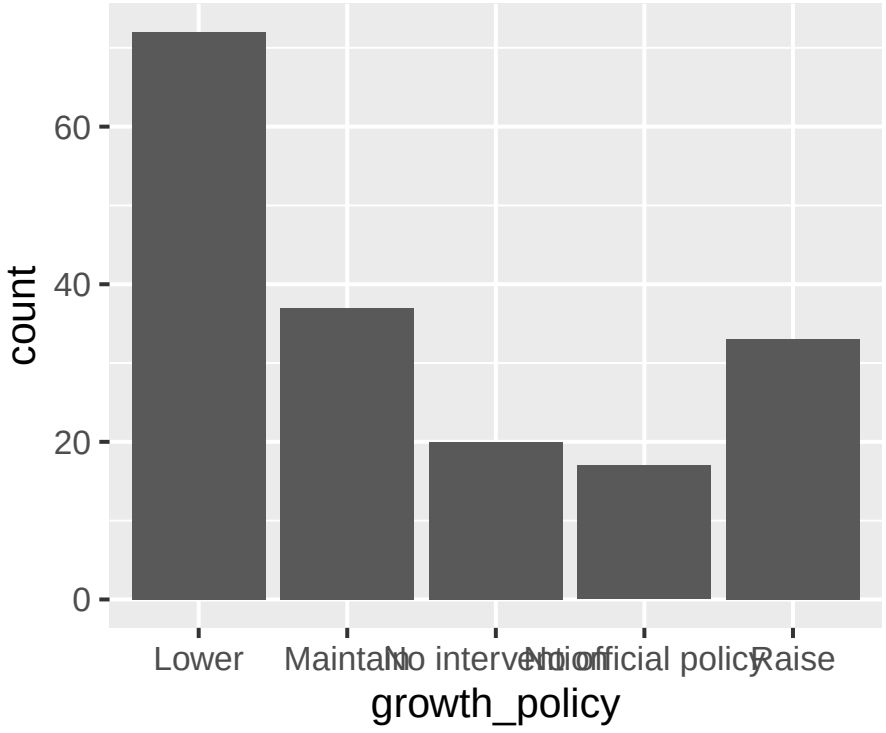
l + geom_contour(aes(z = z))
x, y, z, alpha, colour, group, linetype, size, weight

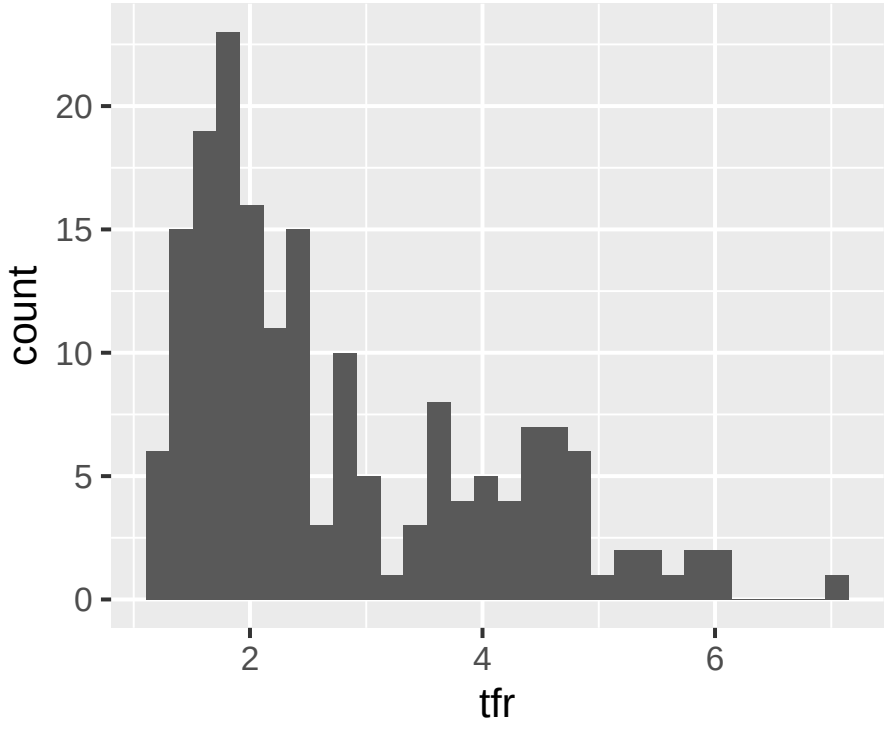
l + geom_raster(aes(fill = z), hjust=0.5, vjust=0.5, interpolate=FALSE)
x, y, alpha, fill

l + geom_tile(aes(fill = z)), x, y, alpha, color, fill, linetype, size, width

Geom Examples: One Variable

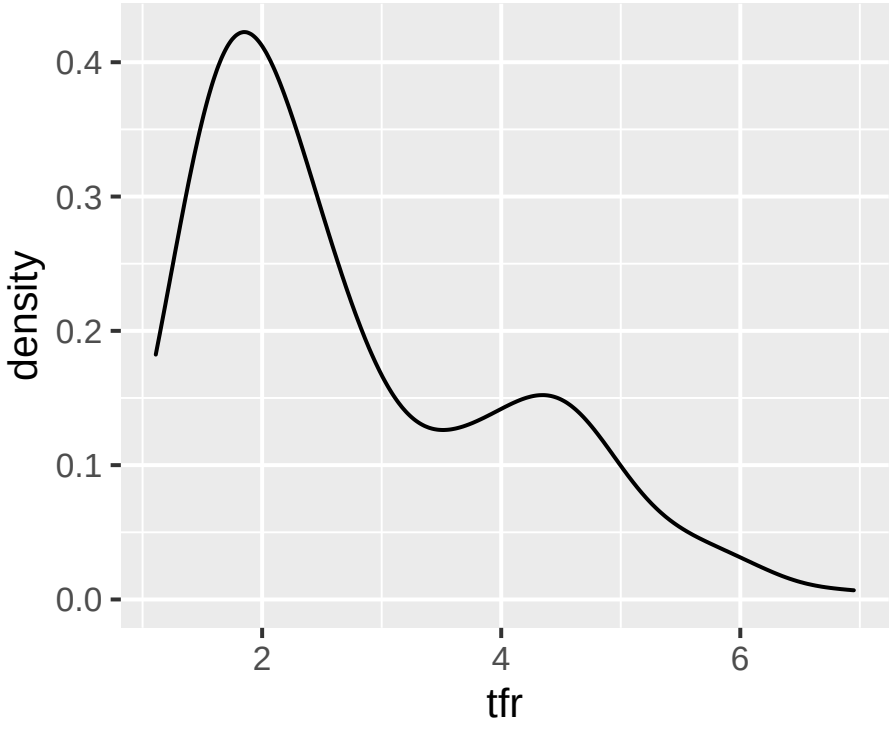
```
> # left: one discrete variable
> ggplot(data = d, mapping = aes(x = growth_policy)) +
+   geom_bar()
> # right: one continuous variable
> ggplot(data = d, mapping = aes(x = tfr)) +
+   geom_histogram()
```

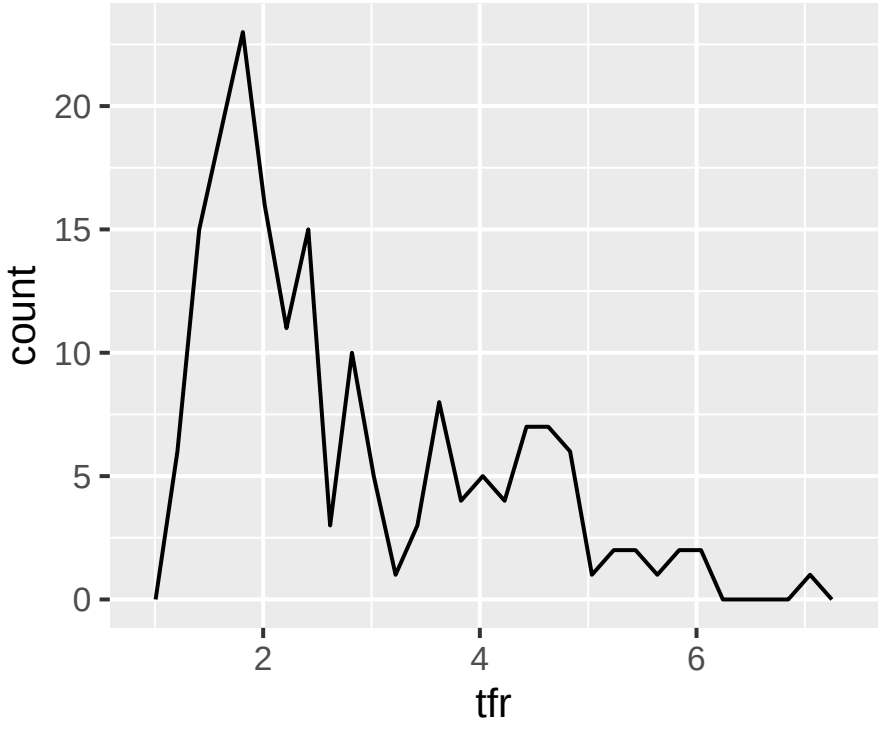




Geom Examples: One Variable

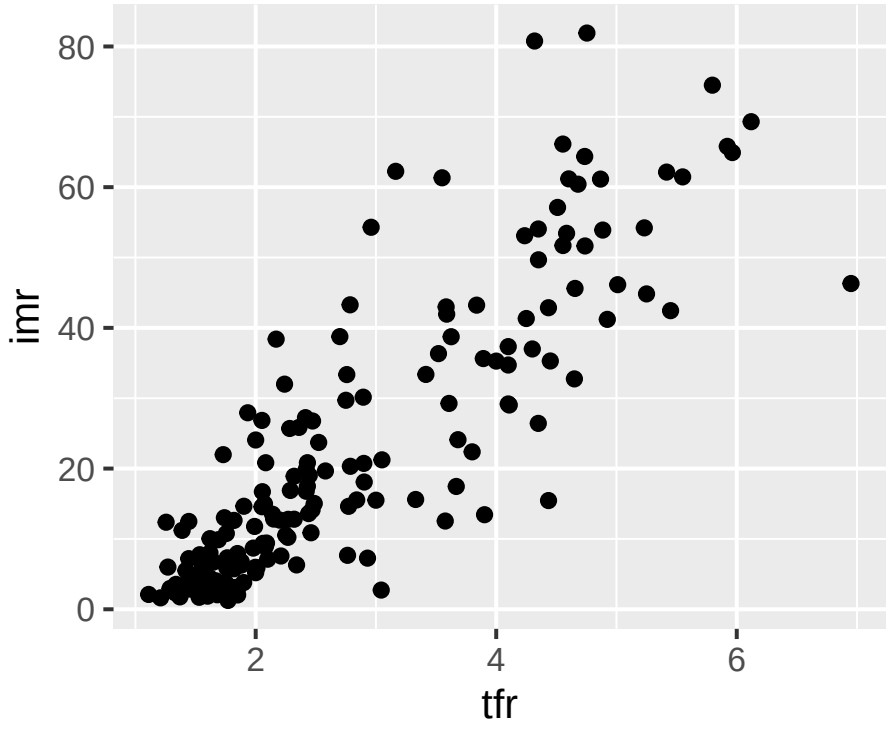
```
> # left: one continuous variable
> ggplot(data = d, mapping = aes(x = tfr)) +
+   geom_density()
> # right: one continuous variable
> ggplot(data = d, mapping = aes(x = tfr)) +
+   geom_freqpoly()
```

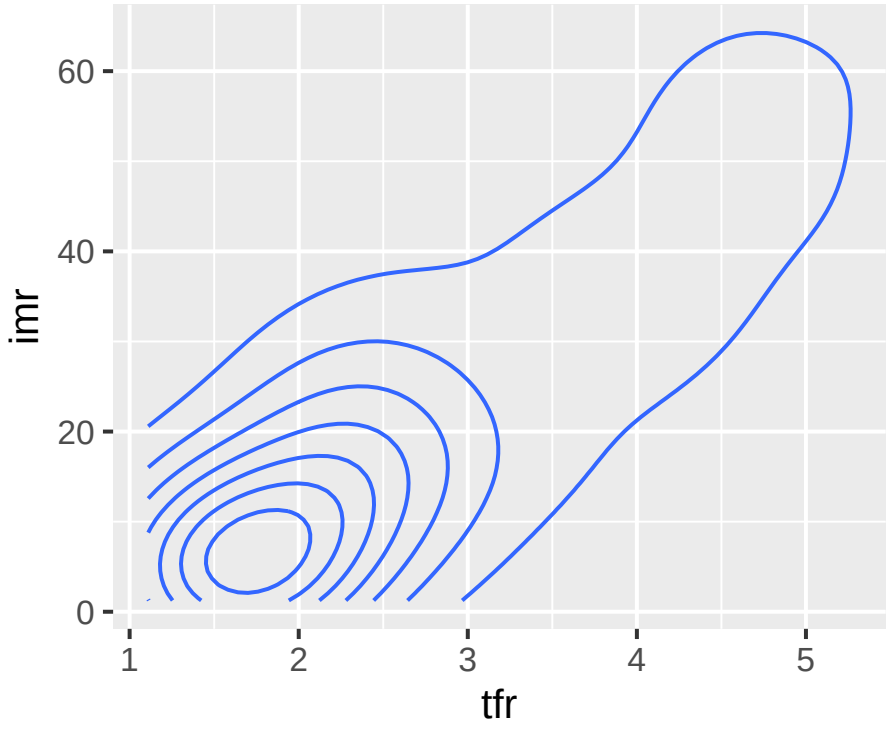




Geom Examples: Two Variables

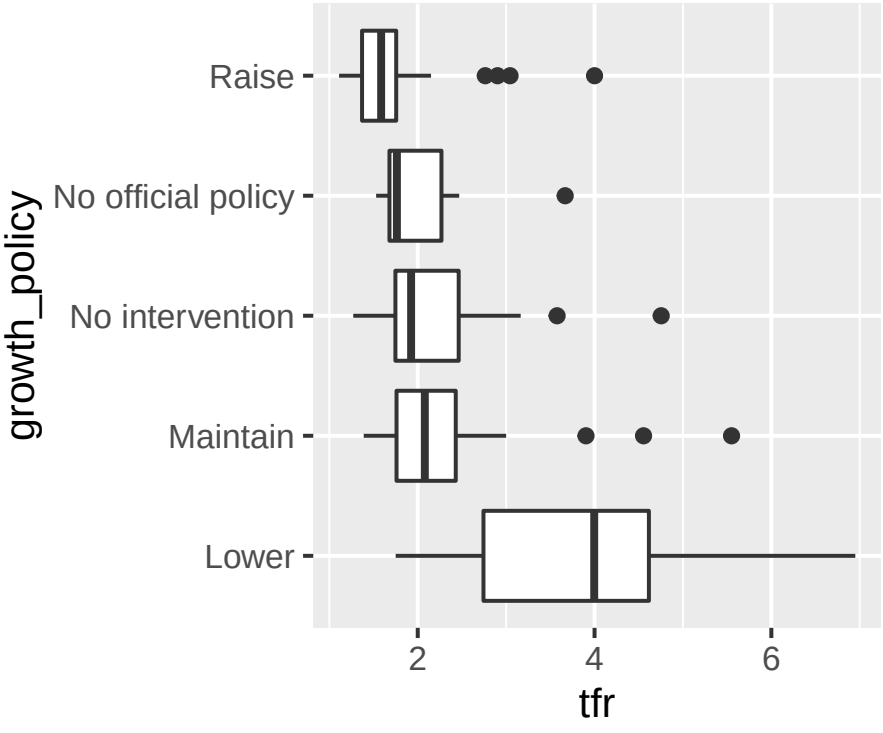
```
> # left: both continuous variable
> ggplot(data = d, mapping = aes(x = tfr, y = imr)) +
+   geom_point()
> # right: both continuous variable
> ggplot(data = d, mapping = aes(x = tfr, y = imr)) +
+   geom_density2d()
```

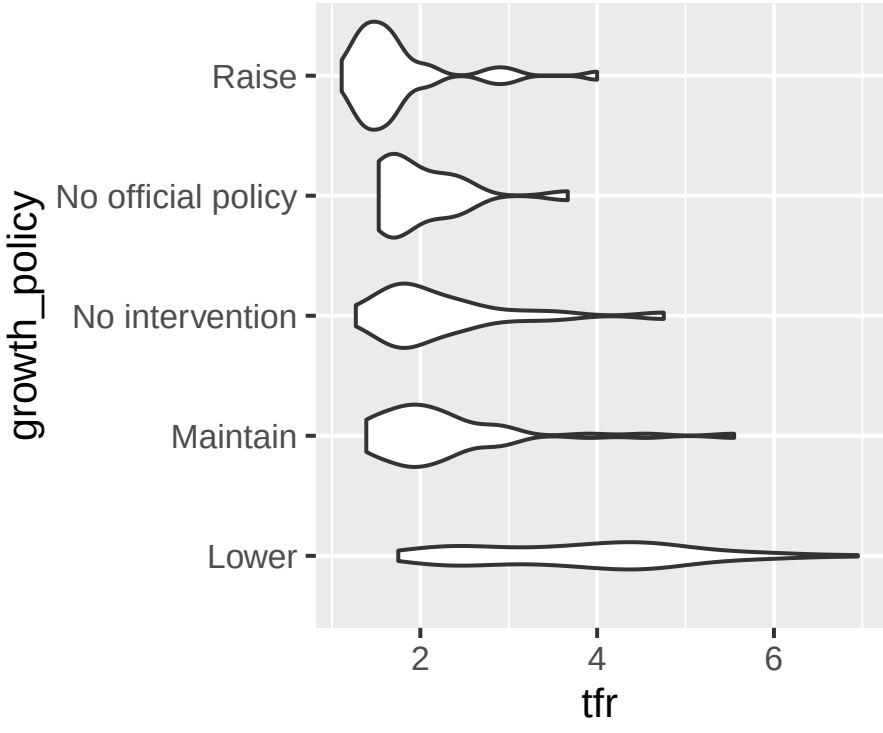




Geom Examples: Two Variables

```
> # left: one continuous, one discrete variable
> ggplot(data = d, mapping = aes(x = tfr, y = growth_policy)) +
+   geom_boxplot()
> # right: one continuous, one discrete variable
> ggplot(data = d, mapping = aes(x = tfr, y = growth_policy)) +
+   geom_violin()
```



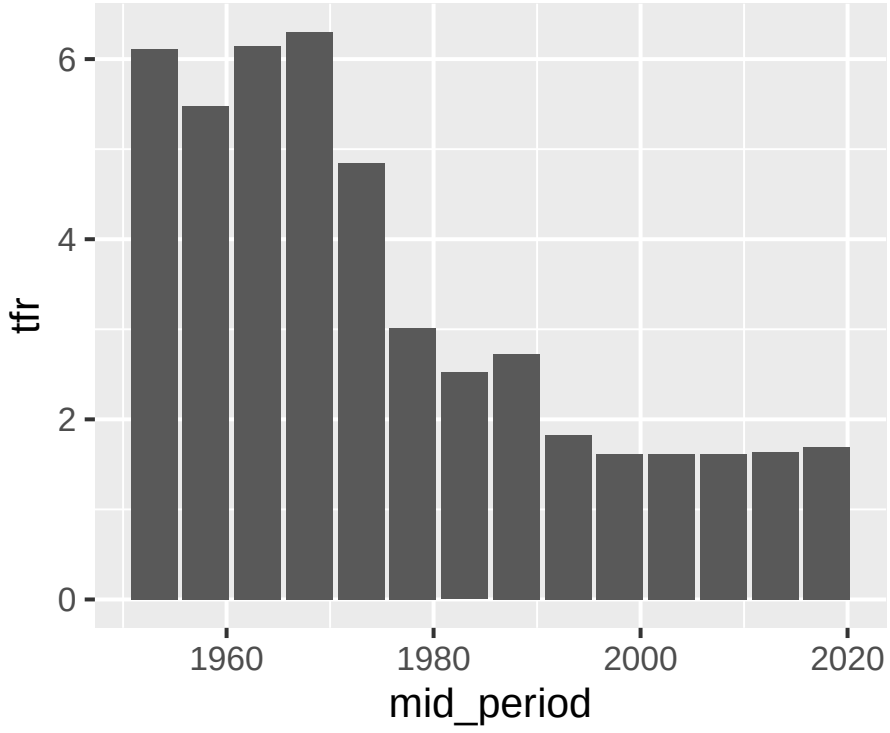


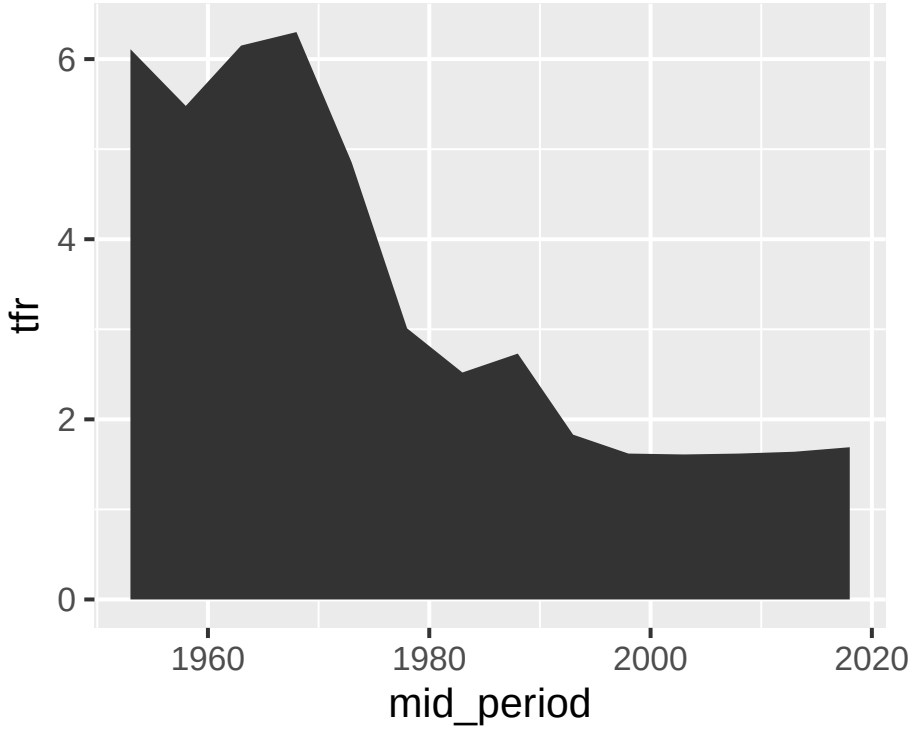
Geom Examples: Time Variable

```
> china
# A tibble: 14 x 5
   name  period    mid_period    imr   tfr
   <chr> <chr>          <dbl>  <dbl> <dbl>
 1 China 1950-1955       1953 129.    6.11
 2 China 1955-1960       1958 131.    5.48
 3 China 1960-1965       1963 135.    6.15
 4 China 1965-1970       1968  93.8   6.3
 5 China 1970-1975       1973  71.9   4.85
 6 China 1975-1980       1978  55.0   3.01
 7 China 1980-1985       1983  44.6   2.52
 8 China 1985-1990       1988  42.3   2.73
 9 China 1990-1995       1993  41.3   1.83
10 China 1995-2000       1998  35.1   1.62
11 China 2000-2005       2003  27.1   1.61
12 China 2005-2010       2008  18.1   1.62
13 China 2010-2015       2013  12.3   1.64
14 China 2015-2020       2018   9.89  1.69
```

Geom Examples: Time Variable

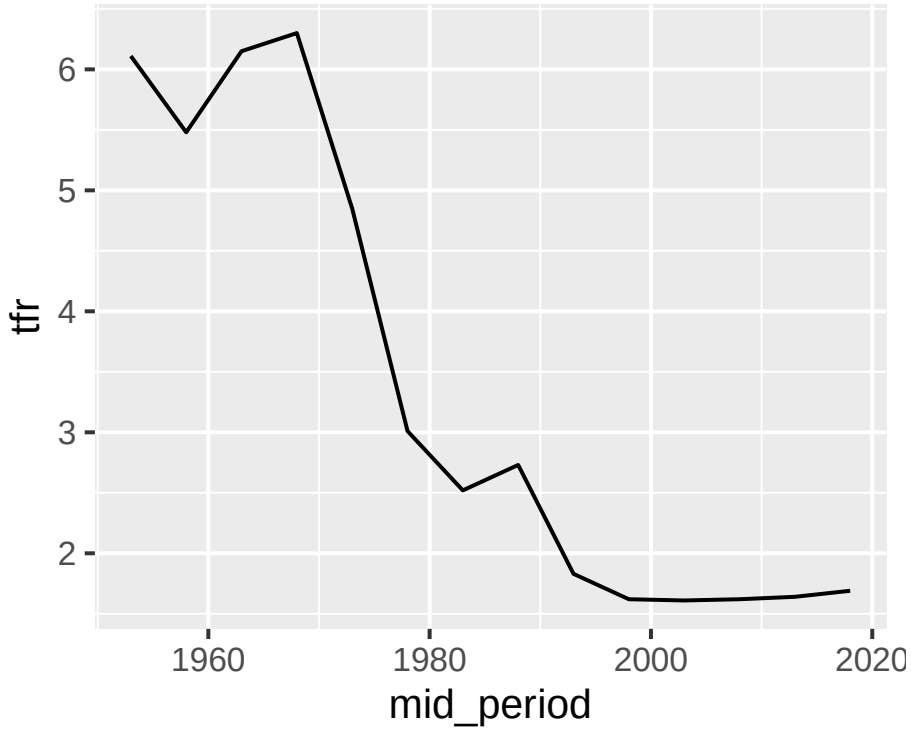
```
> # left
> ggplot(data = china, mapping = aes(x = mid_period, y = tfr)) +
+   geom_col()
> # right
> ggplot(data = china, mapping = aes(x = mid_period, y = tfr)) +
+   geom_area()
```

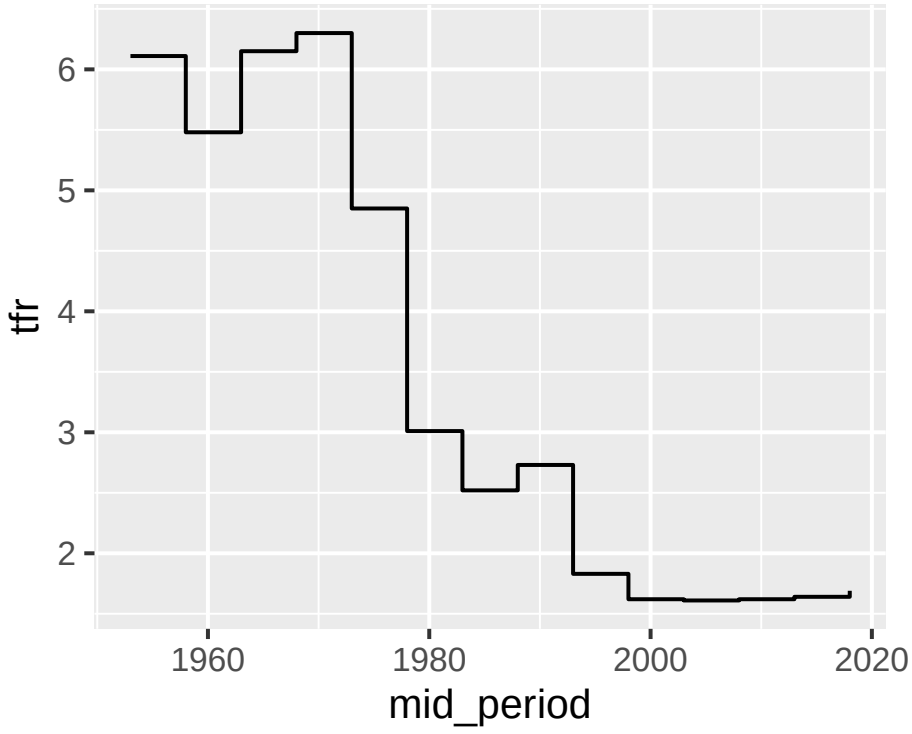




Geom Examples: Time Variable

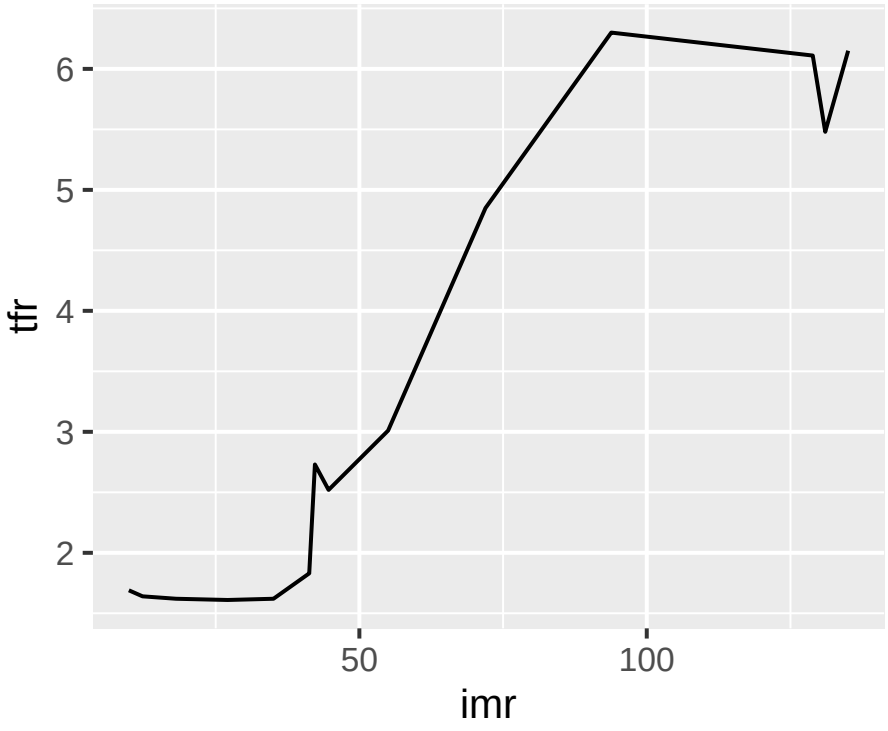
```
> # left
> ggplot(data = china, mapping = aes(x = mid_period, y = tfr)) +
+   geom_line()
> # right
> ggplot(data = china, mapping = aes(x = mid_period, y = tfr)) +
+   geom_step()
```

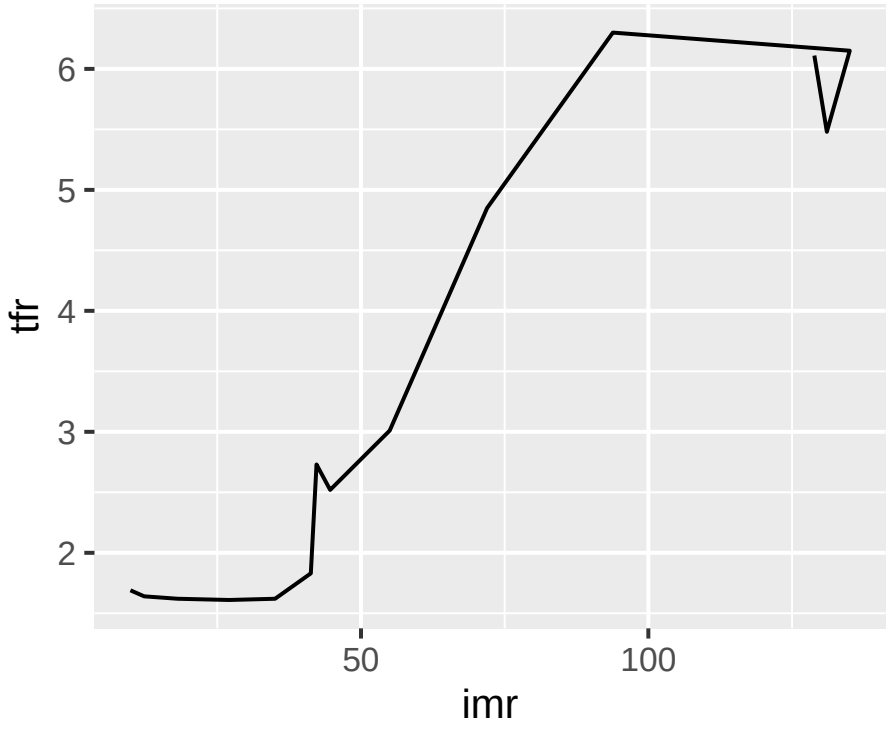




Geom Examples: Time Variable

```
> # left: follows order on x-axis (if x is not time can cause problem)
> ggplot(data = china, mapping = aes(x = imr, y = tfr)) +
+   geom_line()
> # right: follows order in data
> ggplot(data = china, mapping = aes(x = imr, y = tfr)) +
+   geom_path()
```



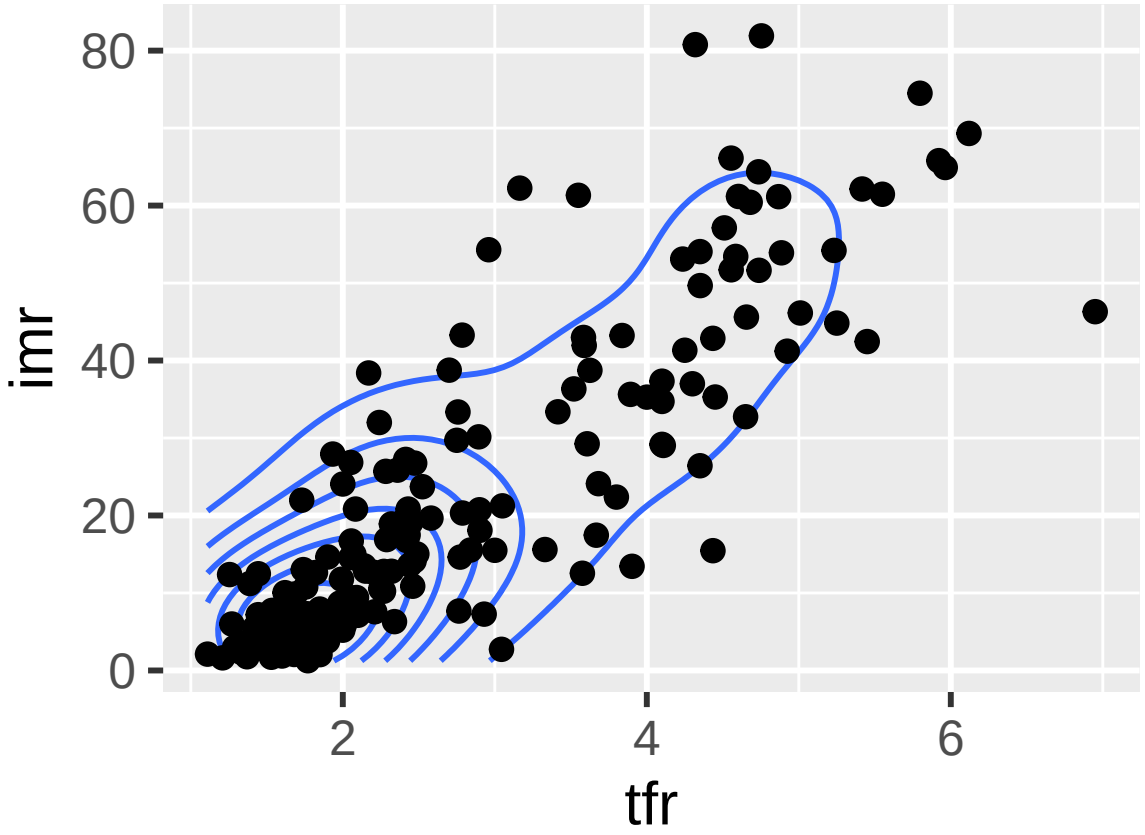


Layers

- Geoms can be added in layers
  - Adds more detail the plots
- The `data` and `mapping` aesthetics in the `ggplot` function are shared by all the geom functions
- To overwrite for a individual geom you can place `mappings` or `data` arguments in the geom function
  - This will treat mappings or data local to the layer only.

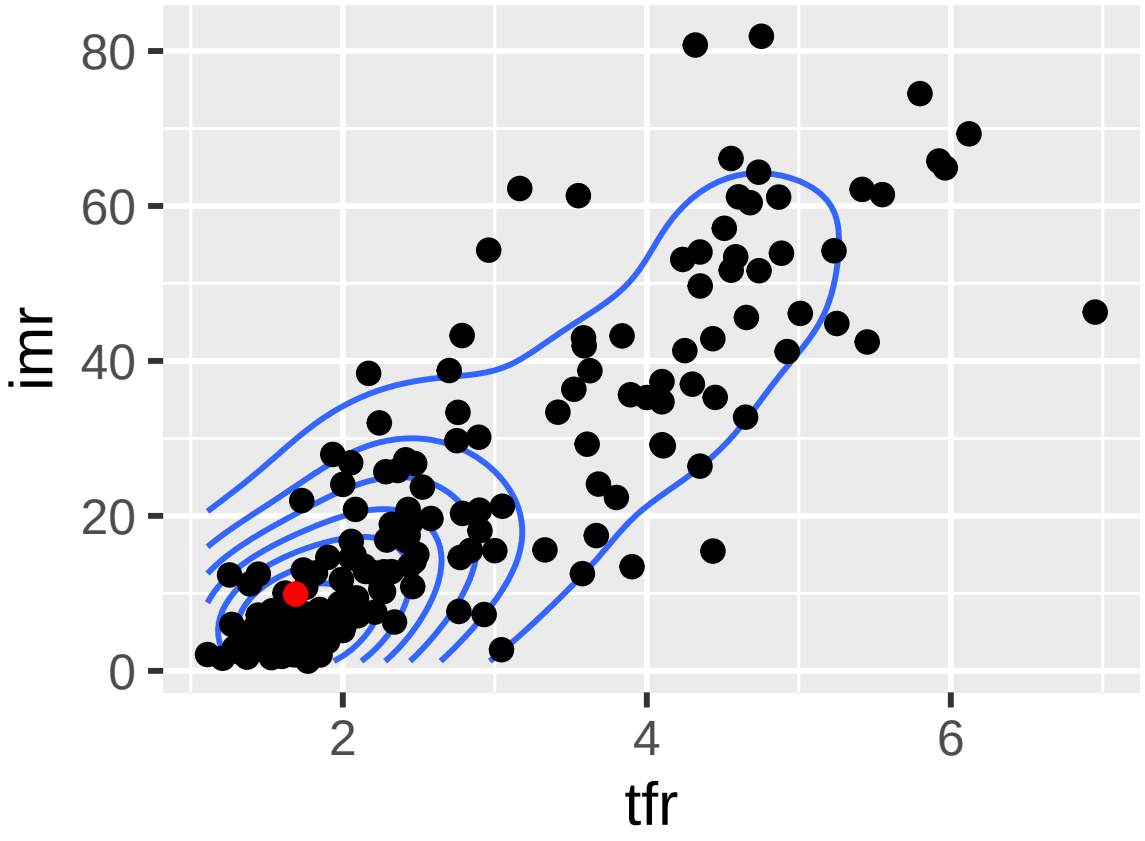
Layers

```
> ggplot(data = d, mapping = aes(x = tfr, y = imr)) +
+   geom_density2d() +
+   geom_point()
```



Layers

```
> # add a layer of red points for latest China data - more on aesthetics later!
> ggplot(data = d, mapping = aes(x = tfr, y = imr)) +
+   geom_density2d() +
+   geom_point() +
+   geom_point(data = china[14,], colour = "red")
```

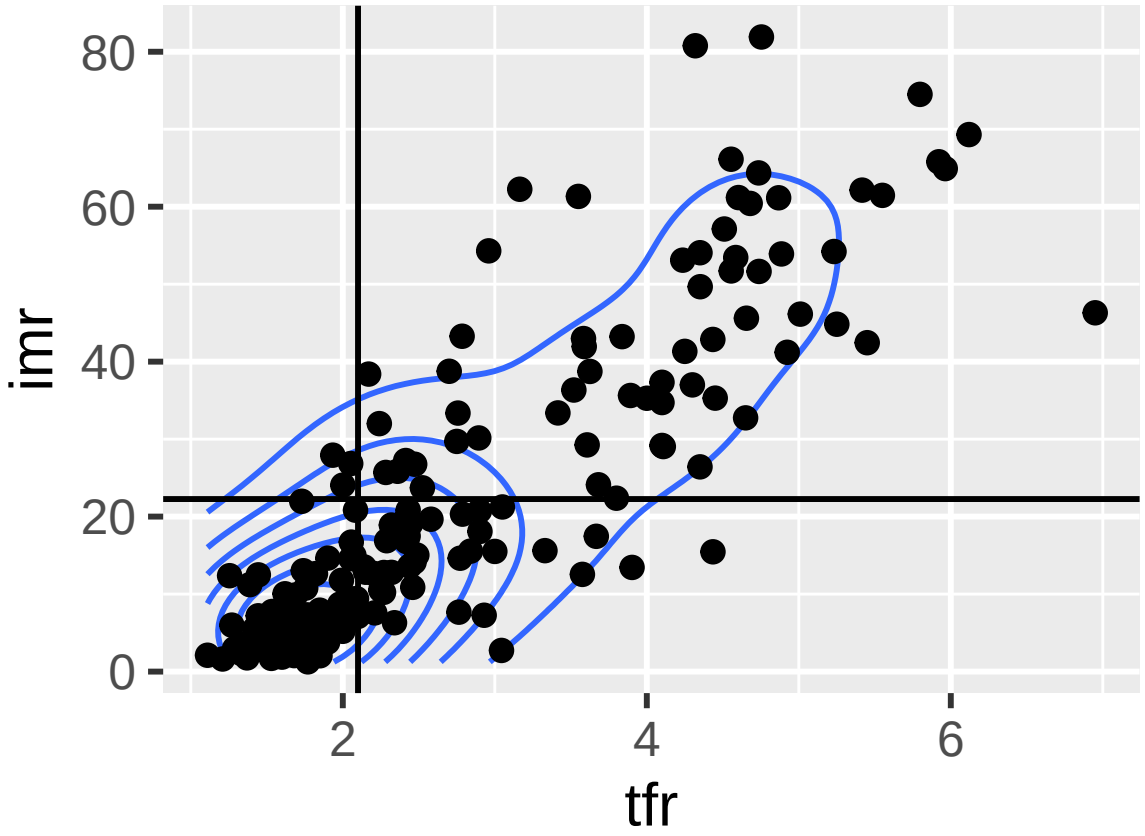


Layers

- Line geoms can help indicate important thresholds
  - The `geom_hline()` function for horizontal line with `yintercept` arguments.
  - The `geom_vline()` function for vertical line with `xintercept` arguments.
  - The `geom_abline()` function for a line with `intercept` and `slope` arguments.
- We can apply a R function to a column before plotting
  - Use within `mapping` argument

Layers

```
> ggplot(data = d, mapping = aes(x = tfr, y = imr)) +
+   geom_density2d() +
+   geom_point() +
+   geom_vline(xintercept = 2.1) +
+   # use mapping when applying a function to a column in the data
+   geom_hline(mapping = aes(yintercept = mean(imr)))
```



Exercise 1 (ex21.R)

```
# 0.  a) Set the working directory to the course folder on your computer by loading
#     b) Check the working directory
getwd()
#     c) Load the tidyverse package (which loads the ggplot2 package amongst others)
library(#####)
#     d) Run the code in ex21_prelim.R to import the UN data for this exercise
source("./exercise./ex21_prelim.R")
#     e) Get familiar with the data by printing to console...
# all countries, 2010-2015 only
d
# UK data, all periods
uk
# South Eastern Asia data, all periods
se_asia
##
##
##
# 1. Create a scatter plot of infant mortality rates (x) against total fertility rat
#    in all countries in the 2010-2015 period
#    (Hint: a) see above to help select the correct data b) use imr and tfr columns)



# 2. Create a bar plot of the immigration policies in different countries from d
#    (Hint: policy data in the immigration_policy variable)
```

Groups

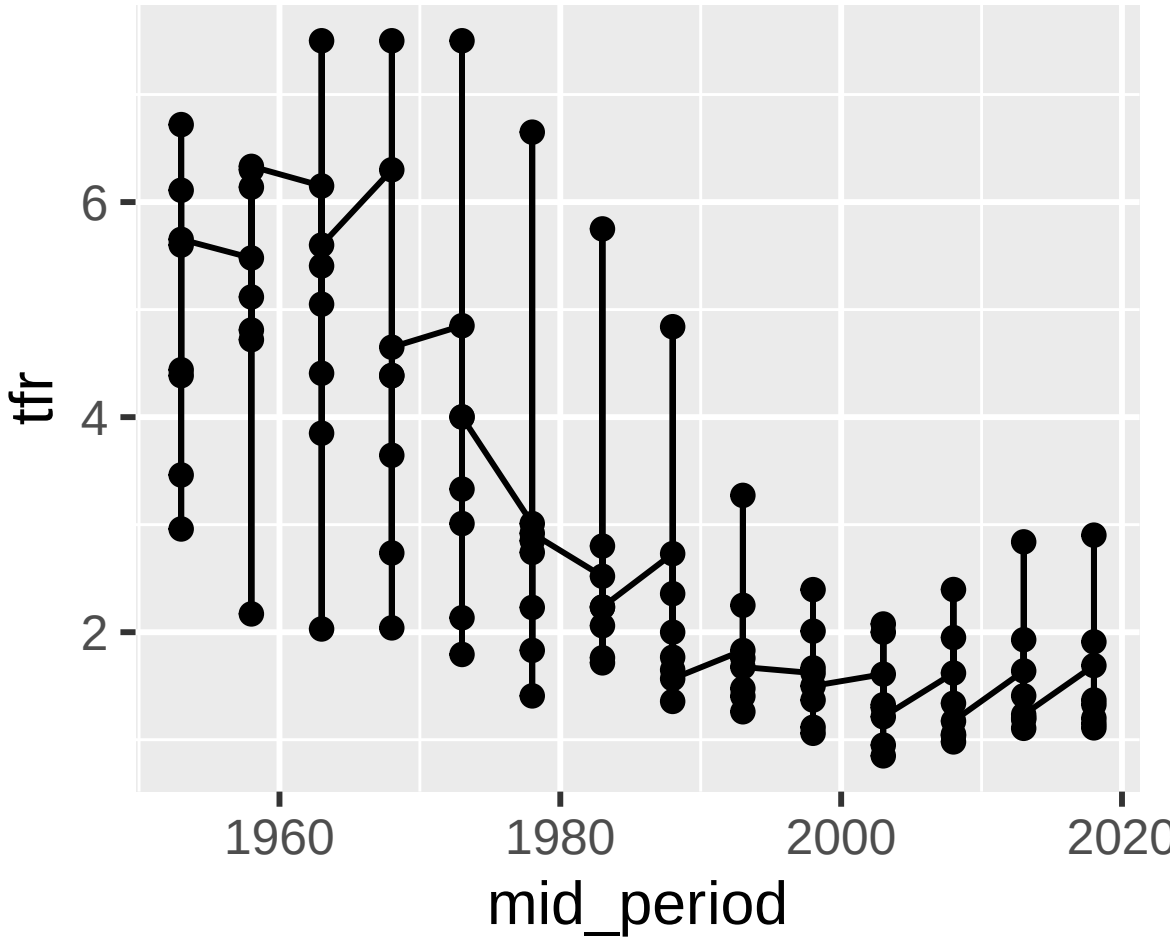
- Many `geoms_` functions use a single object to describe all of the data.
- You can set the `group` aesthetic in the `mappings` to a **discrete** variable to draw multiple objects.
  - This will tell ggplot2 to draw separate object for each unique value of the grouping variable.
- Will not add a legend or distinguishing features to the plot.
  - These are added when we have some more aesthetics for the `mappings`, e.g. `colour` or `linetype` (will get to these soon).

Groups

```
> east_asia
# A tibble: 112 x 7
   name                          period    mid_period   imr   tfr sex_ratio     pop
   <chr>                         <chr>          <dbl> <dbl> <dbl>     <dbl>   <dbl>
 1 China                         1950-1955       1953 129.   6.11      1.07 5.93e5
 2 China, Hong Kong SAR          1950-1955       1953  61.9  4.44      1.09 2.25e3
 3 China, Macao SAR              1950-1955       1953  65.9  4.39      1.05 1.99e2
 4 China, Taiwan Province of ~   1950-1955       1953  78.8  6.72      1.05 8.57e3
 5 Dem. People's Republic of ~   1950-1955       1953 121.   3.46      1.05 9.96e3
 6 Japan                         1950-1955       1953  47.7  2.96      1.06 8.69e4
 7 Mongolia                      1950-1955       1953 183.   5.6       1.03 8.23e2
 8 Republic of Korea             1950-1955       1953 159.   5.65      1.06 2.03e4
 9 China                         1955-1960       1958 131.   5.48      1.07 6.40e5
10 China, Hong Kong SAR          1955-1960       1958  46.3  4.72      1.08 2.83e3
# ... with 102 more rows
```

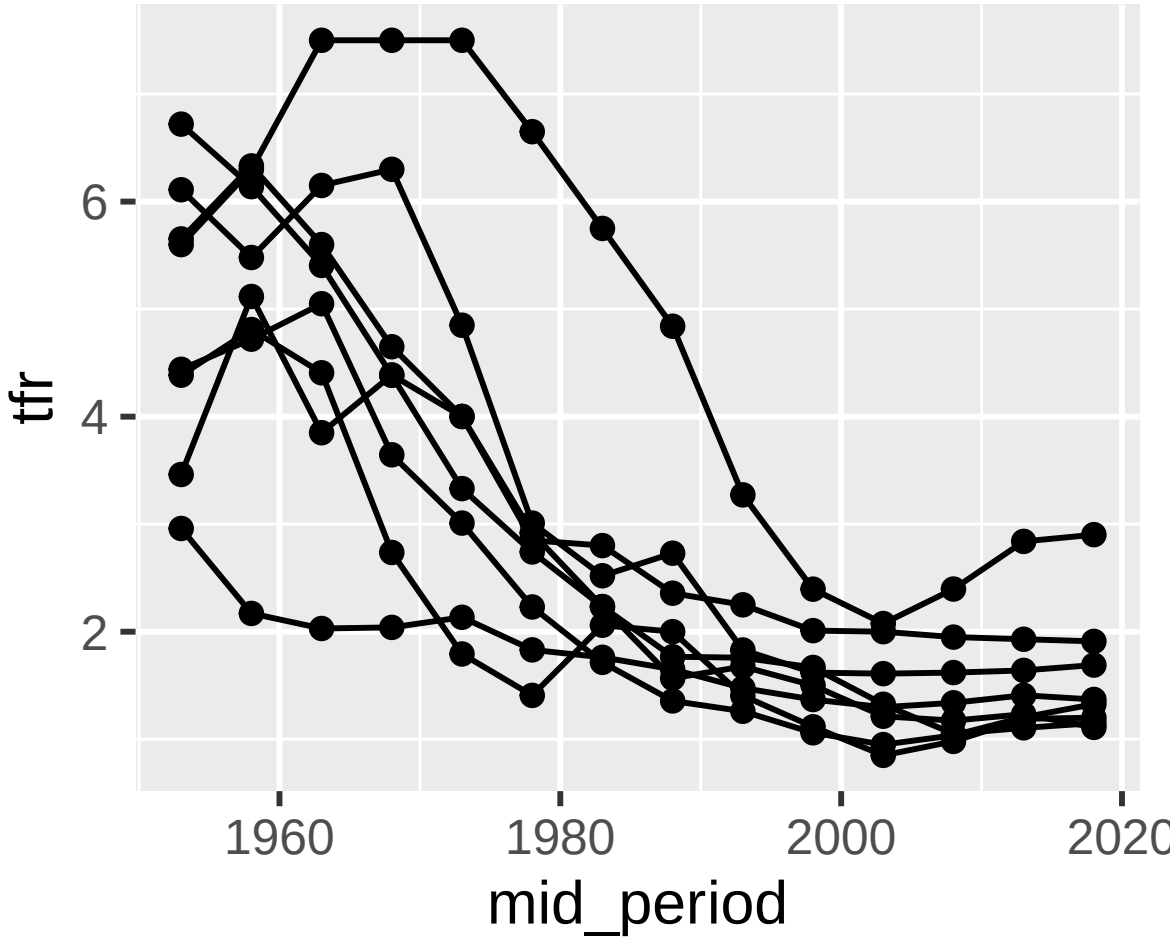
Groups

```
> # eastern asia: line through all points
> ggplot(data = east_asia, mapping = aes(x = mid_period, y = tfr)) +
+   geom_point() +
+   geom_line()
```



Groups

```
> # eastern asia: line for each country (identified by name)
> ggplot(data = east_asia, mapping = aes(x = mid_period, y = tfr, group = name)) +
+   geom_point() +
+   geom_line()
```



Optional Aesthetics

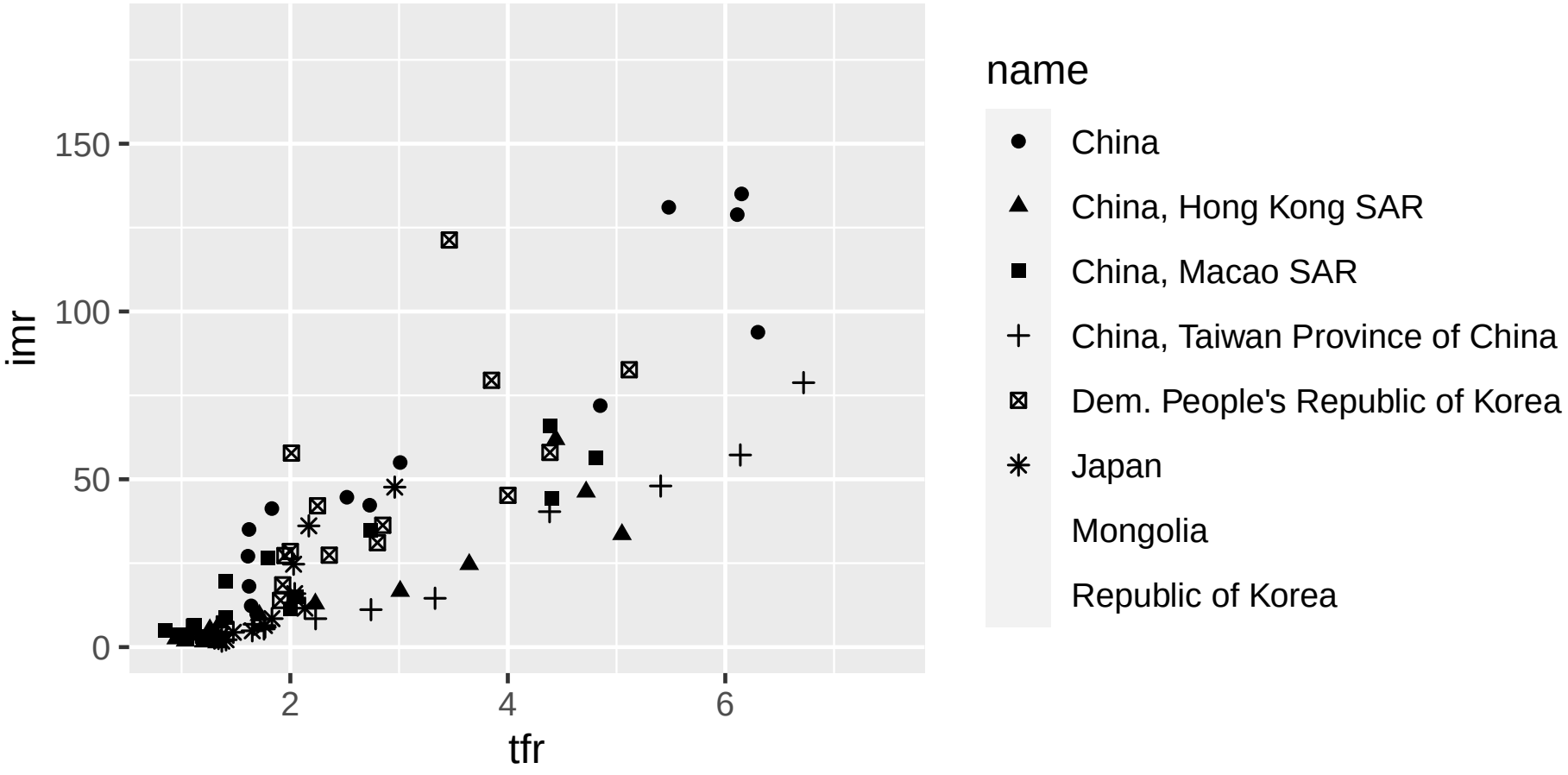
- Beyond `group`, there are other aesthetics (`aes`) that can be used depending on the geom, for example:
  - `shape`: shape of point
  - `linetype`: type of line used
  - `size`: size of object
  - `colour`: border colour (i.e. for dimensional object)
  - `fill`: internal colour (i.e. for two dimensional object)
  - `alpha`: transparency (between 0 and 1)
  - and many more ...
- Not all aesthetics work with all geom.
  - For example `geom_point()` has no `linetype` option.
  - Check the cheatsheet to see what is available.

Optional Aesthetics

- You can set the aesthetic to a
  - Single value to change the appearance for all plotted objects
    - Use outside of `mapping = aes()`
  - Variables (columns) in the data
    - Use inside of `mapping = aes()`
- When set to variable names in the data
  - If discrete will operate by each group (category) of the variable.
  - If continuous will operate along the scale of the variable.
- Not all aesthetics can be set to continuous variables
  - For example, `linetype = mid_period`
- Can set different aesthetics to different variables, allowing you to show more many dimensions of your data.

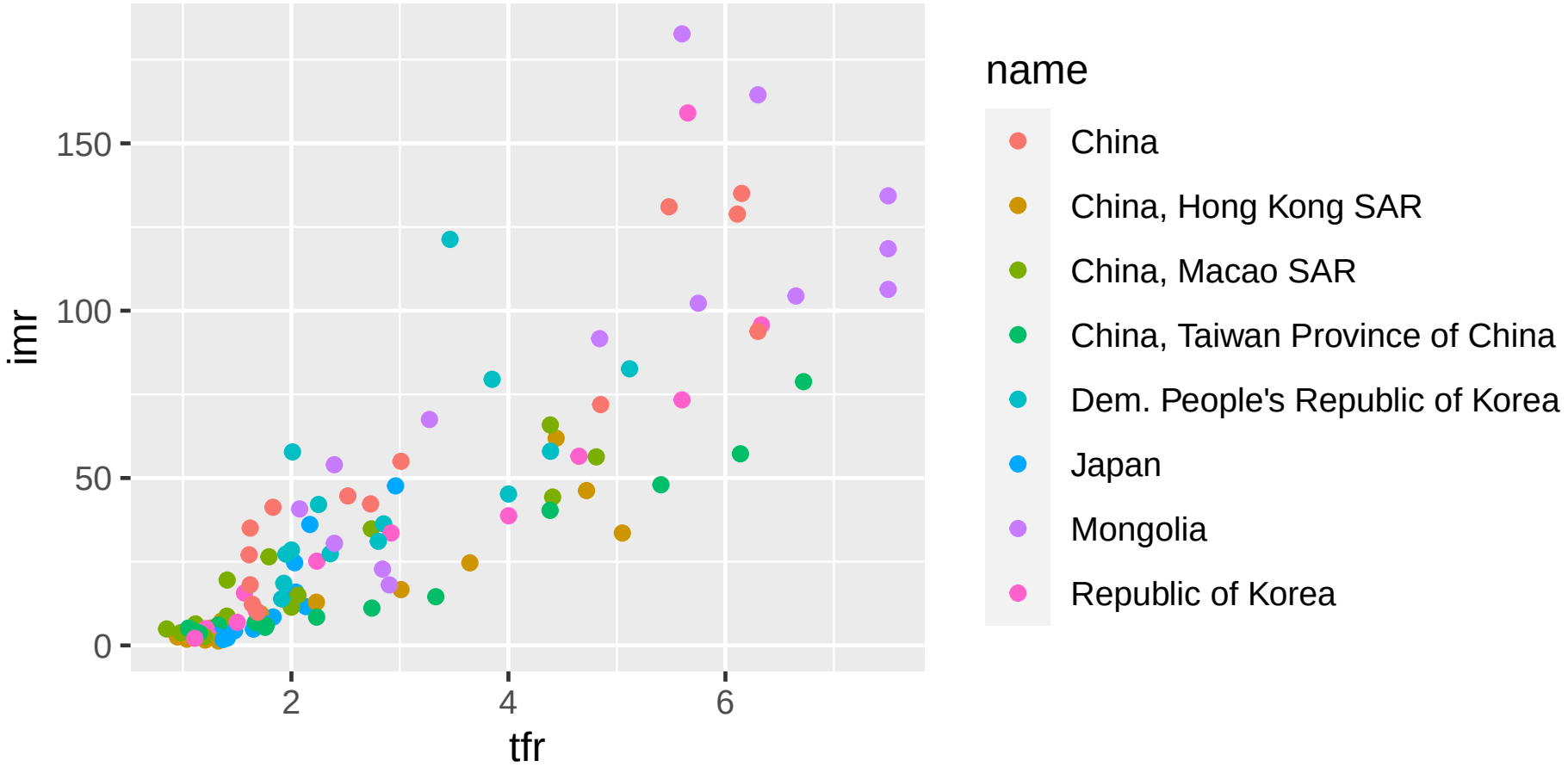
Optional Aesthetics

```
> # eastern asia: set shape from discrete variable
> ggplot(data = east_asia, mapping = aes(x = tfr, y = imr, shape = name)) +
+   geom_point()
```



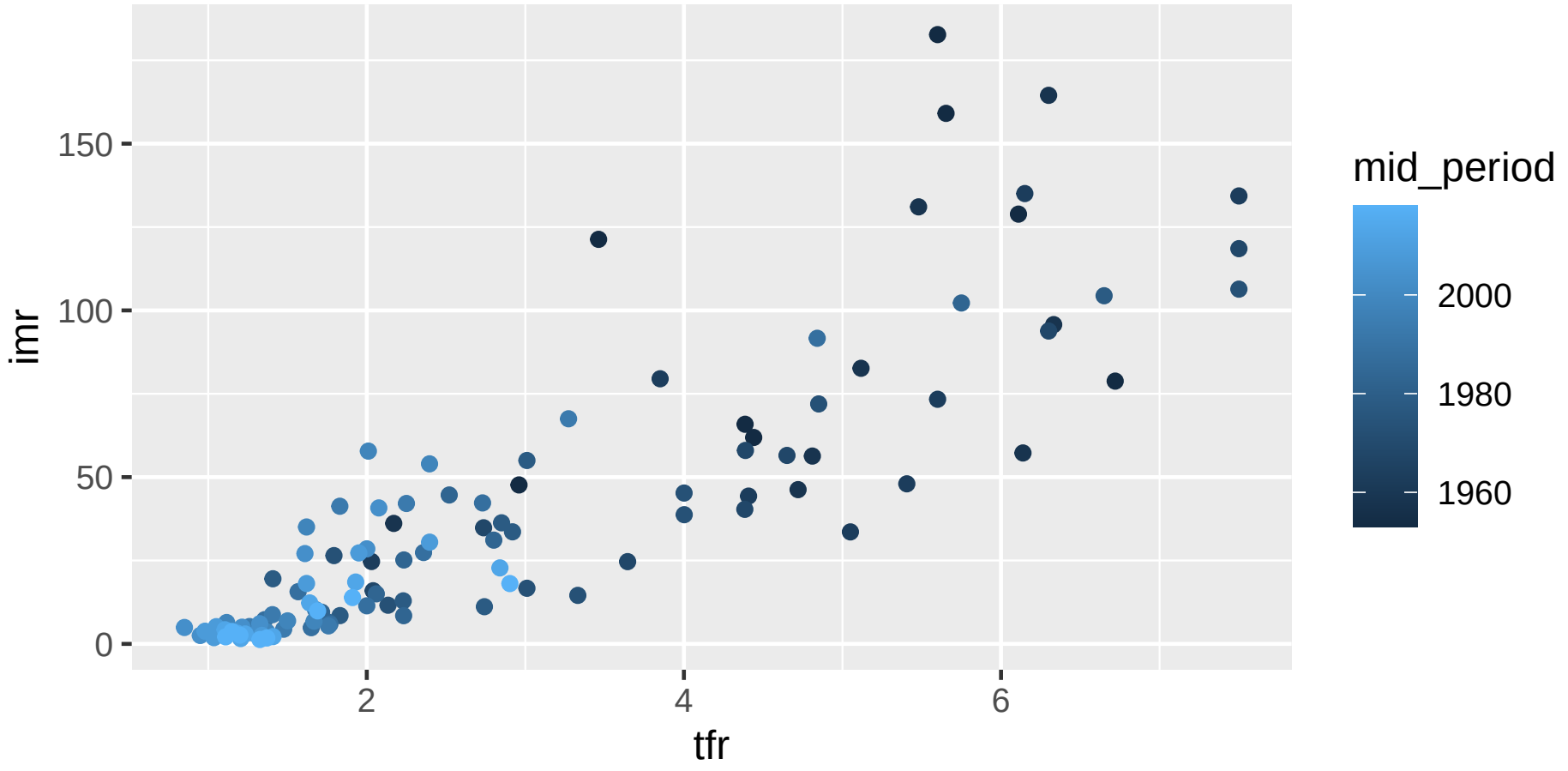
Optional Aesthetics

```
> # eastern asia: set colour from continuous variable
> ggplot(data = east_asia, mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point()
```



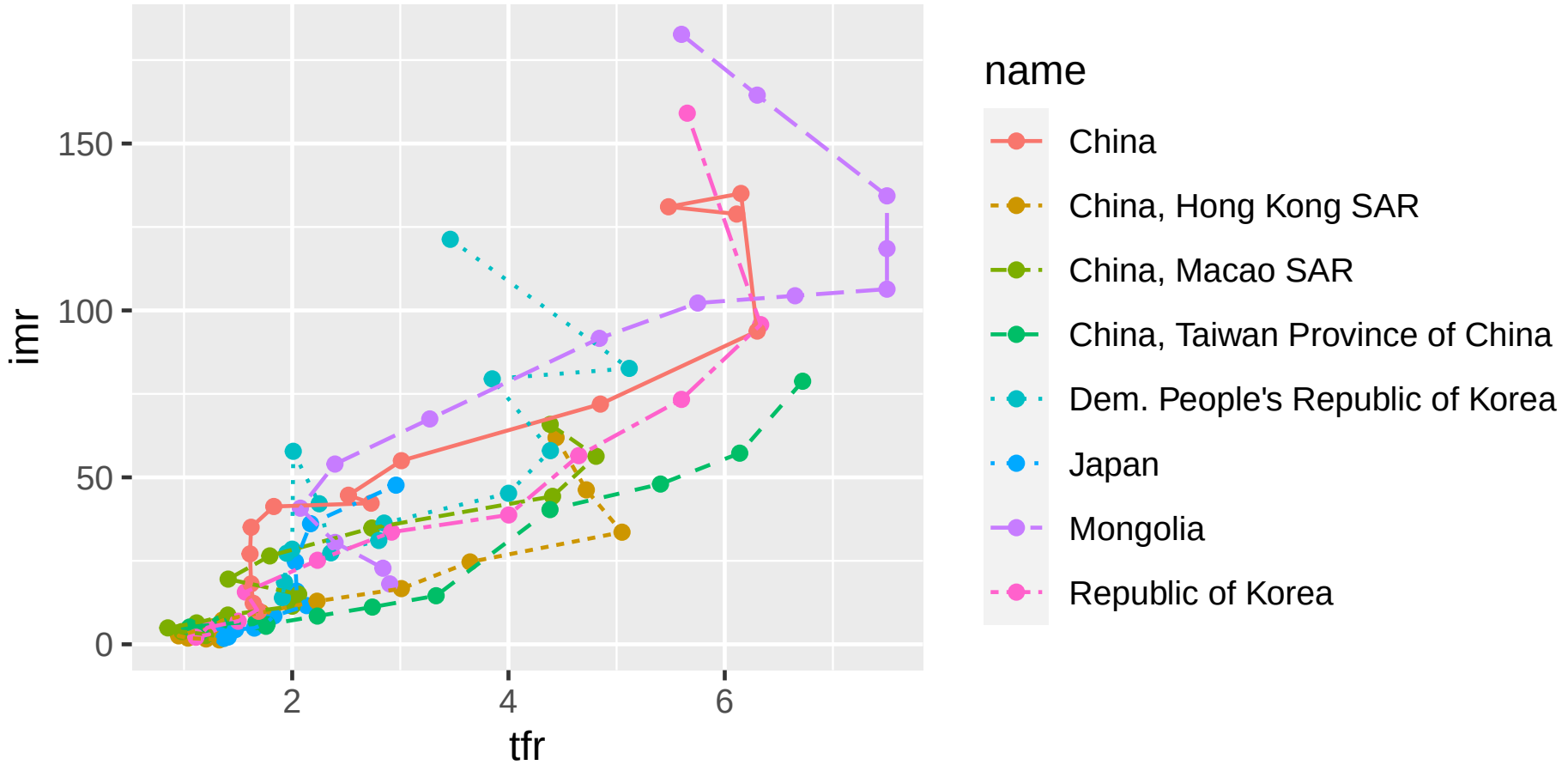
Optional Aesthetics

```
> # eastern asia: set colour from continuous variable
> ggplot(data = east_asia, mapping = aes(x = tfr, y = imr, colour = mid_period)) +
+   geom_point()
```



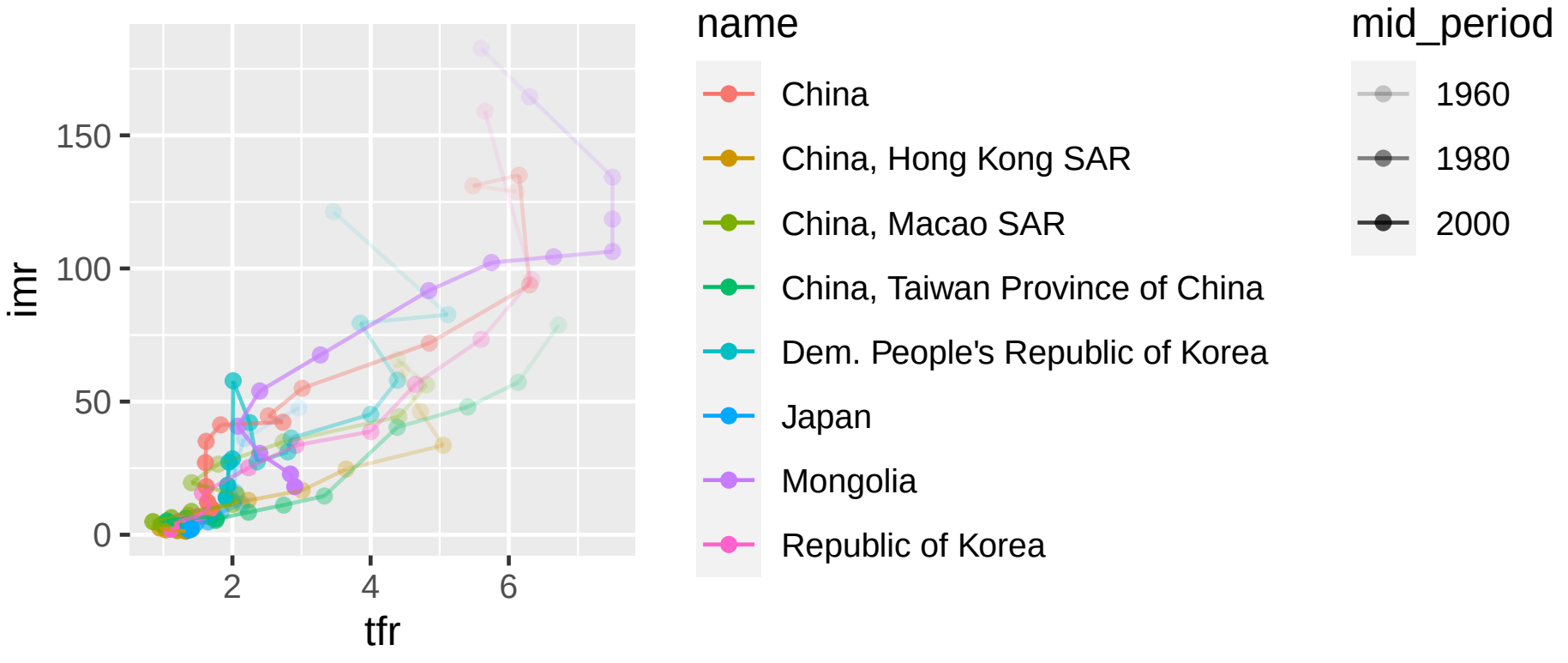
Optional Aesthetics

```
> # eastern asia: set colour and linetype from discrete variable
> ggplot(data = east_asia,
+        mapping = aes(x = tfr, y = imr, colour = name, linetype = name)) +
+   geom_point() +
+   geom_path()
```



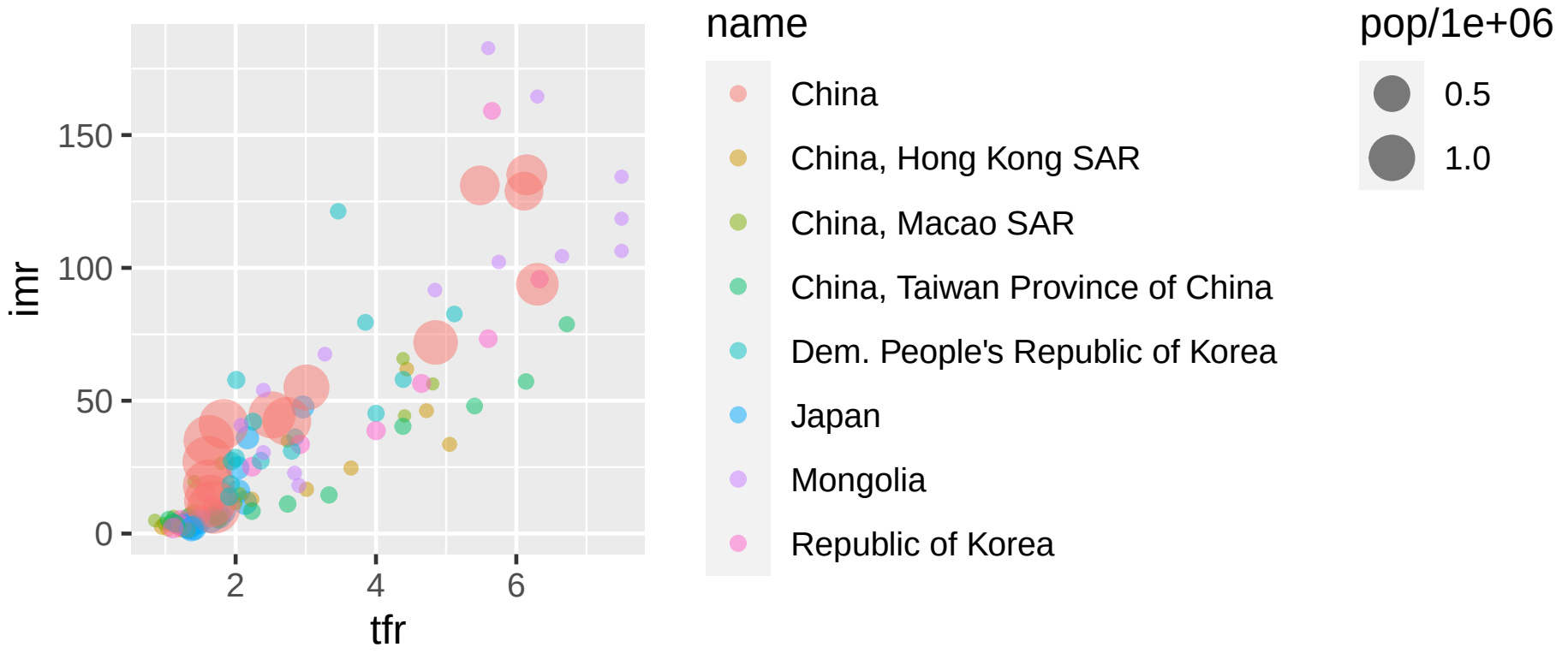
Optional Aesthetics

```
> # eastern asia: set colour from discrete and alpah from continuous variable
> ggplot(data = east_asia,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



Optional Aesthetics

```
> # eastern asia: set colour and size from data, set alpha to 0.5 for all.
> ggplot(data = east_asia,
+        mapping = aes(x = tfr, y = imr, colour = name, size = pop/1e6)) +
+   # all points with same transparency
+   geom_point(alpha = 0.5) +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```

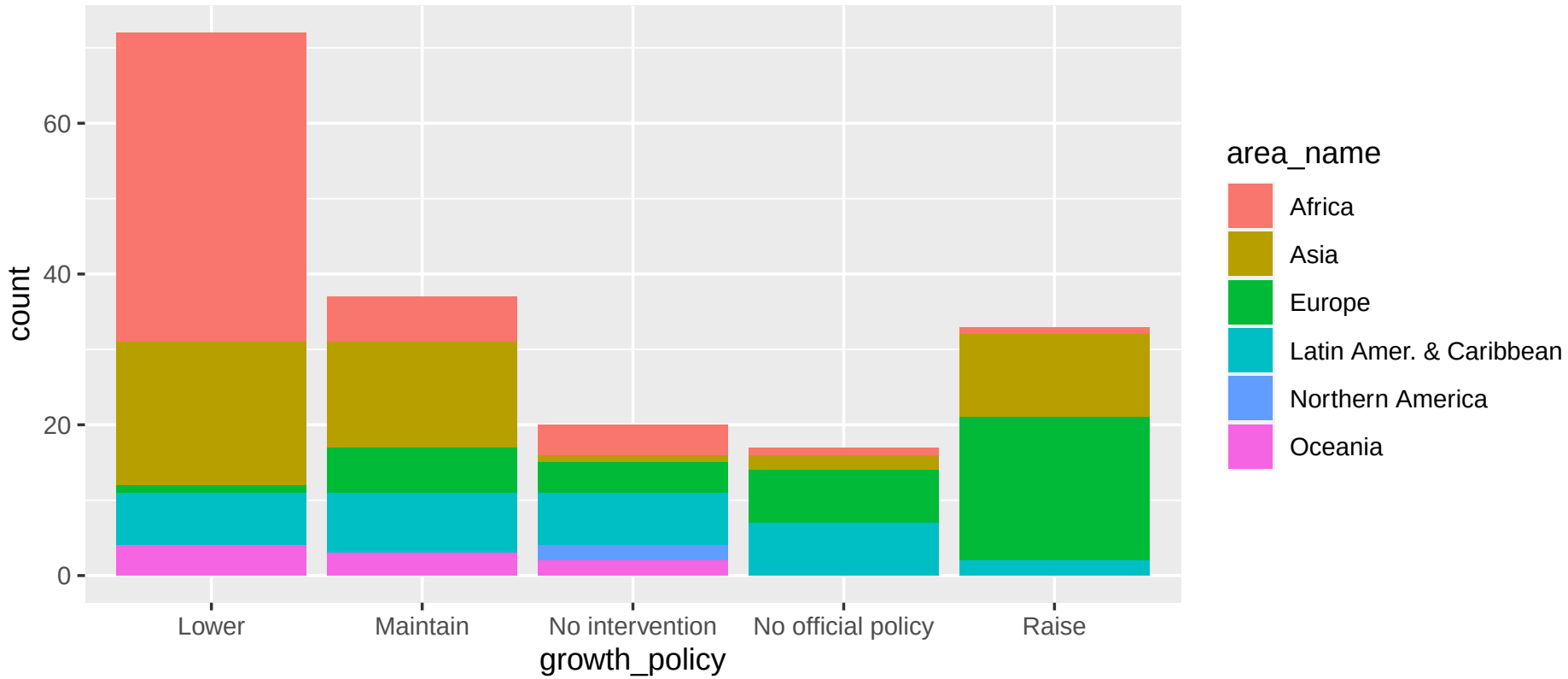


Position

- Each geoms has three main arguments (`mapping`, `position`, `stat`)
- The `position` adjustments determine how to arrange `geoms` that would otherwise occupy the same space.
- For most `geoms` you are unlikely to want to change from the default.
- However, for `geom_bar()` it is useful to know
  - `stack`: stacks elements on top of one another
  - `dodge`: arrange elements side by side
  - `fill`: stack elements on top of one another, normalize height
- For other `geoms` there are other position adjustment possibilities
  - `jitter`: adds random noise to `x` and `y` position of each element to avoid over plotting
  - `nudge`: nudge labels (in `geom_label()`) away from points

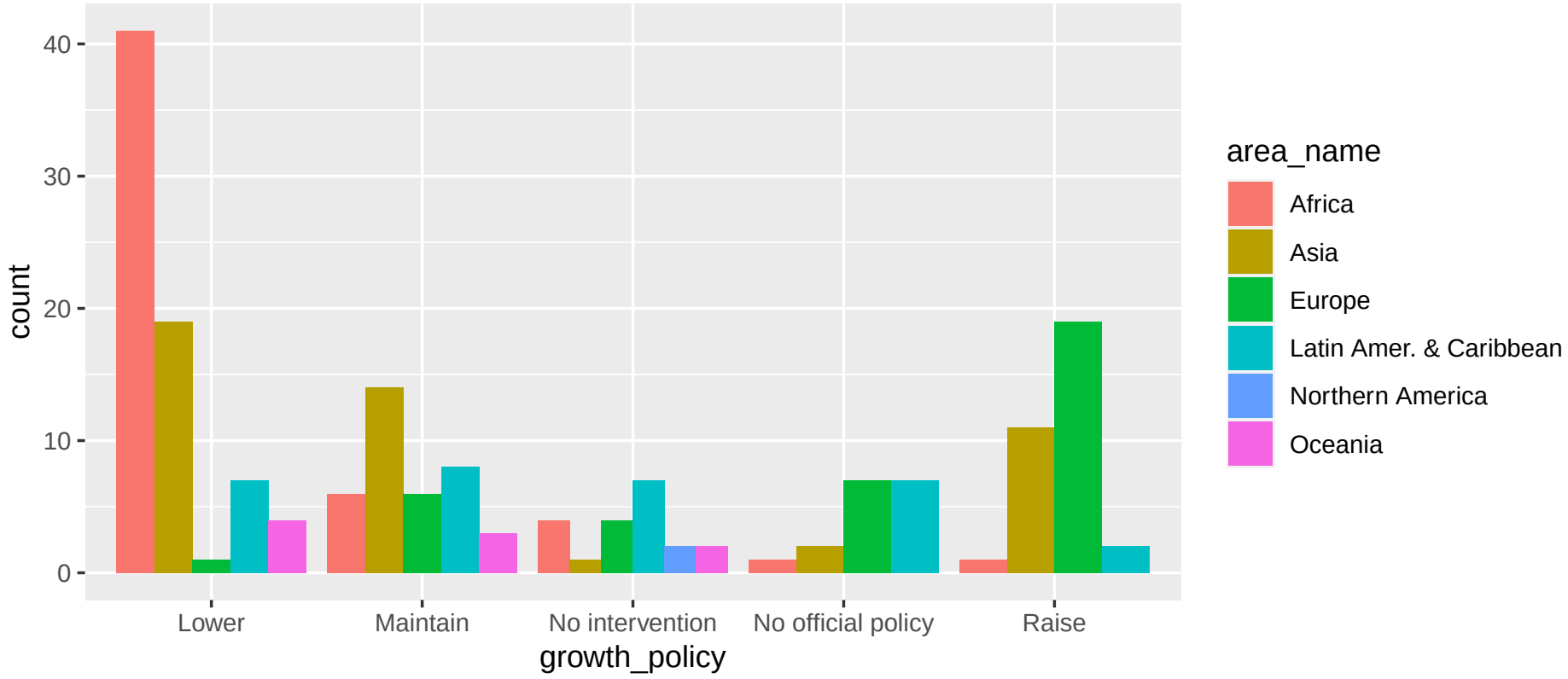
Position

```
> # stack position (default for geom_bar())
> ggplot(data = d, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar()
```



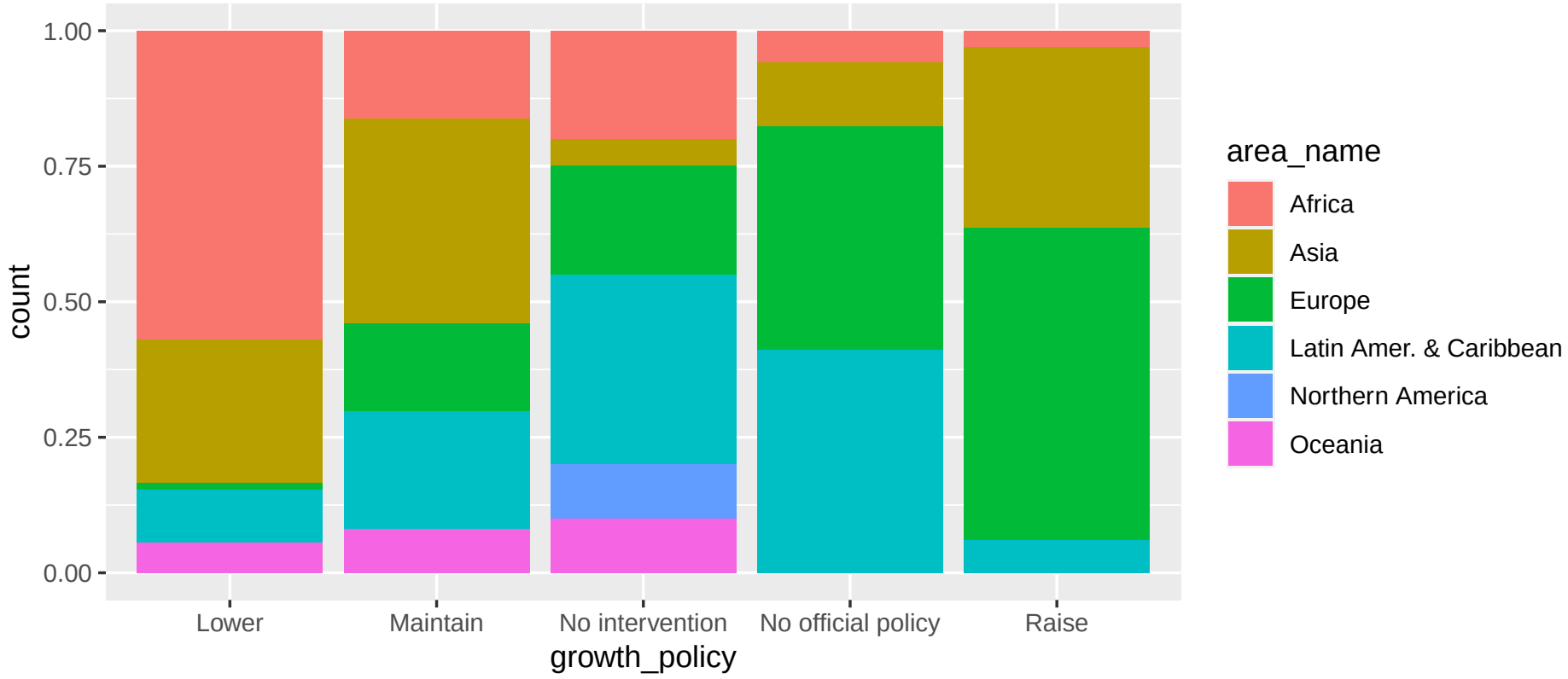
Position

```
> # dodge position
> ggplot(data = d, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar(position = "dodge")
```



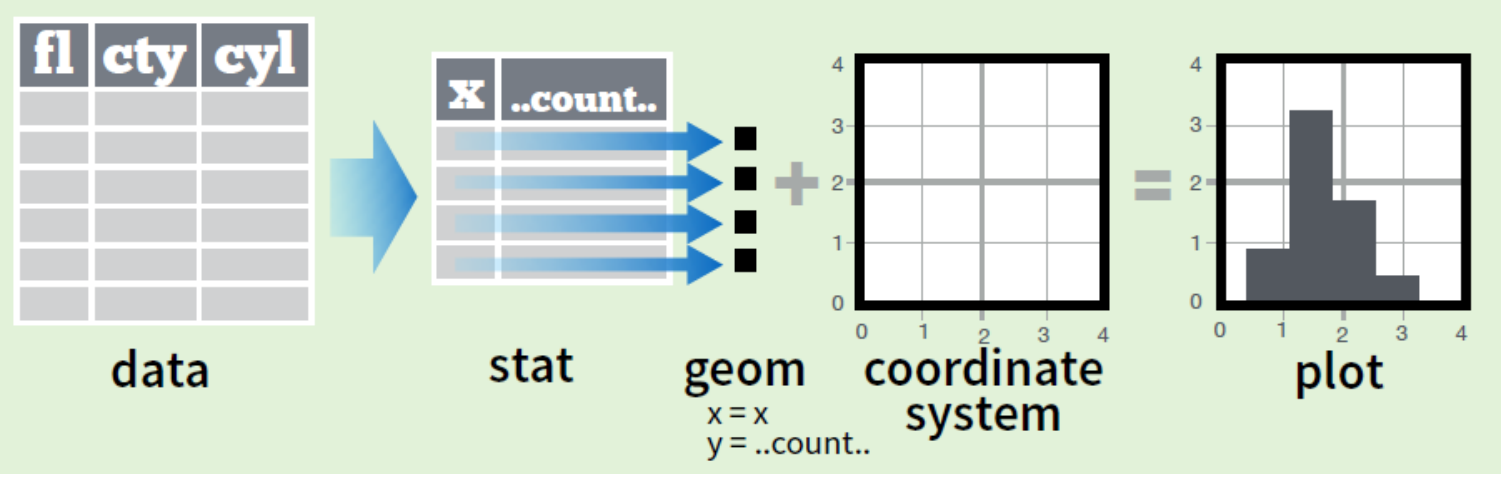
Position

```
> # fill position
> ggplot(data = d, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar(position = "fill")
```



Stats

- Each geoms has three main arguments (`mapping`, `position`, `stat`)
- The `stat` argument builds new variables to plot (e.g., count, prop).
  - Short for statistical transformation.
- Each geom is associated with a default stat that it uses to calculate values to plot.
  - Applied the transformation and stores the results behind the scenes.
  - Uses and intuitive set of defaults.
  - Rarely need to adjust a geom `stat`.



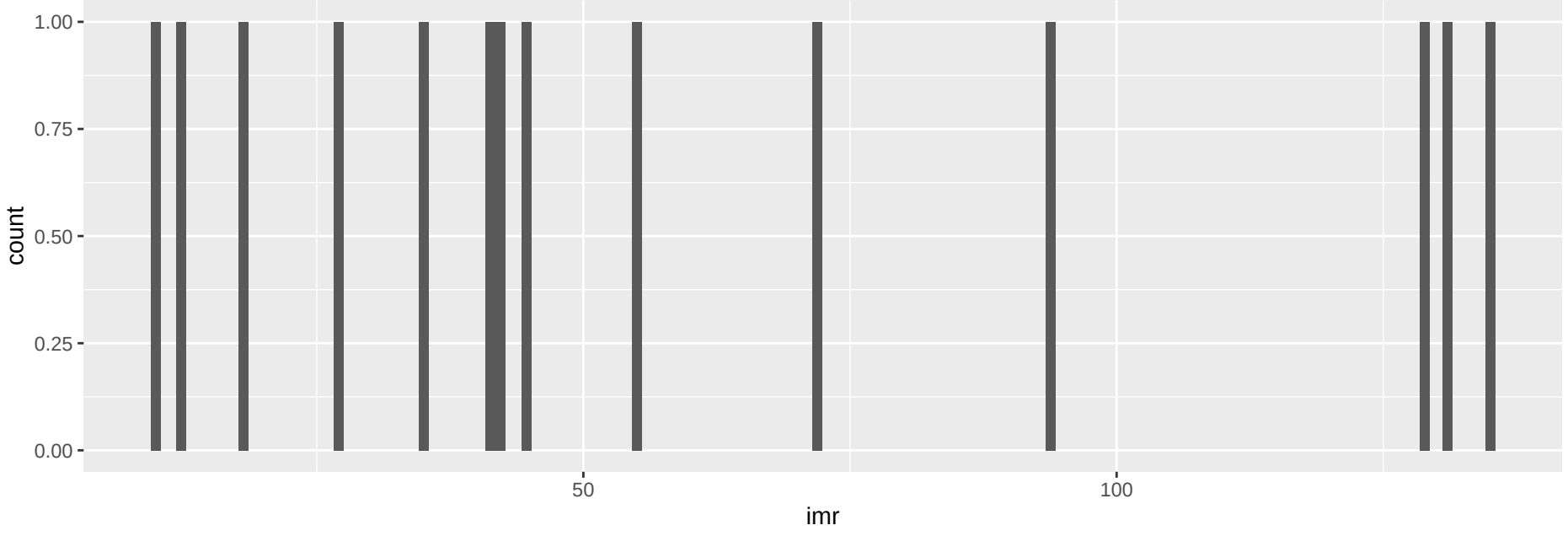
Stats

- Some stats we have already seen in action:
  - `identity`: use raw values, e.g. `geom_point()`
  - `count`: computes two new variables, count and proportion, e.g. `geom_bar()`
  - `bin`: arrange data into bins and counts, e.g. `geom_histogram()`
  - `density`: computes kernel density estimates, e.g. `geom_density()`
  - `smooth`: fit a model to your data and then plot the model line, e.g. `geom_smooth()`
  - `boxplot`: computes box plots statistics (min, max, IQR, median), e.g. `geom_boxplot()`
- For most `geoms` you are unlikely to want to change from the default.
  - Show how to change with `geom_bar()` in to better understand...

Stats

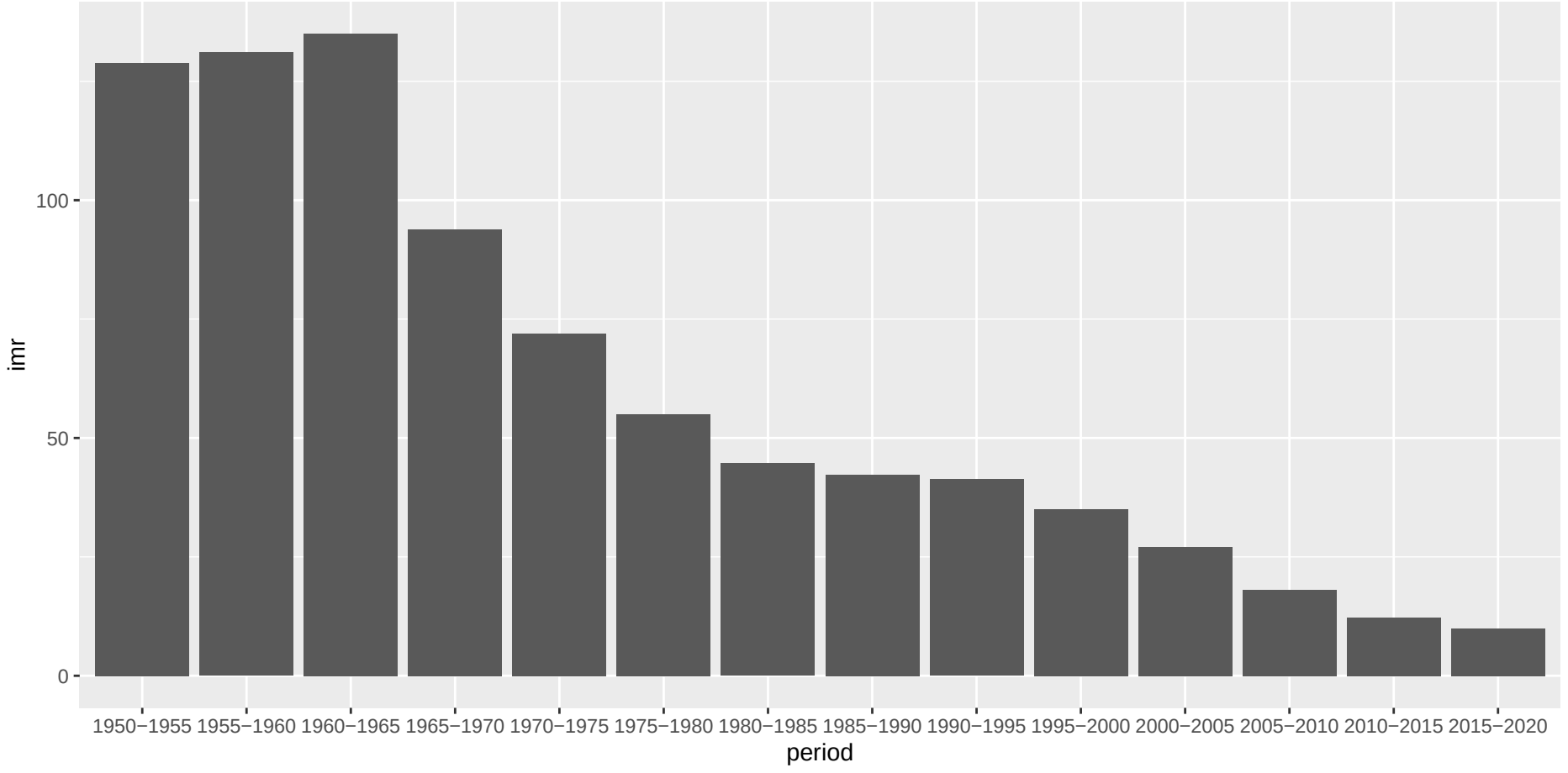
```
> # how can we plot a bar for imr in every period?... this gives an error...
> ggplot(data = china, mapping = aes(x = period, y = imr)) +
+   geom_bar()
Error: stat_count() can only have an x or y aesthetic.
```

```
> # this is not what we want...
> ggplot(data = china, mapping = aes(x = imr)) +
+   geom_bar()
```



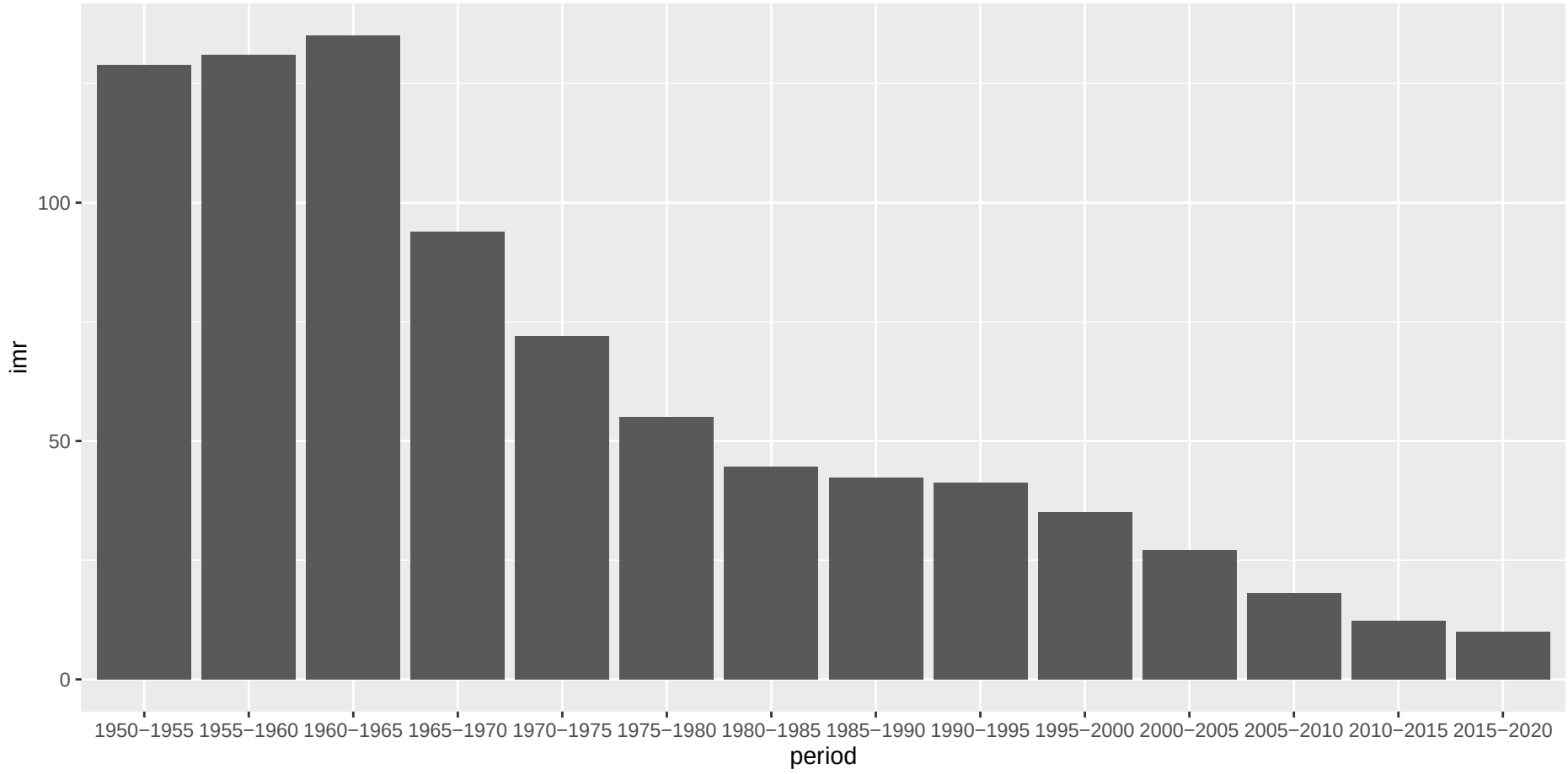
Stats

```
> # china: identity stat
> ggplot(data = china, mapping = aes(x = period, y = imr)) +
+   geom_bar(stat = "identity")
```



Stats

```
> # geom_bar() with identity stat is the same as geom_col()
> ggplot(data = china, mapping = aes(x = period, y = imr)) +
+   geom_col()
```



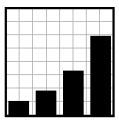
Exercise 2 (ex22.R)

```
# 0.  a) Check your working directory is in the course folder. Load .Rproj file if n
getwd()
#     b) Load the tidyverse package (which loads the ggplot2 package amongst others)
library(tidyverse)
#     c) Run the code in ex22_prelim.R to import the UN data for this exercise
source(#####)
##
##
##
# 1. Create a scatter plot of infant mortality rates (x) against total fertility rat
#    a) point colours matching area names
#    b) point sizes matching the population size in millions (divide pop by 1000)


# 2. Adapt the plot above to add
#    a) horizontal line where tfr is 2.1
#    b) all points to have a transparency of 0.5



# 3. Create a plot of paths for the infant mortality rate (x) against total fertilit
#    relationship for South East Asian countries in se_asia using
#    a) separate paths for each country
#    b) transparency to change by the years in the mid_period column
```

Coordinates

- Plots are based on a coordinate system.
  - The `ggplot()`, like most software, uses the Cartesian coordinate system by default
- Can change the coordinates system of easily using a `coord_` function with `ggplot()`

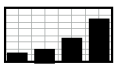
```
r <- d + geom_bar()
```



r + coord_cartesian(xlim = c(0, 5)**)**

xlim, ylim

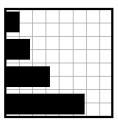
The default cartesian coordinate system



r + coord_fixed(ratio = 1/2**)**

ratio, xlim, ylim

Cartesian coordinates with fixed aspect ratio between x and y units



r + coord_flip()

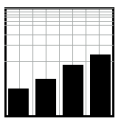
xlim, ylim

Flipped Cartesian coordinates

r + coord_polar(theta = "x", direction=1 **)**

theta, start, direction

Polar coordinates



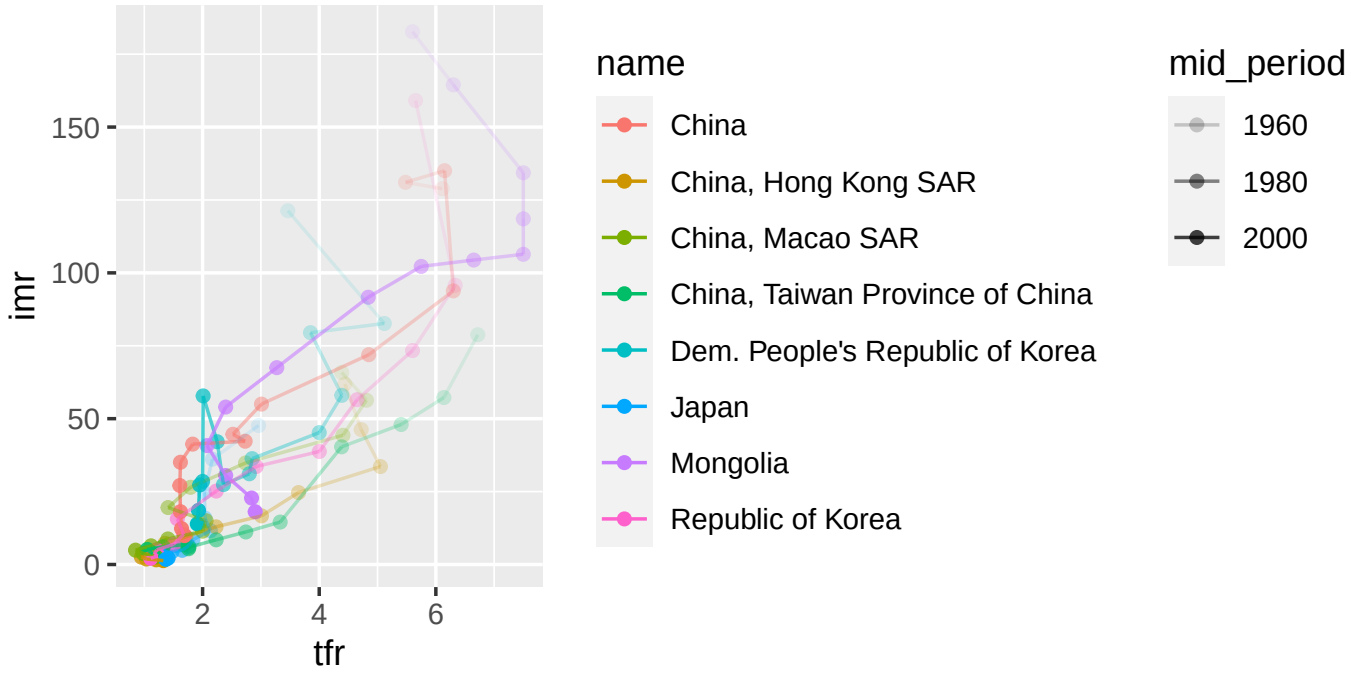
r + coord_trans(ytrans = "sqrt"**)**

xtrans, ytrans, limx, limy

Transformed cartesian coordinates. Set xtrans and ytrans to the name of a window function.

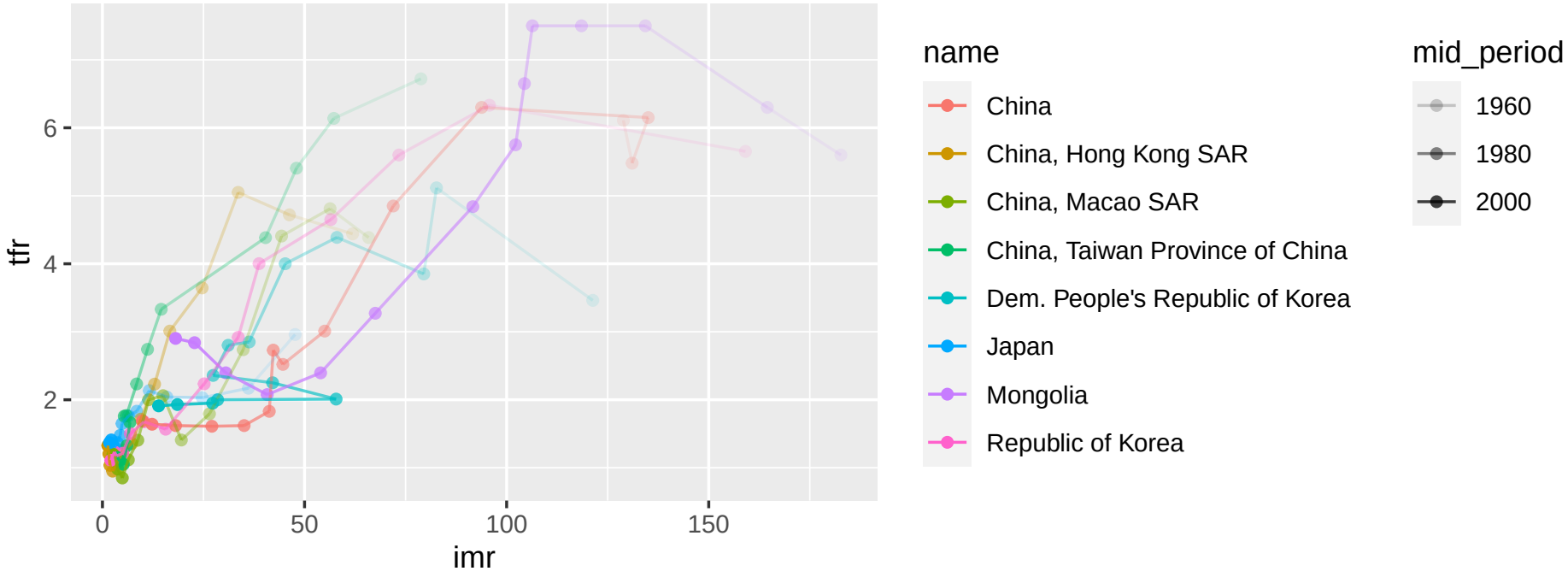
Coordinates

```
> # eastern asia: fix coordinates: 1 coord unit of imr (y) same as 0.05 tfr (x)
> ggplot(data = east_asia,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_fixed(ratio = 0.05) +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



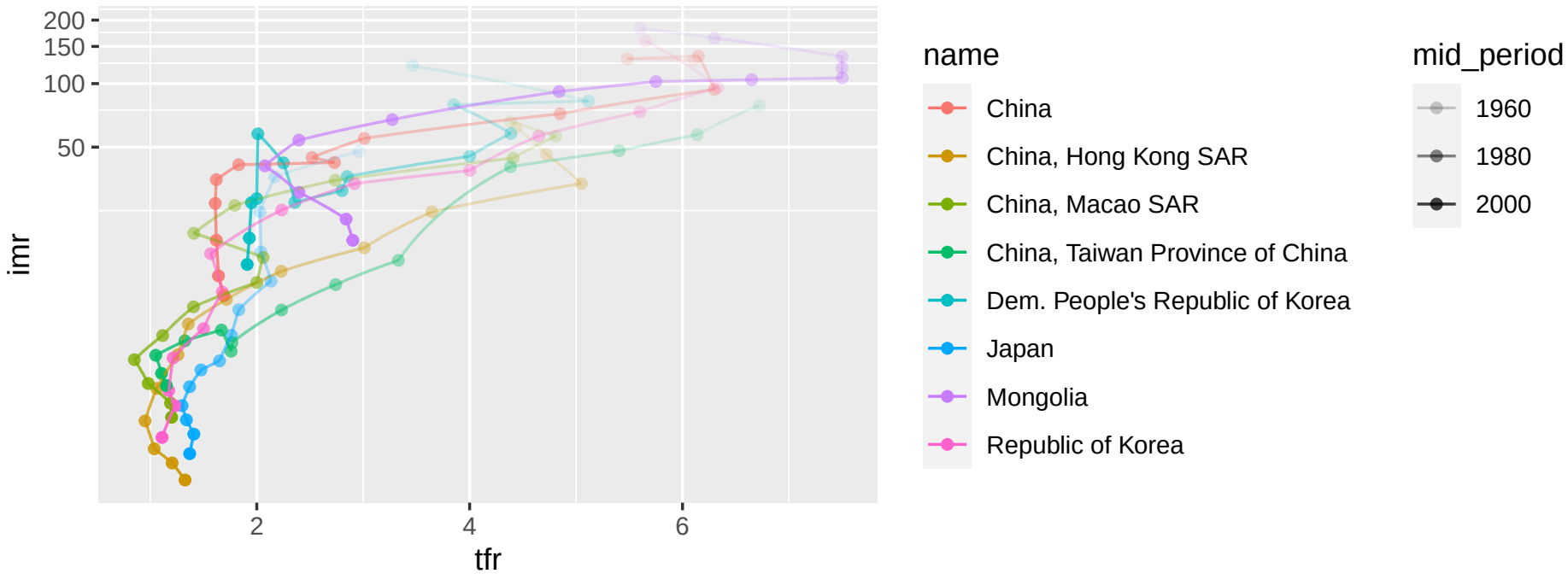
Coordinates

```
> # eastern asia flip coordinates: x is y, y is x
> ggplot(data = east_asia,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_flip() +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



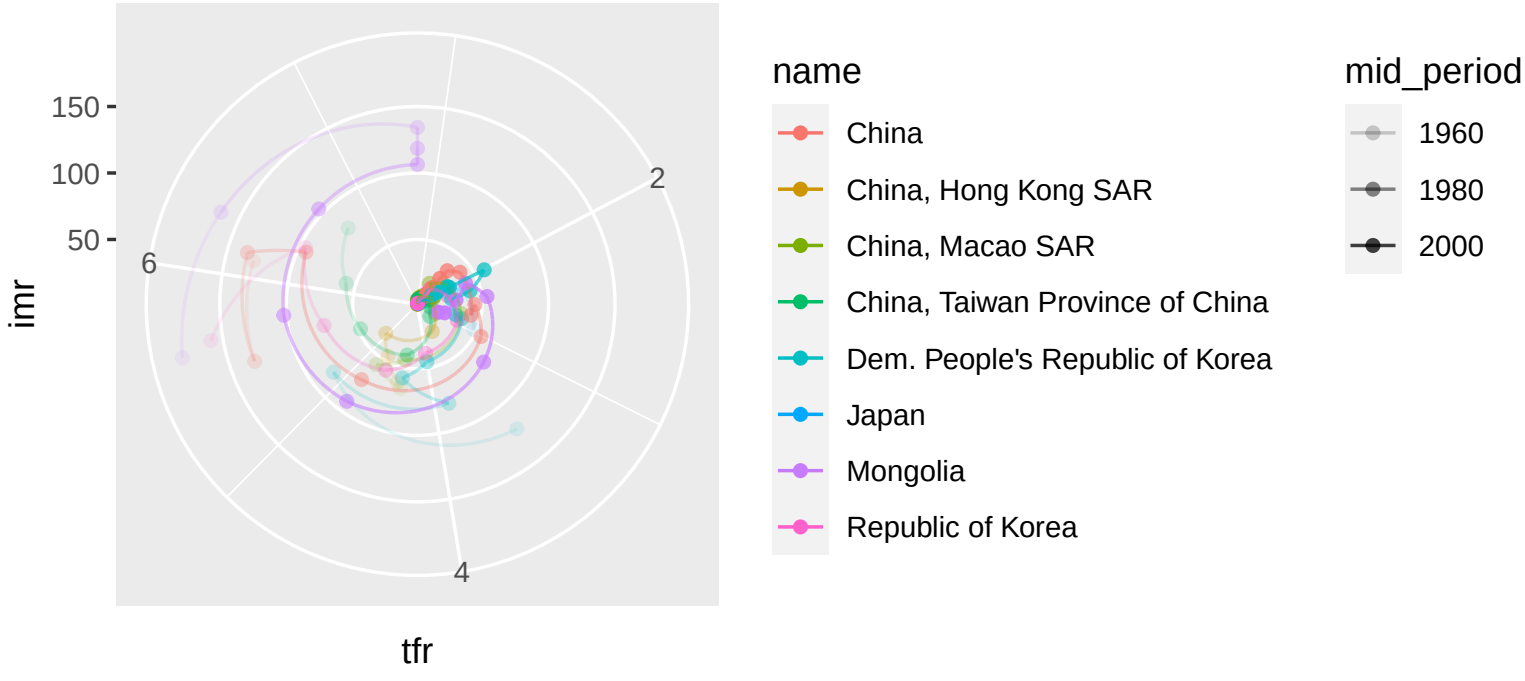
Coordinates

```
> # log y axes
> ggplot(data = east_asia,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_trans(y = "log") +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



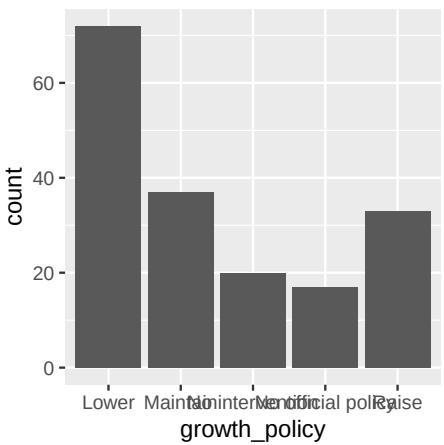
Coordinates

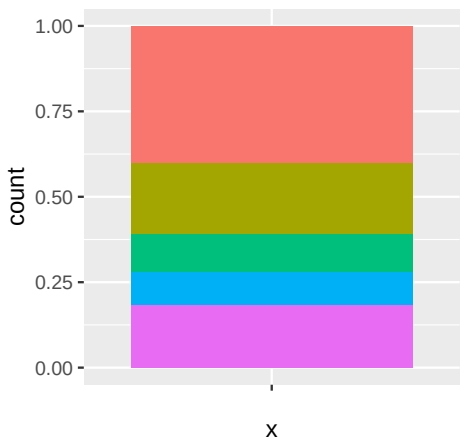
```
> # polar coordinates: x is now the angle in circle and y is distance from centre
> ggplot(data = east_asia,
+        mapping = aes(x = tfr, y = imr, colour = name, alpha = mid_period)) +
+   geom_point() +
+   geom_path() +
+   coord_polar() +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```

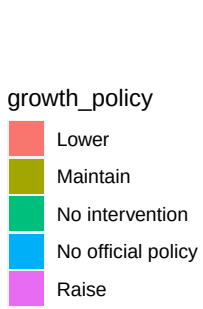


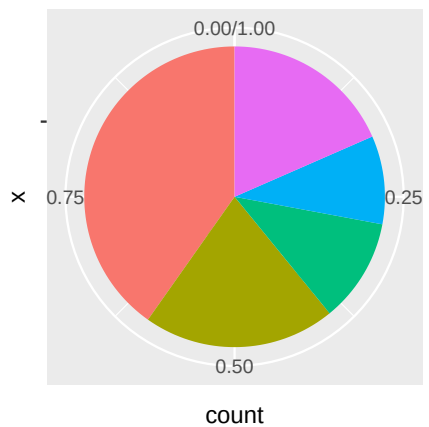
Pie Charts

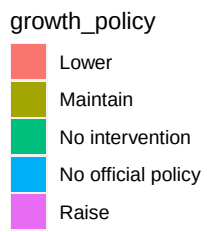
```
> ggplot(data = d, mapping = aes(x = growth_policy)) +
+   geom_bar()
>
> ggplot(data = d, mapping = aes(x = "", fill = growth_policy)) +
+   geom_bar(position = "fill")
>
> ggplot(data = d, mapping = aes(x = "", fill = growth_policy)) +
+   geom_bar(position = "fill") +
+   coord_polar(theta = "y")
```











Facets

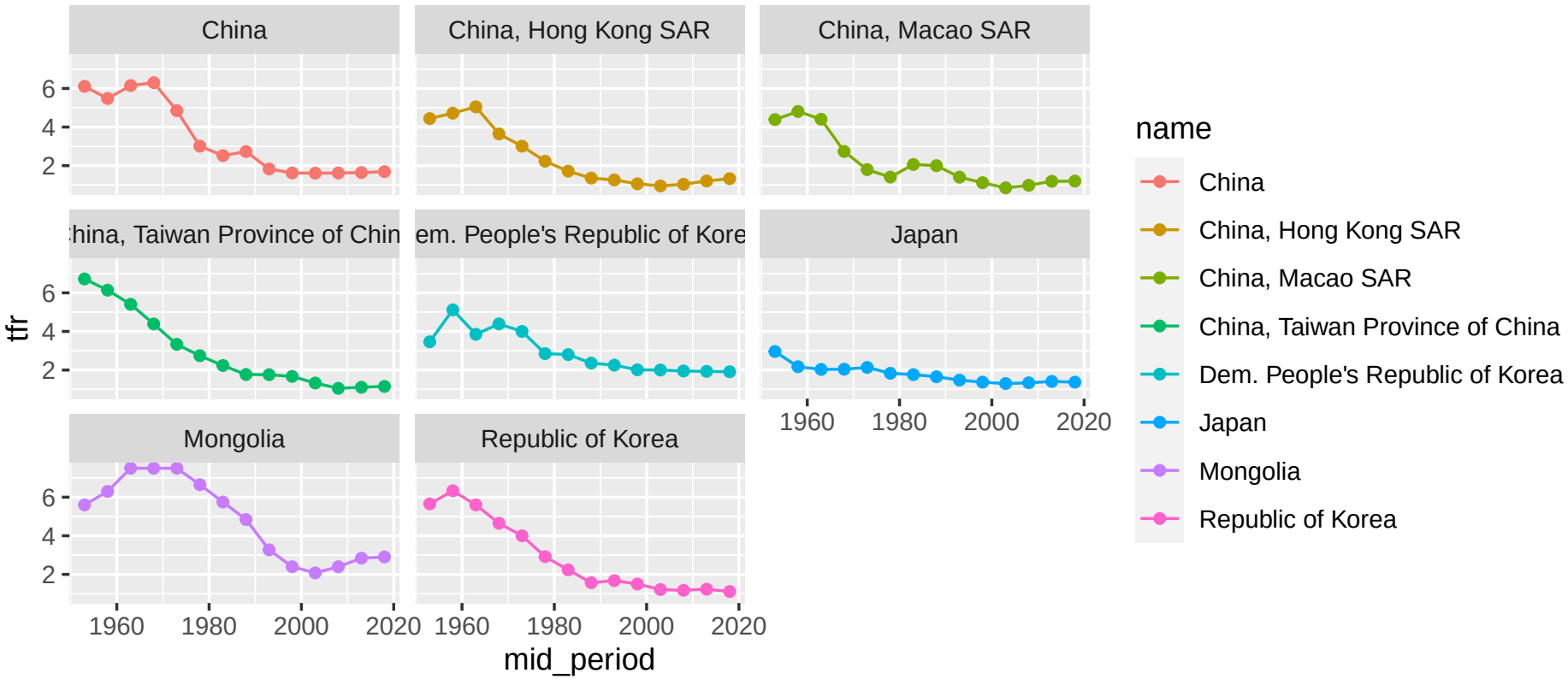
- Facets divide a plot into subplots based on the values of one or more discrete variables
  - Subplots can be a very effective way to compare across discrete (categorical) values
- Two functions:
  - `facet_wrap()` wraps a sequence of panels defined by a discrete variable(s) onto a page in roughly rectangular form.
  - `facet_grid()` forms a matrix of panels defined by row and column faceting variables. It is most useful when you have two discrete variables, and all combinations of the variables exist in the data.

Facets

- Define facet layouts using arguments depending on function
  - `facet_wrap()` use `facet = "a"` or `facet = vars(a)`
  - `facet_grid()` use `row = vars(a)`, `col = vars(b)`
- Other arguments are similar
  - `nrow, ncol`: Number of rows and columns.
  - `scales`: fixes or frees scales in facets
    - `"fixed"`: both scales fixed (default)
    - `"free"`: both scales free
    - `"free_x"` or `"free_y"`: scales free in one dimension.
  - `labeller`: adjust facet strip labels,
    - for example `labeller = label_wrap_gen(10)` to make sure each facet strip label is only a maximum 10 characters wide.

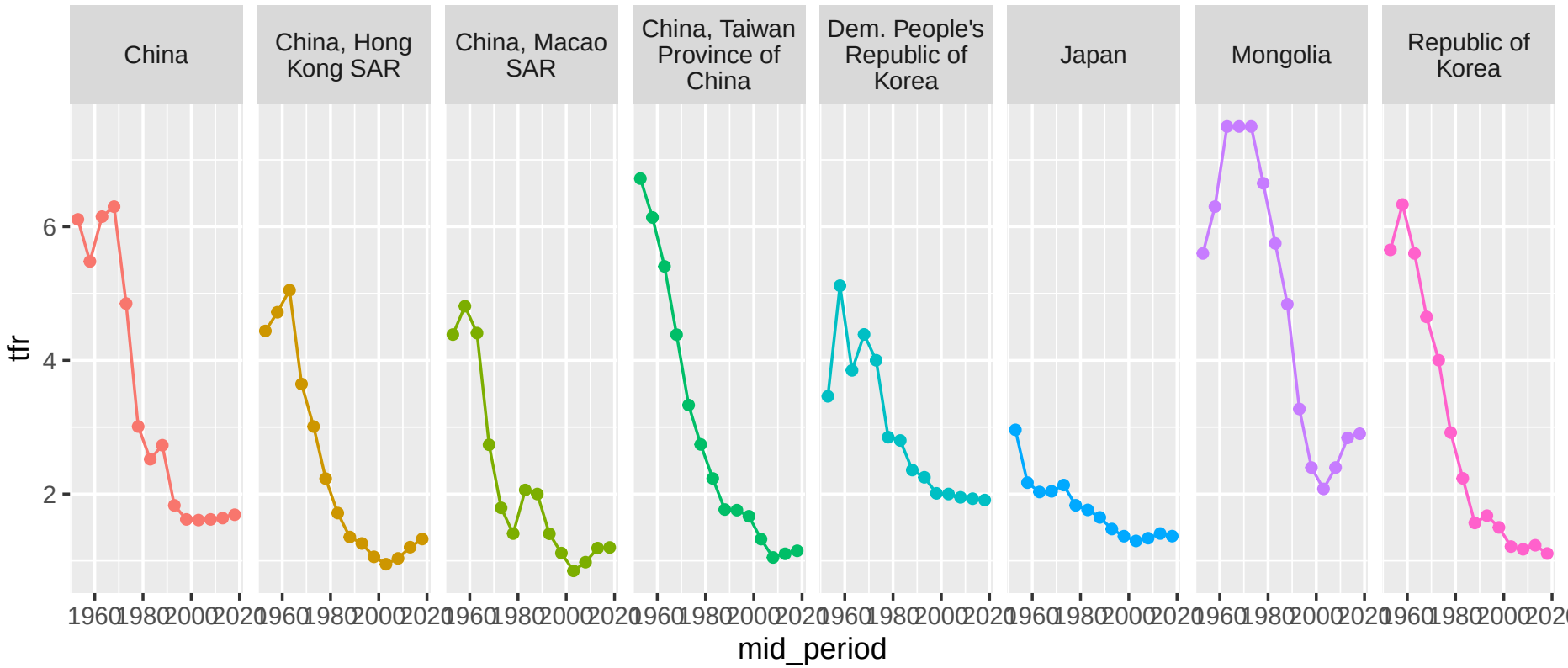
Facets

```
> # eastern asia: facet_wrap() function for each country (name)
> ggplot(data = east_asia, mapping = aes(x = mid_period, y = tfr, colour = name)) +
+   geom_point() +
+   geom_line() +
+   facet_wrap(facets = "name") +
+   # to fit legend on my slides
+   theme(legend.box = "horizontal")
```



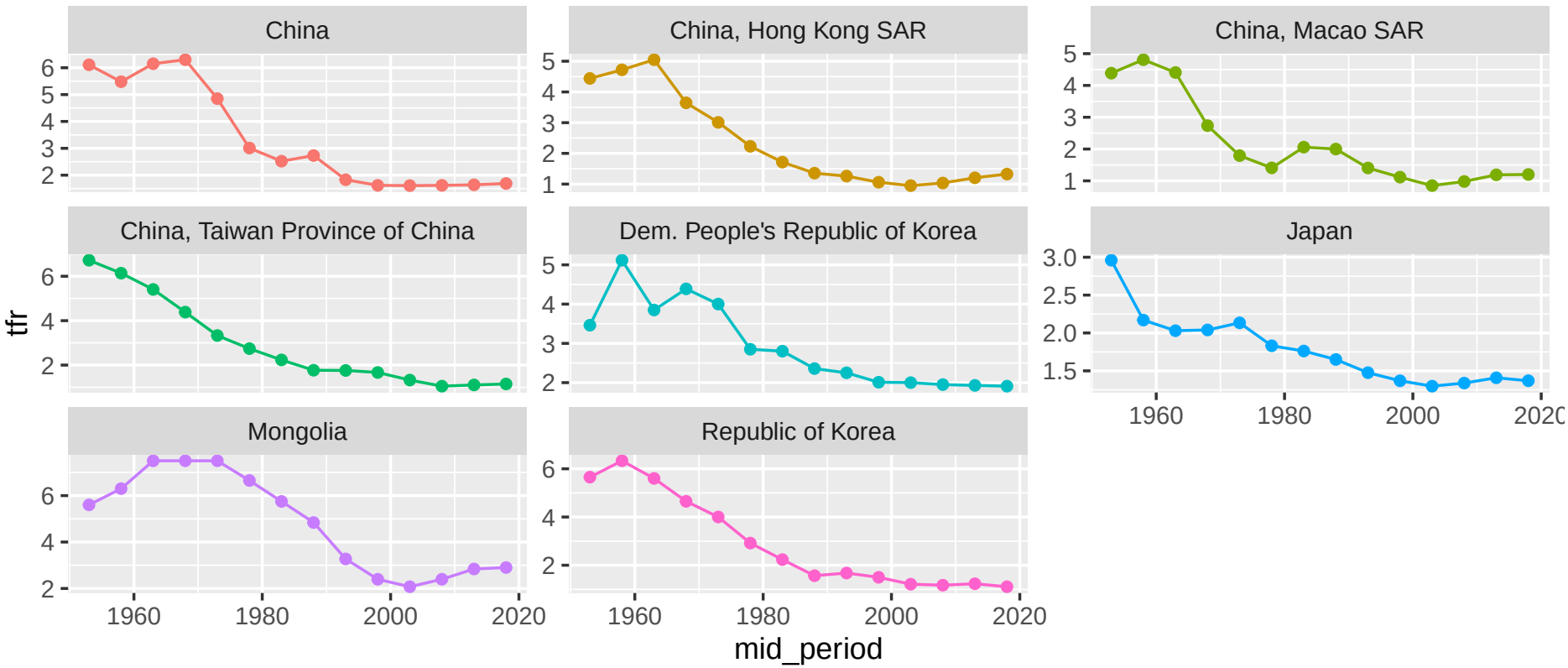
Facets

```
> # facet_wrap() function using one row and restrict label width
> ggplot(data = east_asia, mapping = aes(x = mid_period, y = tfr, colour = name)) +
+   geom_point() +
+   geom_line() +
+   facet_wrap(facets = vars(name), nrow = 1, labeller = label_wrap_gen(15)) +
+   # drop country name guide
+   guides(colour = FALSE)
```



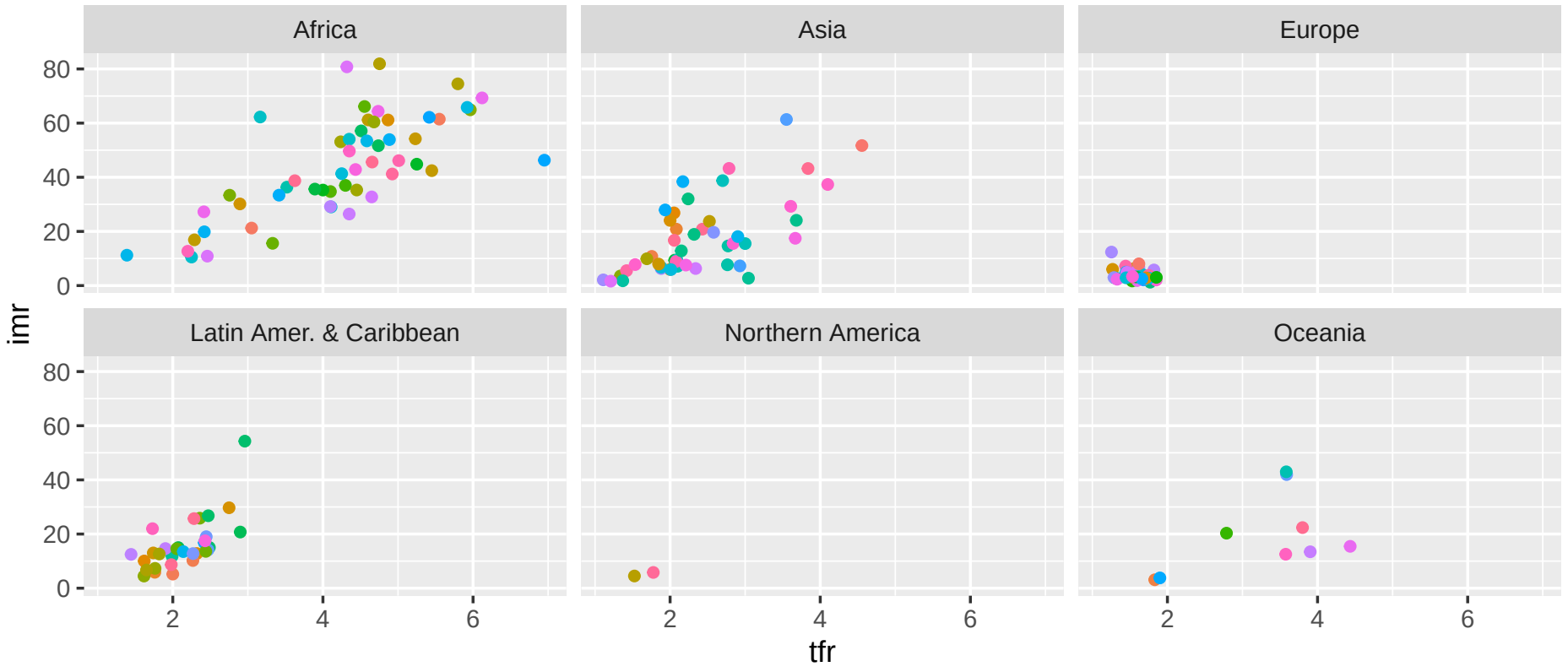
Facets

```
> # facet_wrap() function with different y axis limits
> ggplot(data = east_asia, mapping = aes(x = mid_period, y = tfr, colour = name)) +
+   geom_point() +
+   geom_line() +
+   facet_wrap(facets = vars(name), scales = "free_y") +
+   guides(colour = FALSE)
```



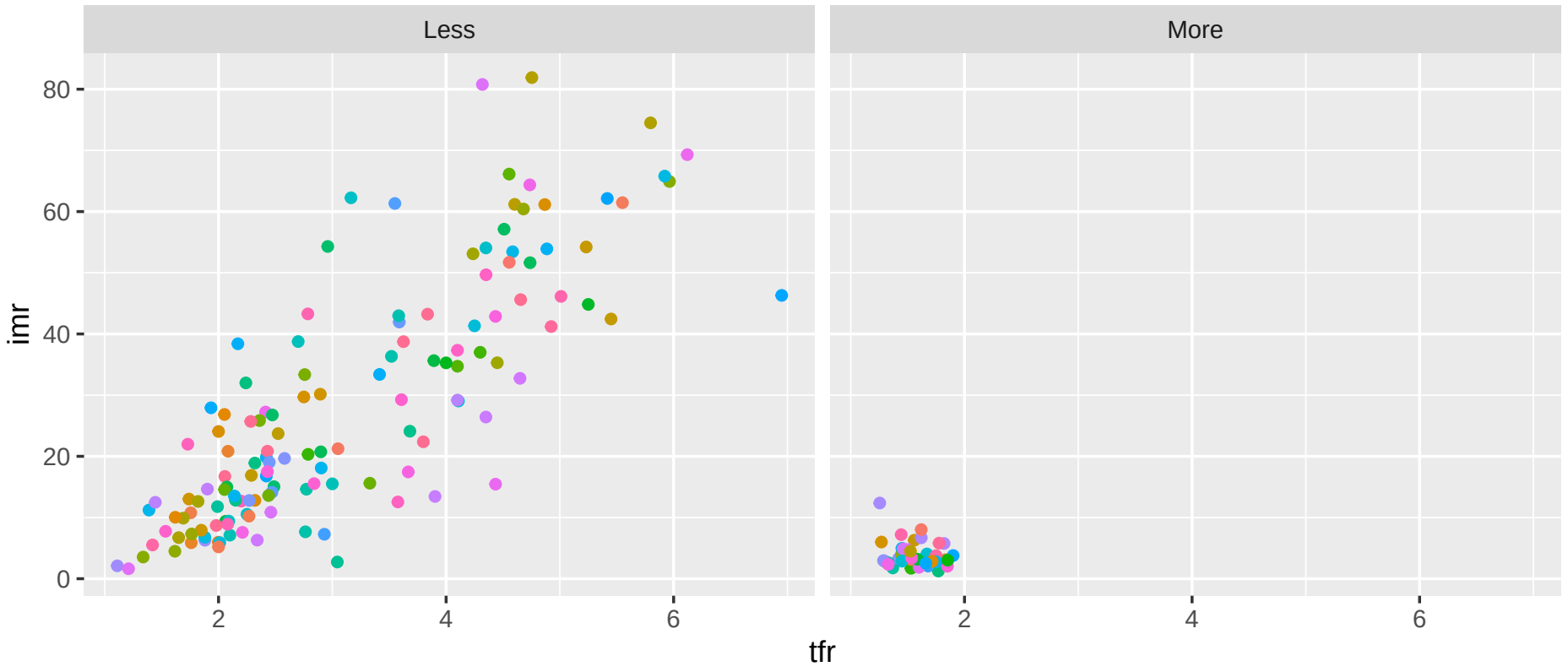
Facets

```
> # facet_wrap() function scatter plot
> ggplot(data = d,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_wrap(facets = vars(area_name)) +
+   guides(colour = FALSE)
```



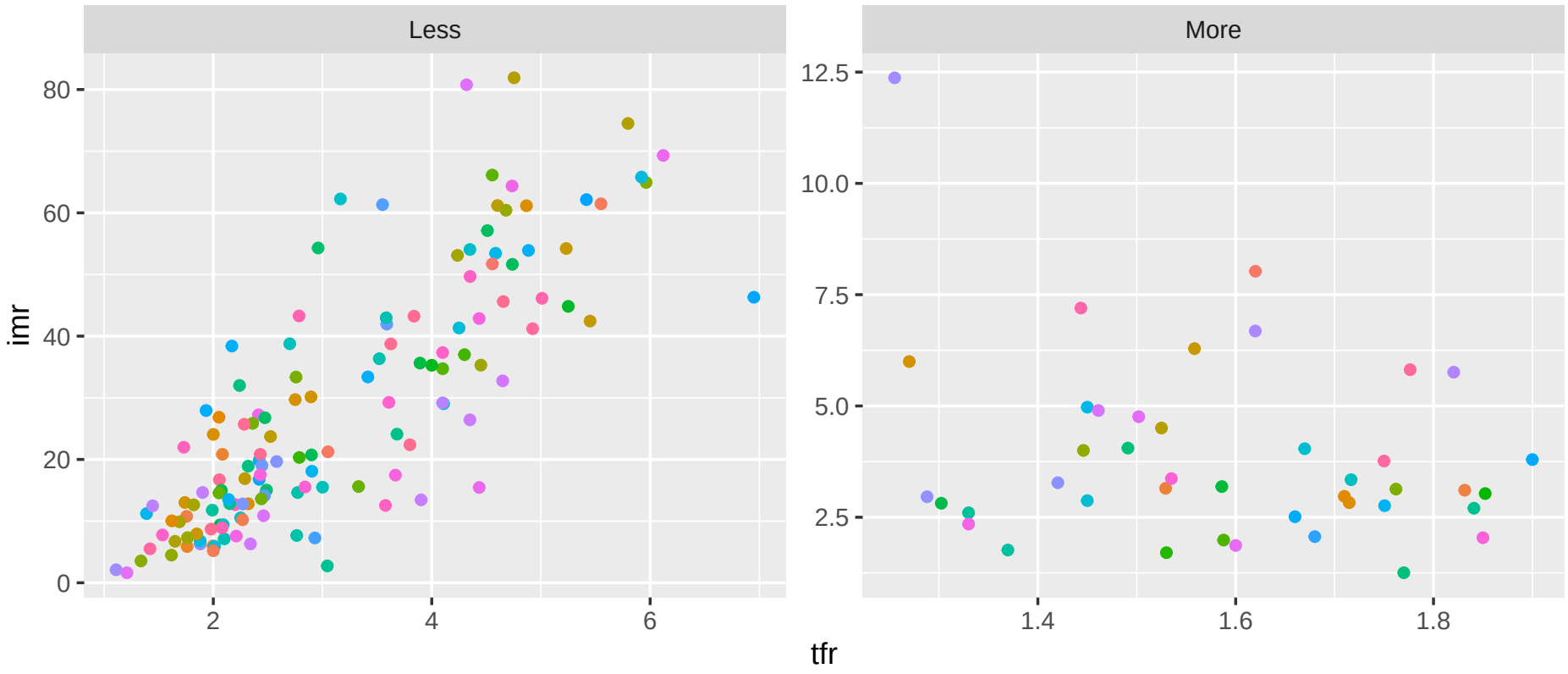
Facets

```
> # facet_wrap() function scatter plot using development level
> ggplot(data = d,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_wrap(facets = vars(developed)) +
+   guides(colour = FALSE)
```



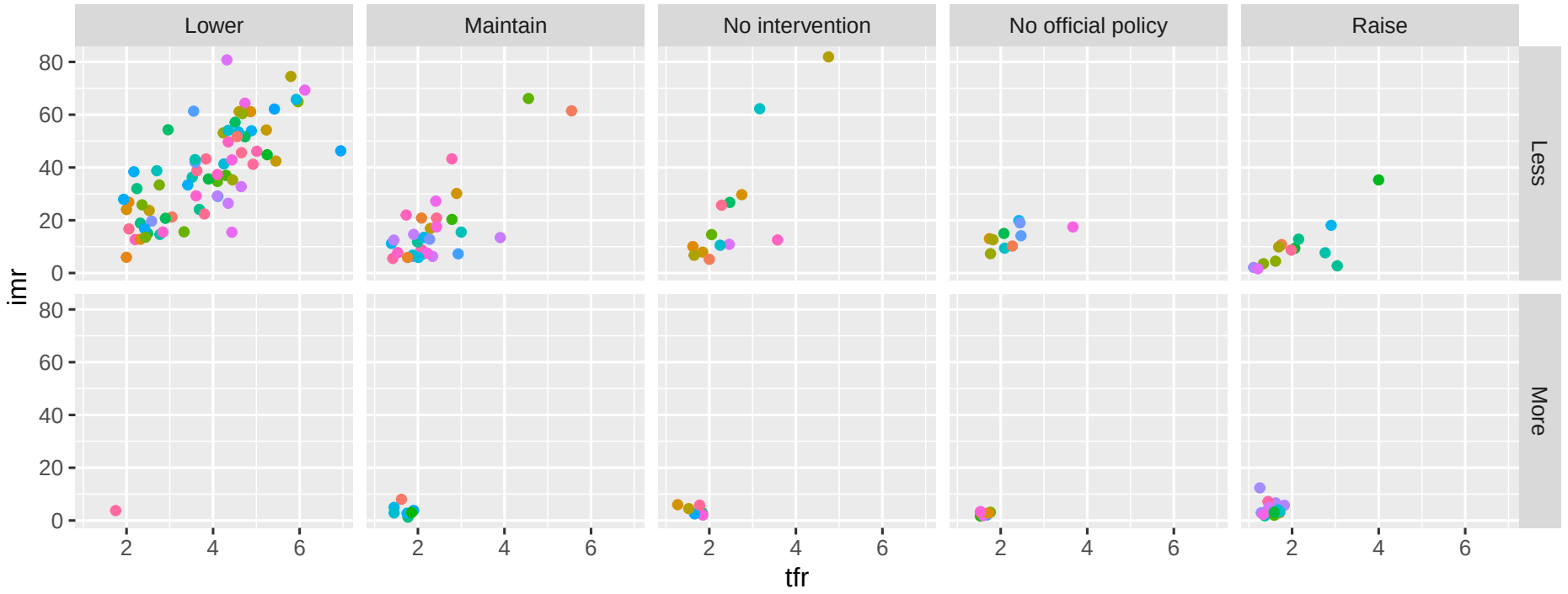
Facets

```
> # all data: facet_wrap() function scatter plot with x and y scales free
> ggplot(data = d,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_wrap(facets = "developed", scales = "free") +
+   guides(colour = FALSE)
```



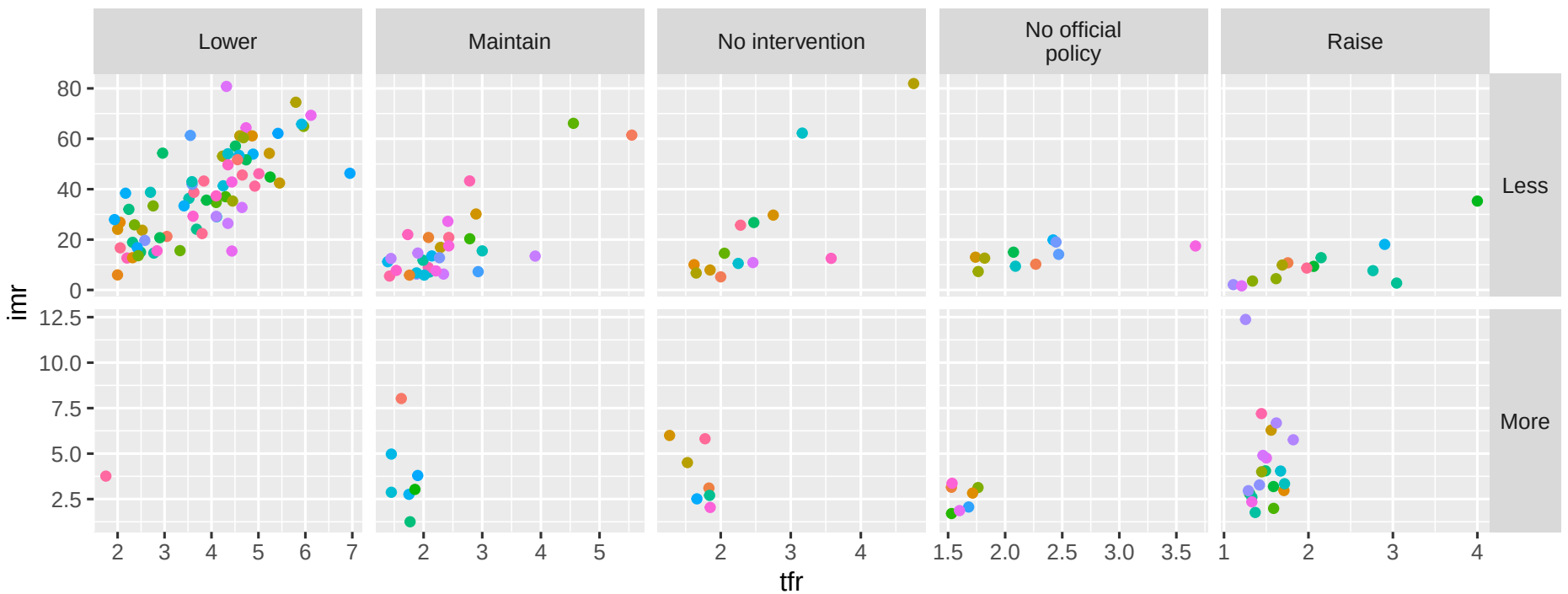
Facets

```
> # facet_grid() function scatter plot using development status and population growt
> ggplot(data = d,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   facet_grid(row = vars(developed), col = vars(growth_policy)) +
+   guides(colour = FALSE)
```



Facets

```
> # ... alter labels and free grid scales
> ggplot(data = d,
+        mapping = aes(x = tfr, y = imr, colour = name)) +
+   geom_point() +
+   # rotate growth policy labels to fit legend on my slides
+   facet_grid(row = vars(developed), col = vars(growth_policy),
+              scales = "free", labeller = label_wrap_gen(18)) +
+   guides(colour = FALSE) +
+   # rotate growth policy labels to fit legend on my slides
+   theme(strip.text.y = element_text(angle = 0))
```



Exercise 3 (ex23.R)

```
# 0.  a) Check your working directory is in the course folder. Load .Rproj file if n
getwd()
#     b) Load the tidyverse package (which loads the ggplot2 package amongst others)

#     c) Run the code in ex23_prelim.R to import the UN data for this exercise
source("./exercise/ex23_prelim.R")
##
##
##
# 1. Create a pie chart of the immigration policies in different countries from d




# 2. Adapt the code from the question above to create pie charts for the growth_poli
#    a. seperate facets for each area
#    b. no axis
#    (Hint: use theme_void() to drop axis)




# 3. Uncomment the solution to Question 1 of ex22 and then adapt so that the infant
#    transformed to the log10 scale
# ggplot(data = d, mapping = aes(x = imr, y = tfr, colour = area_name, size = pop/10
```

Scales

- The `scale` functions change aesthetics from their default.
- Each aesthetic has its own functions. Take a general form:
  - `scale_*_continuous()`: alter aesthetics based on continuous variables
  - `scale_*_discrete()`: alter aesthetics based on discrete variables
  - `scale_*_manual(values = c())`: map discrete values to manually chosen visual ones

Color and fill scales (Discrete)

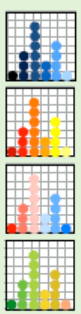
n <- d + geom_bar(aes(fill = fl))

n + **scale_fill_brewer**(palette = "Blues")
For palette choices: RColorBrewer::display.brewer.all()

n + **scale_fill_grey**(start = 0.2, end = 0.8, na.value = "red")

Color and fill scales (Continuous)

o <- c + geom_dotplot(aes(fill = ..x..))



o + **scale_fill_distiller**(palette = "Blues")

o + **scale_fill_gradient**(low="red", high="yellow")

o + **scale_fill_gradient2**(low="red", high="blue", mid = "white", midpoint = 25)

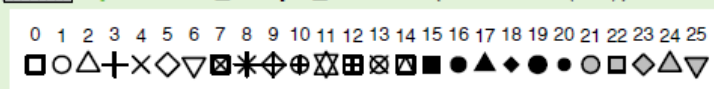
o + **scale_fill_gradientn**(colours=topo.colors(6))
Also: rainbow(), heat.colors(), terrain.colors(), cm.colors(), RColorBrewer::brewer.pal()

Shape and size scales

p <- e + geom_point(aes(shape = fl, size = cyl))

p + **scale_shape**() + **scale_size**()

p + **scale_shape_manual**(values = c(3:7))



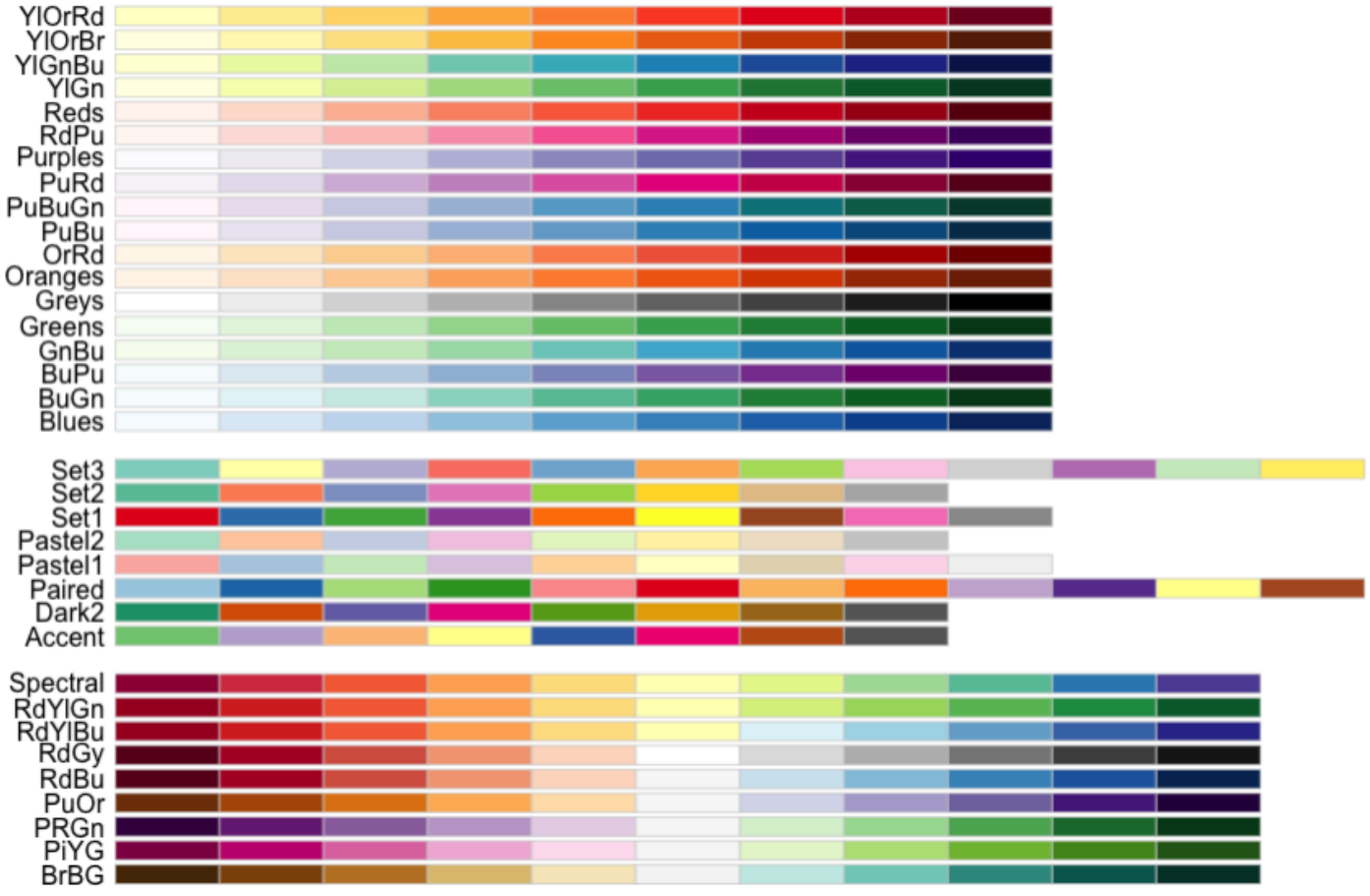
p + **scale_radius**(range = c(1,6))

p + **scale_size_area**(max_size = 6)

Maps to radius of circle, or area

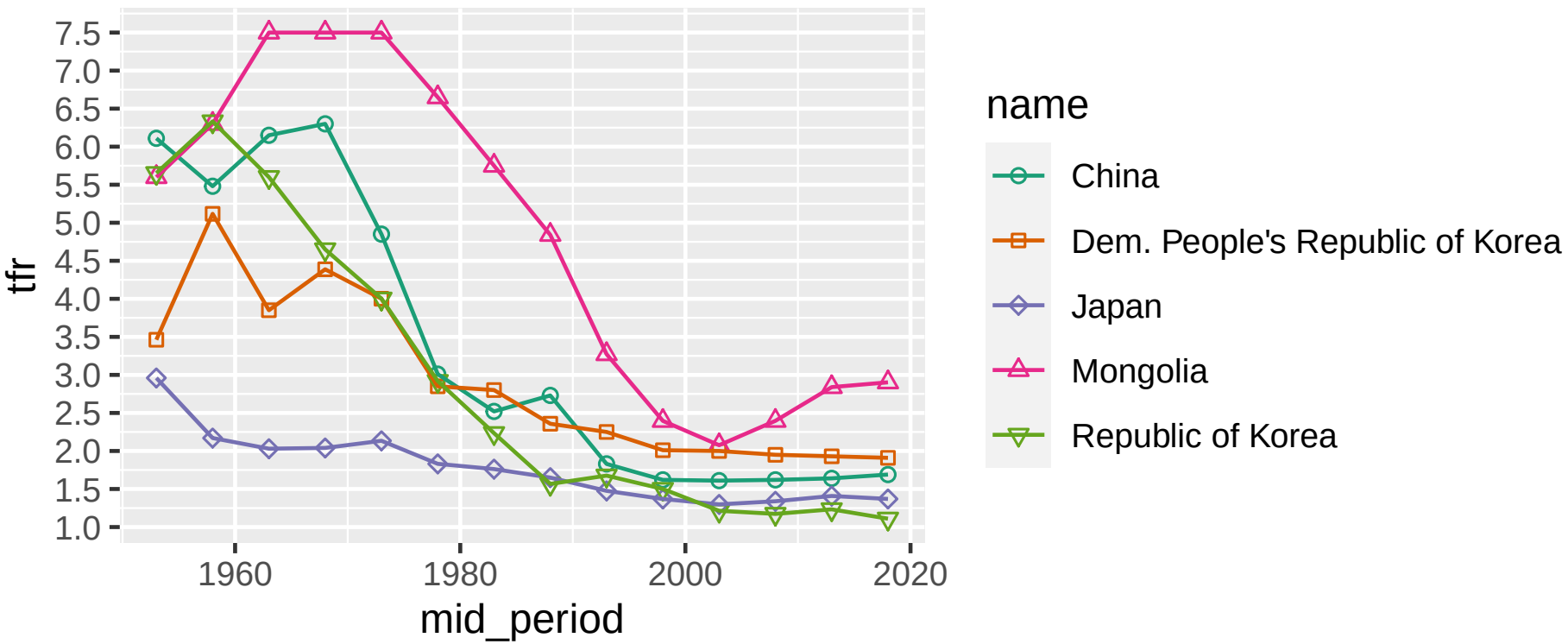
Scales

- Colour schemes from ColorBrewer that are loaded with `ggplot2`
  - `http://colorbrewer2.org`



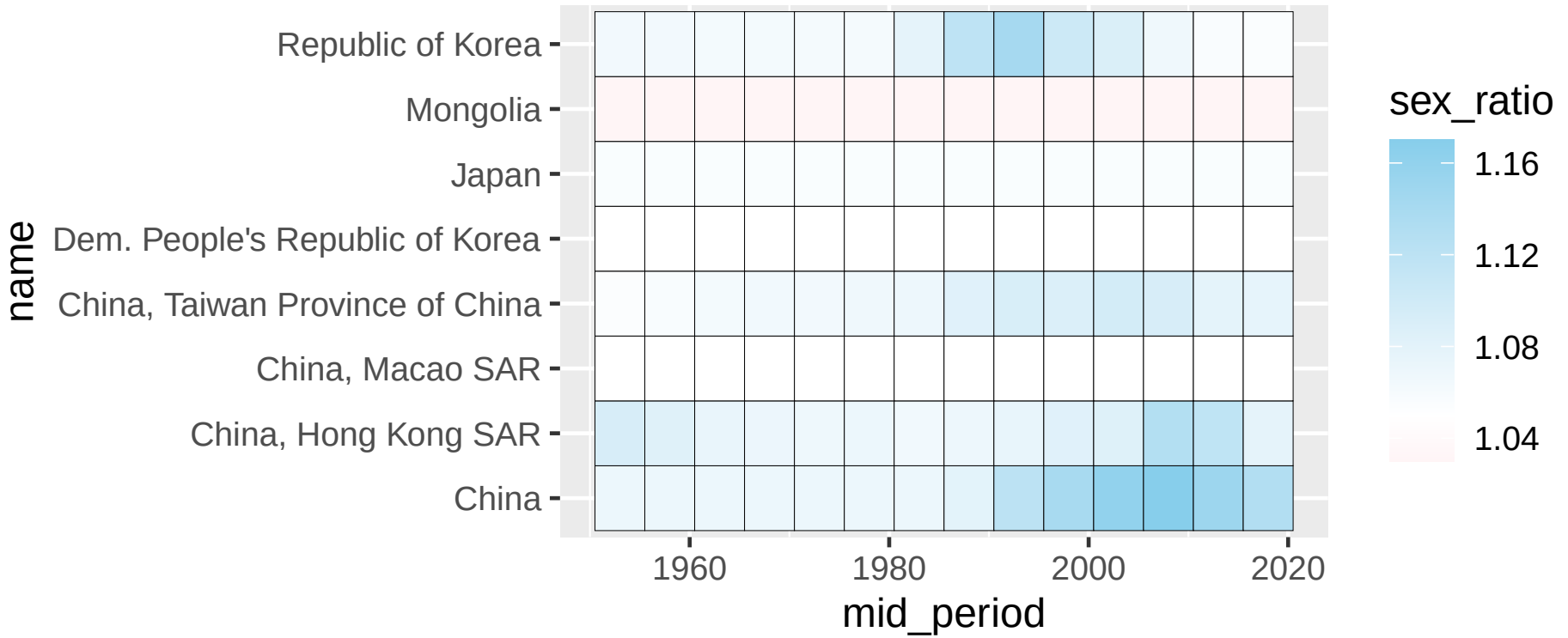
Scales

```
> # eastern asia without Hong Kong, Macau and Taiwan
> ggplot(data = east_asia %>%
+          filter(!str_detect(string = name, pattern = ",")),
+        mapping = aes(x = mid_period, y = tfr, colour = name, shape = name)) +
+   geom_point() +
+   geom_line() +
+   scale_color_brewer(palette = "Dark2") +
+   scale_shape_manual(values = 21:25) +
+   scale_y_continuous(breaks = seq(from = 1, to= 8, by = 0.5))
```



Scales

```
> ggplot(data = east_asia, mapping = aes(x = mid_period, y = name, fill = sex_ratio
+   geom_tile(colour = "black") +
+   scale_fill_gradient2(low="pink", high="skyblue", mid="white", midpoint=1.05)
```

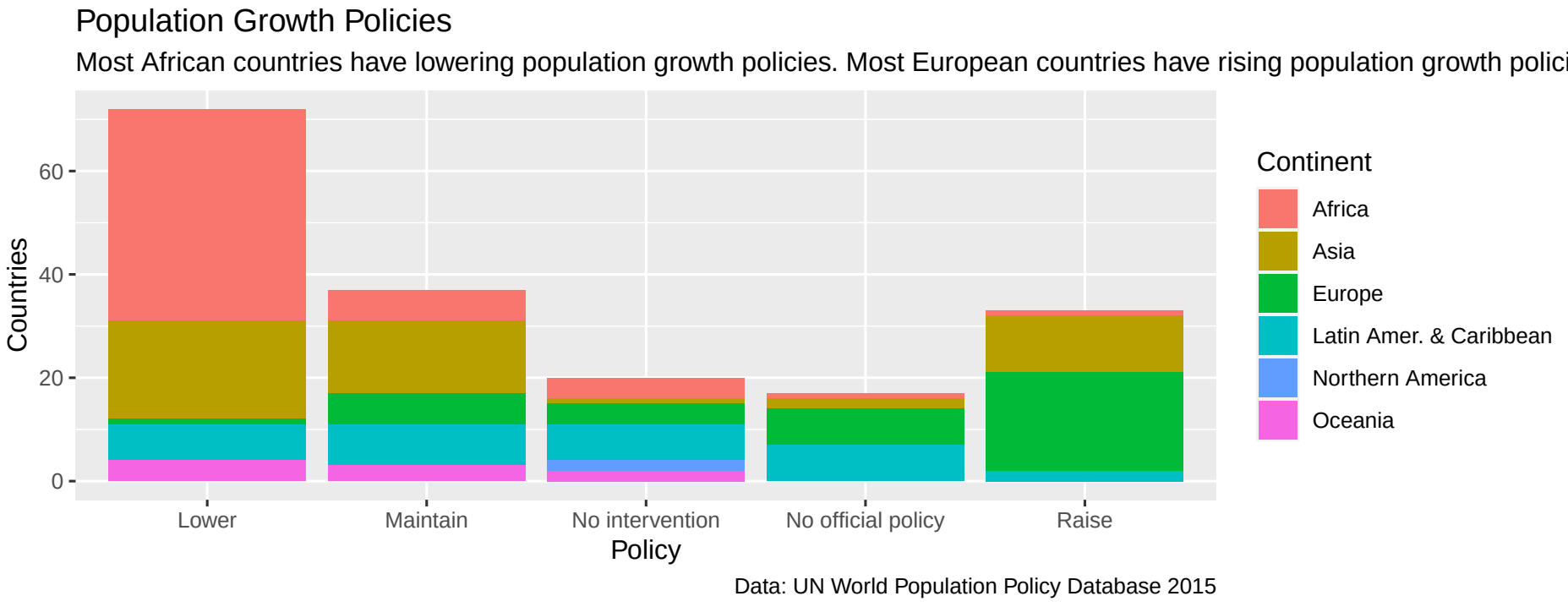


Labels

- Good labels are critical for making your plots accessible to a wider audience.
- The `labs()` function can add
  - `title`: main title
  - `subtitle`: highlight main message
  - `caption`: data source information
  - `x`, `y`, `fill`, `colour`, `alpha`, ... : full variable names for aesthetics

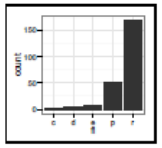
Labels

```
> # all countries 2010-15 data
> ggplot(data = d, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar() +
+   labs(title = "Population Growth Policies",
+        subtitle = "Most African countries have lowering population growth policie
+        caption = "Data: UN World Population Policy Database 2015",
+        x = "Policy", y = "Countries", fill = "Continent")
```



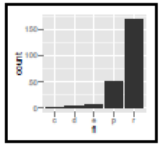
Themes

- The `theme` functions customize the "look" of plots
  - Changes how the plot looks without changing the information that the plot displays.
- There are eight theme functions in `ggplot2`
- The `ggthemes` package has many themes to match publication styles e.g. Economist or FiveThirtyEight



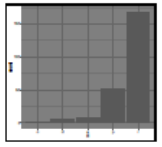
r + **theme_bw()**

White background with grid lines



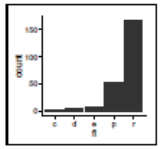
r + **theme_gray()**

Grey background (default theme)



r + **theme_dark()**

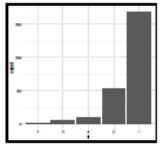
dark for contrast



r + **theme_classic()**

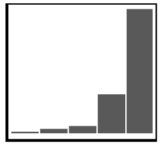
r + **theme_light()**

r + **theme_linedraw()**



r + **theme_minimal()**

Minimal themes

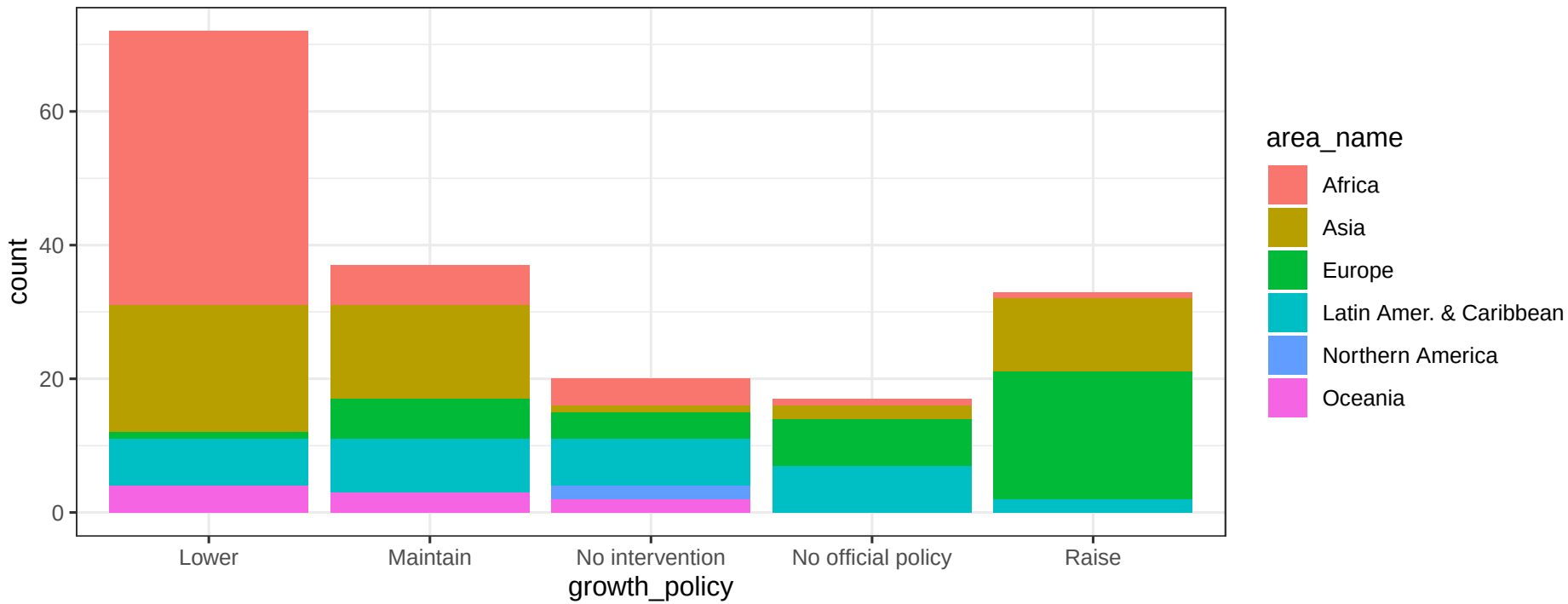


r + **theme_void()**

Empty theme

Themes

```
> # change theme
> ggplot(data = d, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar() +
+   theme_bw()
```



Saving

- Can assign a plot to an R object
  - Can then keep adding to the plot with the +

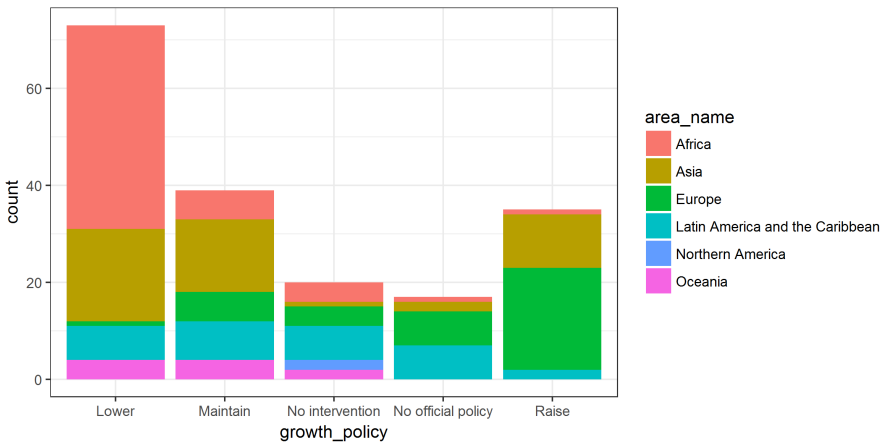
```
> # save a plot to an object
> g <- ggplot(data = d, mapping = aes(x = growth_policy, fill = area_name)) +
+   geom_bar()
> # plot g with the black and white theme
> g + theme_bw()
```

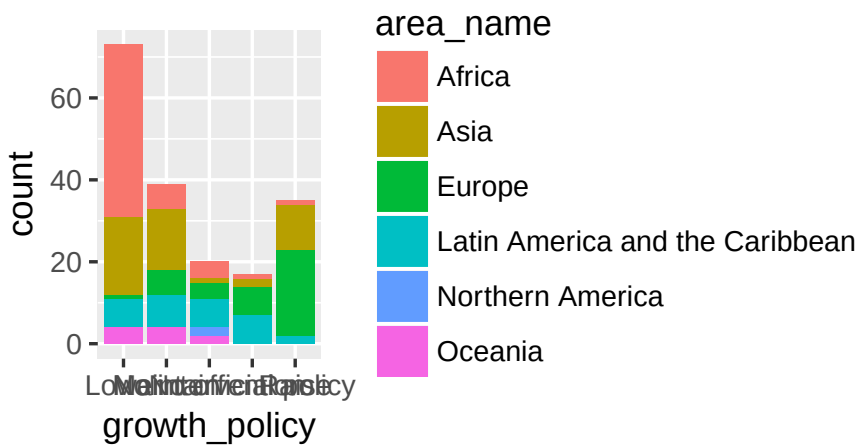
- The ggsave() function to save plot from
  - filename: matches file type to file extension, e.g. filename = myplot.pdf will create a PDF. If no path is given in the file name, the file will appear in the current working directory (getwd()).
  - width, height, units: plot size, uses RStudio window size by default
  - scale: scales the size of the plots objects

```
> # saves the last plot from RStudio as a PNG
> ggsave(filename = "myplot.png", width = 10, height = 5, unit = "cm", scale = 2)
> # saves the plot from object g as a PDF
> ggsave(filename = "myplot.pdf", width = 10, height = 5, unit = "cm", plot = g)
```

Scale

- Scale alters the point size:
  - Left: PNG with scale = 2
  - Right: PDF with scale = 1 (default)





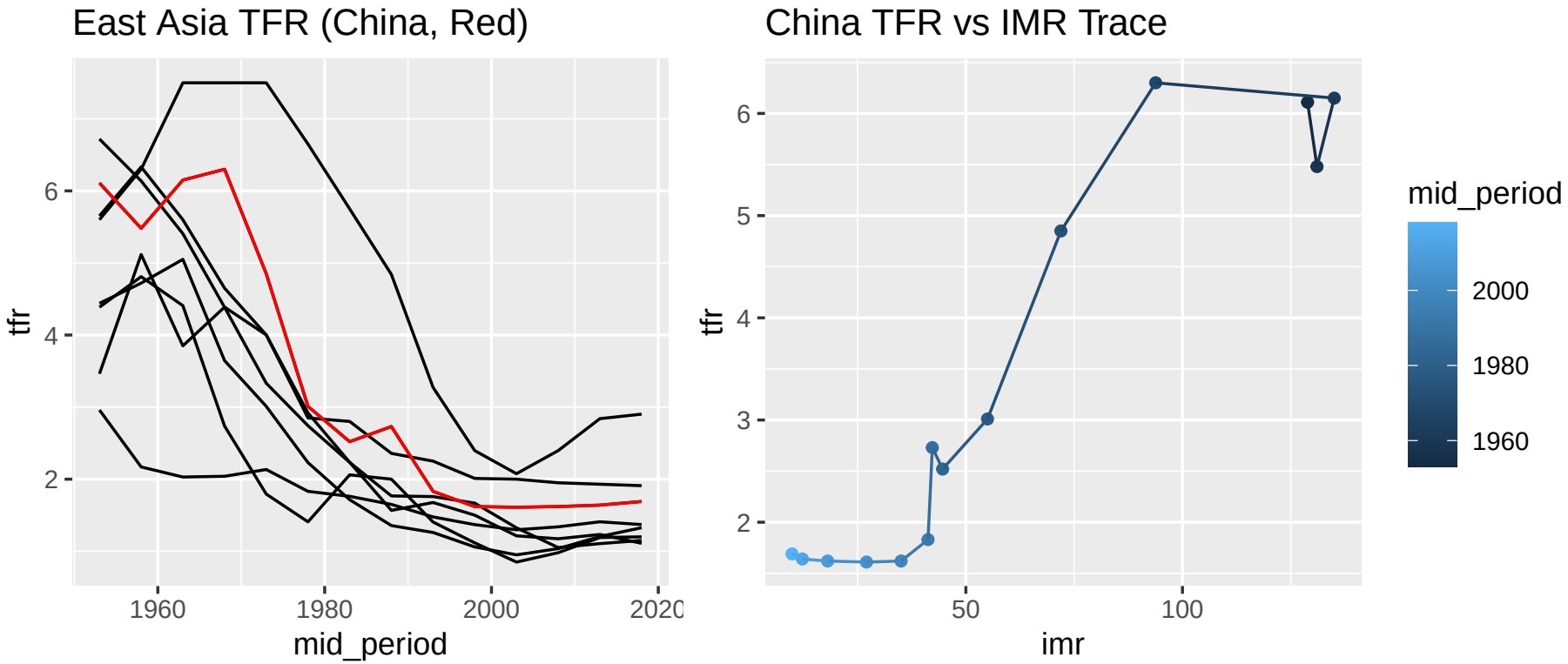
Combining Plots

- Use the `patchwork` package to combine plots
- Simple syntax to arrange plots
  - `+` to place side by side
  - `/` to place on top of each other
  - `()` to combine plots on a row
  - `plot_layout(widths = c(2, 1))` to control layout options

```
> g1 <- ggplot(data = east_asia,
+              mapping = aes(x = mid_period, y = tfr, group = name)) +
+   geom_line() +
+   geom_line(data = china, colour = "red") +
+   labs(title = "East Asia TFR (China, Red)")
> g2 <- ggplot(data = china,
+              mapping = aes(x = imr, y = tfr, colour = mid_period)) +
+   geom_point() +
+   geom_path() +
+   labs(title = "China TFR vs IMR Trace")
```

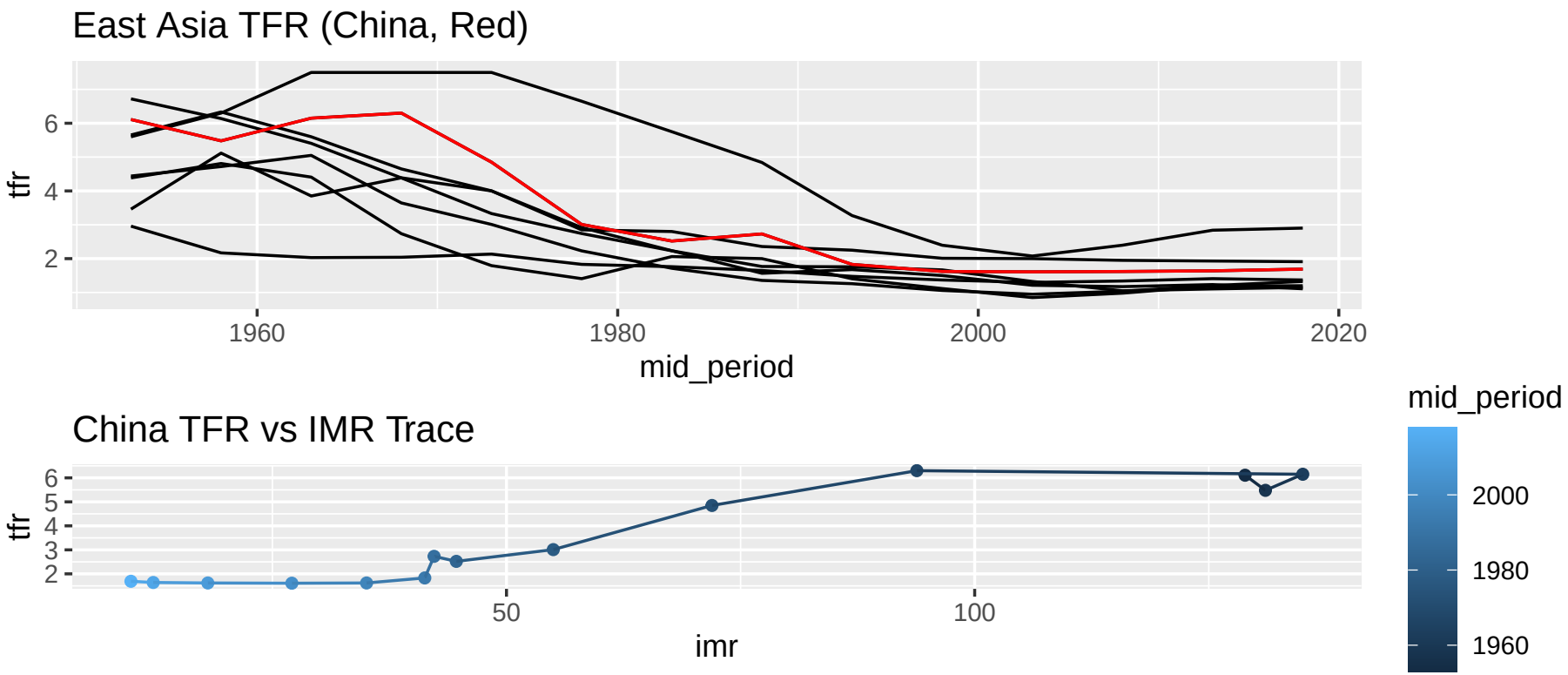
Combining Plots

```
> library(patchwork)
> g1 + g2
```



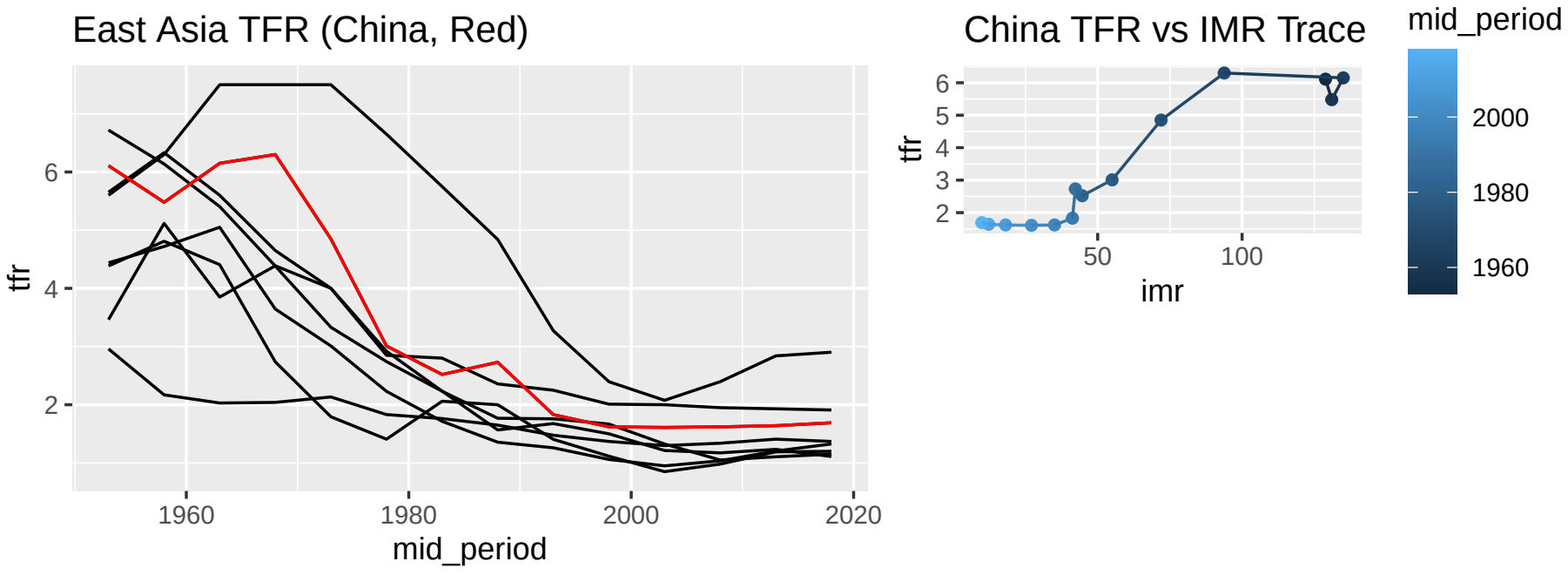
Combining Plots

```
> g1 / g2 + plot_layout(heights = c(2, 1))
```



Combining Plots

```
> layout <- "
+ AAB
+ AA#
+ "
> g1 + g2 + plot_layout(design = layout)
```



RStudio Cheatsheet

Data Visualization with ggplot2 : : CHEAT SHEET

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.

required

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

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.

aesthetic mappings | data | geom

qplot(x = cty, y = hwy, data = mpg, geom = "point**")** Creates a complete plot with given data, geom, and mappings. Supplies many useful defaults.

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.

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()
(Useful for expanding limits)

b + geom_curve(aes(yend = lat + 1, xend=long+1,curvature=z)**)** - 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(group = group)**)**
x, y, alpha, color, fill, group, 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

continuous x , continuous y

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

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

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

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, check_overlap = TRUE**)**, x, y, label, alpha, angle, color, family, fontface, hjust, lineheight, size, vjust

discrete x , continuous y

```
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

discrete x , discrete y

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

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

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_density2d()
x, y, alpha, colour, group, linetype, size

h + geom_hex()
x, y, alpha, colour, 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

```
data <- data.frame(murder = USArrests$Murder,
state = tolower(rownames(USArrests)))
map <- map_data("state")
k <- ggplot(data, aes(fill = murder))
```

k + geom_map(aes(map_id = state), map = map**)**
+ expand_limits(x = map$long, y = map$lat**)**,
map_id, alpha, color, fill, linetype, 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, colour, group, linetype, size, weight

l + geom_raster(aes(fill = z), hjust=0.5, vjust=0.5, interpolate=FALSE**)**
x, y, alpha, fill

l + geom_tile(aes(fill = z)**)**, x, y, alpha, color, fill, linetype, size, width

RStudio Cheatsheet

Stats An alternative way to build a layer

A stat builds new variables to plot (e.g., count, prop).

Visualize a stat by changing the default stat of a geom function, **geom_bar(stat="count")** or by using a stat function, **stat_count(geom="bar")**, which calls a default geom to make a layer (equivalent to a geom function). Use **..name..** syntax to map stat variables to aesthetics.

geom to use | stat function | geommappings

i + stat_density2d(aes(fill = ..level..), geom = "polygon")

variable created by stat

c + stat_bin(binwidth = 1, origin = 10)
x, y | ..count.., ..ncount.., ..density.., ..ndensity..

c + stat_count(width = 1) **x, y,** | ..count.., ..prop..

c + stat_density(adjust = 1, kernel = "gaussian")
x, y, | ..count.., ..density.., ..scaled..

e + stat_bin_2d(bins = 30, drop = T)
x, y, fill | ..count.., ..density..

e + stat_bin_hex(bins=30) **x, y, fill** | ..count.., ..density..

e + stat_density_2d(contour = TRUE, n = 100)
x, y, color, size | ..level..

e + stat_ellipse(level = 0.95, segments = 51, type = "t")

l + stat_contour(aes(z = z)) **x, y, z, order** | ..level..

l + stat_summary_hex(aes(z = z), bins = 30, fun = max)
x, y, z, fill | ..value..

l + stat_summary_2d(aes(z = z), bins = 30, fun = mean)
x, y, z, fill | ..value..

f + stat_boxplot(coef = 1.5) **x, y** | ..lower.., ..middle.., ..upper.., ..width.. , ..ymin.., ..ymax..

f + stat_ydensity(kernel = "gaussian", scale = "area") **x, y** | ..density.., ..scaled.., ..count.., ..n.., ..violinwidth.., ..width..

e + stat_ecdf(n = 40) **x, y** | ..x.., ..y..

e + stat_quantile(quantiles = c(0.1, 0.9), formula = y ~ log(x), method = "rq") **x, y** | ..quantile..

e + stat_smooth(method = "lm", formula = y ~ x, se=T, level=0.95) **x, y** | ..se.., ..x.., ..y.., ..ymin.., ..ymax..

ggplot() + stat_function(aes(x = -3:3), n = 99, fun = dnorm, args = list(sd=0.5)) **x** | ..x.., ..y..

e + stat_identity(na.rm = TRUE)

ggplot() + stat_qq(aes(sample=1:100), dist = qt, dparam=list(df=5)) **sample, x, y** | ..sample.., ..theoretical..

e + stat_sum() **x, y, size** | ..n.., ..prop..

e + stat_summary(fun.data = "mean_cl_boot")

h + stat_summary_bin(fun.y = "mean", geom = "bar")

e + stat_unique()

Scales

Scales map data values to the visual values of an aesthetic. To change a mapping, add a new scale.

(n <- d + geom_bar(aes(fill = fl)))

scale_ | aesthetic to adjust | prepackaged scale to use | scale-specific arguments

n + scale_fill_manual(
values = c("skyblue", "royalblue", "blue", "navy"),
limits = c("d", "e", "p", "r"), breaks =c("d", "e", "p", "r"),
name = "fuel", labels = c("D", "E", "P", "R"))

range of values to include in mapping | title to use in legend/axis | labels to use in legend/axis | breaks to use in legend/axis

GENERAL PURPOSE SCALES

Use with most aesthetics

scale_*_continuous() - map cont' values to visual ones
scale_*_discrete() - map discrete values to visual ones
scale_*_identity() - use data values **as** visual ones
scale_*_manual(values = c()) - map discrete values to manually chosen visual ones
scale_*_date(date_labels = "%m/%d"), date_breaks = "2 weeks") - treat data values as dates.
scale_*_datetime() - treat data x values as date times. Use same arguments as scale_x_date(). See ?strptime for label formats.

X & Y LOCATION SCALES

Use with x or y aesthetics (x shown here)

scale_x_log10() - Plot x on log10 scale
scale_x_reverse() - Reverse direction of x axis
scale_x_sqrt() - Plot x on square root scale

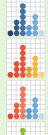
COLOR AND FILL SCALES (DISCRETE)

n <- d + geom_bar(aes(fill = fl))

n + scale_fill_brewer(palette = "Blues")
For palette choices:
RColorBrewer::display.brewer.all()

n + scale_fill_grey(start = 0.2, end = 0.8, na.value = "red")

COLOR AND FILL SCALES (CONTINUOUS)



o <- c + geom_dotplot(aes(fill = ..x..))

o + scale_fill_distiller(palette = "Blues")

o + scale_fill_gradient(low="red", high="yellow")

o + scale_fill_gradient2(low="red", high="blue", mid = "white", midpoint = 25)

o + scale_fill_gradientn(colours=topo.colors(6))
Also: rainbow(), heat.colors(), terrain.colors(), cm.colors(), RColorBrewer::brewer.pal()

SHAPE AND SIZE SCALES

p <- e + geom_point(aes(shape = fl, size = cyl))
p + scale_shape() + scale_size()
p + scale_shape_manual(values = c(3:7))

p + scale_radius(range = c(1,6))
p + scale_size_area(max_size = 6)

Coordinate Systems

r <- d + geom_bar()

r + coord_cartesian(xlim = c(0, 5))
xlim, ylim
The default cartesian coordinate system

r + coord_fixed(ratio = 1/2)
ratio, xlim, ylim
Cartesian coordinates with fixed aspect ratio between x and y units

r + coord_flip()
xlim, ylim
Flipped Cartesian coordinates

r + coord_polar(theta = "x", direction=1)
theta, start, direction
Polar coordinates

r + coord_trans(ytrans = "sqrt")
xtrans, ytrans, limx, limy
Transformed cartesian coordinates. Set xtrans and ytrans to the name of a window function.

π + coord_quickmap()
π + coord_map(projection = "ortho", orientation=c(41, -74, 0))projection, orienztation, xlim, ylim
Map projections from the mapproj package (mercator (default), azequalarea, lagrange, etc.)

Position Adjustments

Position adjustments determine how to arrange geoms that would otherwise occupy the same space.

s <- ggplot(mpg, aes(fl, fill = drv))

s + geom_bar(position = "dodge")
Arrange elements side by side

s + geom_bar(position = "fill")
Stack elements on top of one another, normalize height

e + geom_point(position = "jitter")
Add random noise to X and Y position of each element to avoid overplotting

e + geom_label(position = "nudge")
Nudge labels away from points

s + geom_bar(position = "stack")
Stack elements on top of one another

Each position adjustment can be recast as a function with manual **width** and **height** arguments
s + geom_bar(position = position_dodge(width = 1))

Themes

r + theme_bw()
White background with grid lines

r + theme_gray()
Grey background (default theme)

r + theme_dark()
dark for contrast

r + theme_classic()
r + theme_light()
r + theme_linedraw()
r + theme_minimal()
Minimal themes
r + theme_void()
Empty theme

Faceting

Facets divide a plot into subplots based on the values of one or more discrete variables.

t <- ggplot(mpg, aes(cty, hwy)) + geom_point()

t + facet_grid(cols = vars(fl))
facet into columns based on fl

t + facet_grid(rows = vars(year))
facet into rows based on year

t + facet_grid(rows = vars(year), cols = vars(fl))
facet into both rows and columns

t + facet_wrap(vars(fl))
wrap facets into a rectangular layout

Set **scales** to let axis limits vary across facets

t + facet_grid(rows = vars(drv), cols = vars(fl), scales = "free")
x and y axis limits adjust to individual facets
"free_x" - x axis limits adjust
"free_y" - y axis limits adjust

Set **labeller** to adjust facet labels

t + facet_grid(cols = vars(fl), labeller = label_both)

fl: c	fl: d	fl: e	fl: p	fl: r

t + facet_grid(rows = vars(fl), labeller = label_bquote(alpha ^ .(fl)))

α^c	α^d	α^e	α^p	α^r

Labels

t + labs(x = "New x axis label", **y** = "New y axis label", **title** ="Add a title above the plot", **subtitle** = "Add a subtitle below title", **caption** = "Add a caption below plot", <AES> = "New <AES> legend title")

Use scale functions to update legend labels

t + annotate(geom = "text", x = 8, y = 9, label = "A")

geom to place | manual values for geom's aesthetics

Legends

n + theme(legend.position = "bottom")
Place legend at "bottom", "top", "left", or "right"

n + guides(fill = "none")
Set legend type for each aesthetic: colorbar, legend, or none (no legend)

n + scale_fill_discrete(name = "Title", labels = c("A", "B", "C", "D", "E"))
Set legend title and labels with a scale function.

Zooming

Without clipping (preferred)

t + coord_cartesian(
xlim = c(0, 100), ylim = c(10, 20))

With clipping (removes unseen data points)

t + xlim(0, 100) **+ ylim**(10, 20)

t + scale_x_continuous(limits = c(0, 100)) **+ scale_y_continuous**(limits = c(0, 100))

Exercise 4 (ex24.R)

```
# 0.  a) Check your working directory is in the course folder. Load the .Rproj file
getwd()
#     b) Load the tidyverse package (which loads the ggplot2 package amongst others)
library(#####)
#     c) Run the code in ex24_prelim.R to import the UN data for this exercise
source("./exercise/ex24_prelim.R")
##
##
##
# 1. Uncomment the code below (from ex23.R) and adapt to
#    a. change the colour of the points to come from the "Set1" palette
#    b. add more breaks in the size legend
#    (Hint: use scale_size_continuous() with breaks argument set to a vector of
#    typical population values such as c(50, 250, 500, 1000) )
#    c. x-axis label: "Infant Mortality Rate"
#    d. y-axis label: "Total Fertility Rate"
#    e. colour label: "Continent"
#    f. size label: "Population (m)"
# ggplot(data = d, mapping = aes(x = imr, y = tfr, colour = area_name, size = pop/10
#   geom_point() +
#   coord_trans(x = "log10")
```