Project 7: Difference-in-Differences and Synthetic Control

```r
# Install and load packages
if (!require("pacman")) install.packages("pacman")
```

```
## Loading required package: pacman
```

```r
devtools::install_github("ebenmichael/augsynth")
```

```
## Skipping install of 'augsynth' from a github remote, the SHA1 (0f4f1bcc) has not changed since last i
##   Use `force = TRUE` to force installation
```

```r
pacman::p_load(# Tidyverse packages including dplyr and ggplot2
               tidyverse,
               ggthemes,
               augsynth,
               gsynth)

# set seed
set.seed(44)

# load data
medicaid_expansion <- read_csv('./data/medicaid_expansion.csv')
```

```
## Rows: 663 Columns: 5
```

```
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (1): State
## dbl  (3): year, uninsured_rate, population
## date (1): Date_Adopted
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Introduction

For this project, you will explore the question of whether the Affordable Care Act increased health insurance coverage (or conversely, decreased the number of people who are uninsured). The ACA was passed in March 2010, but several of its provisions were phased in over a few years. The ACA instituted the "individual mandate" which required that all Americans must carry health insurance, or else suffer a tax penalty. There are four mechanisms for how the ACA aims to reduce the uninsured population:

- Require companies with more than 50 employees to provide health insurance.
- Build state-run healthcare markets ("exchanges") for individuals to purchase health insurance.
- Provide subsidies to middle income individuals and families who do not qualify for employer based coverage.
- Expand Medicaid to require that states grant eligibility to all citizens and legal residents earning up to 138% of the federal poverty line. The federal government would initially pay 100% of the costs of this expansion, and over a period of 5 years the burden would shift so the federal government would pay 90% and the states would pay 10%.

In 2012, the Supreme Court heard the landmark case NFIB v. Sebelius, which principally challenged the constitutionality of the law under the theory that Congress could not institute an individual mandate. The Supreme Court ultimately upheld the individual mandate under Congress's taxation power, but struck down the requirement that states must expand Medicaid as impermissible subordination of the states to the federal government. Subsequently, several states refused to expand Medicaid when the program began on January 1, 2014. This refusal created the "Medicaid coverage gap" where there are indivudals who earn too much to qualify for Medicaid under the old standards, but too little to qualify for the ACA subsidies targeted at middle-income individuals.

States that refused to expand Medicaid principally cited the cost as the primary factor. Critics pointed out however, that the decision not to expand primarily broke down along partisan lines. In the years since the initial expansion, several states have opted into the program, either because of a change in the governing party, or because voters directly approved expansion via a ballot initiative.

You will explore the question of whether Medicaid expansion reduced the uninsured population in the U.S. in the 7 years since it went into effect. To address this question, you will use difference-in-differences estimation, and synthetic control.

Data

The dataset you will work with has been assembled from a few different sources about Medicaid. The key variables are:

- **State**: Full name of state
- **Medicaid Expansion Adoption**: Date that the state adopted the Medicaid expansion, if it did so.
- **Year**: Year of observation.
- **Uninsured rate**: State uninsured rate in that year.

Exploratory Data Analysis

Create plots and provide 1-2 sentence analyses to answer the following questions:

- Which states had the highest uninsured rates prior to 2014? The lowest?
- Which states were home to most uninsured Americans prior to 2014? How about in the last year in the data set? **Note**: 2010 state population is provided as a variable to answer this question. In an actual study you would likely use population estimates over time, but to simplify you can assume these numbers stay about the same.

```
medicaid_expansion
```

```
## # A tibble: 663 x 5
##    State                Date_Adopted  year uninsured_rate population
##    <chr>                <date>       <dbl>          <dbl>      <dbl>
##  1 Alabama              NA            2008         0.140     4849377
##  2 Alaska               2015-09-01    2008         0.208      737732
##  3 Arizona              2014-01-01    2008         0.187     6731484
##  4 Arkansas             2014-01-01    2008         0.179     2994079
##  5 California           2014-01-01    2008         0.178    38802500
##  6 Colorado             2014-01-01    2008         0.170     5355856
##  7 Connecticut          2014-01-01    2008         0.0891    3596677
##  8 Delaware             2014-01-01    2008         0.108      935614
##  9 District of Columbia 2014-01-01    2008         0.0805         NA
## 10 Florida              NA            2008         0.209    19893297
## # i 653 more rows
```

```r
# highest and lowest uninsured rates
pre2014 <- medicaid_expansion %>%
  filter(year < 2014)

# Filter for the highest and lowest 5% using dplyr
lowest_5pct <- pre2014 %>%
  filter(uninsured_rate <= quantile(uninsured_rate, 0.05))

highest_5pct <- pre2014 %>%
  filter(uninsured_rate >= quantile(uninsured_rate, 0.95))


lowest_uninsured_states <- pull(distinct(lowest_5pct, State))
highest_uninsured_states <- pull(distinct(highest_5pct, State))

print(lowest_uninsured_states)
```

```
## [1] "Hawaii"               "Massachusetts"        "District of Columbia"
## [4] "Vermont"
```

```r
print(highest_uninsured_states)
```

```
## [1] "Florida"    "Nevada"     "New Mexico" "Utah"       "Texas"
```

- Which states were home to most uninsured Americans prior to 2014? How about in the last year in the data set? **Note**: 2010 state population is provided as a variable to answer this question. In an actual study you would likely use population estimates over time, but to simplify you can assume these numbers stay about the same.

```r
# most uninsured Americans

pre2014 <-
  pre2014 %>%

  mutate(uninsured_pop = (pre2014$uninsured_rate * pre2014$population))

state_uninsured <-
  pre2014 %>%

  group_by(State) %>%

  summarize(AvgUninsured = mean(uninsured_pop, na.rm = TRUE))

sorted_most <- state_uninsured %>%
  arrange(desc(AvgUninsured), State)
sorted_least <- state_uninsured %>%
  arrange(AvgUninsured, State)

sorted_most
```

```
## # A tibble: 51 x 2
##    State          AvgUninsured
##    <chr>                 <dbl>
##  1 California         6970785.
##  2 Texas              5372081.
##  3 Florida            4115094.
```

```
##   4 New York           2262138.
##   5 Georgia            1935272.
##   6 Illinois           1693876.
##   7 North Carolina     1622044.
##   8 Ohio               1378521.
##   9 Pennsylvania       1260889.
##  10 Arizona            1180133.
## # i 41 more rows
```

```
sorted_least
```

```
## # A tibble: 51 x 2
##    State          AvgUninsured
##    <chr>                 <dbl>
##  1 Vermont              60715.
##  2 North Dakota         74965.
##  3 Wyoming              75130.
##  4 Delaware             91424.
##  5 Hawaii               99643.
##  6 Rhode Island        112053.
##  7 South Dakota        114558.
##  8 Maine               142888.
##  9 New Hampshire       143760.
## 10 Alaska              145397.
## # i 41 more rows
```

What about in the last year of the dataset?

```
medicaid2020 <-
  filter(medicaid_expansion, year == 2020)

# Same analysis as above but with 2020 data


medicaid2020 <-
  medicaid2020 %>%
  mutate(uninsured_pop = (medicaid2020$uninsured_rate * medicaid2020$population))

state_uninsured2020 <-
  medicaid2020 %>%

  group_by(State) %>%

  summarize(AvgUninsured = mean(uninsured_pop, na.rm = TRUE))

sorted_most2020 <- state_uninsured2020 %>%
  arrange(desc(AvgUninsured), State)
sorted_least2020 <- state_uninsured2020 %>%
  arrange(AvgUninsured, State)

sorted_most2020
```

```
## # A tibble: 51 x 2
##    State            AvgUninsured
##    <chr>                   <dbl>
##  1 Texas                4960080.
```

```
##  2 California         2987792.
##  3 Florida            2625915.
##  4 Georgia            1353044.
##  5 North Carolina     1123668.
##  6 New York           1026804.
##  7 Illinois            953163.
##  8 Ohio                765215.
##  9 Arizona             760658.
## 10 Pennsylvania        741658.
## # i 41 more rows
```

```r
sorted_least2020
```

```
## # A tibble: 51 x 2
##    State          AvgUninsured
##    <chr>                 <dbl>
##  1 Vermont              28170.
##  2 Rhode Island         43262.
##  3 North Dakota         51024.
##  4 Hawaii               59622.
##  5 Delaware             61751.
##  6 Wyoming              71851.
##  7 New Hampshire        83589.
##  8 Montana              84957.
##  9 South Dakota         87024.
## 10 Alaska               90003.
## # i 41 more rows
```

The rate of uninsured certainly appears to be more valuable given how much the raw values are contingent upon state population. That being said, seeing Texas overtake California with nearly double the number of uninsured individuals really drives home the premise that Texas might benefit from enrolling in Medicaid Expansion. I would also be interested to see this compared to the state budget or GDP to make an assessment of the premise that refusal to enroll was a "cost issue" rather than a partisan divide. As far as low rates, I'm not surprised to see Massachusetts given their own universal healthcare bill (RomneyCare lol) that likely distinguishes them from many if not all other states.

Difference-in-Differences Estimation

Estimate Model

Do the following:

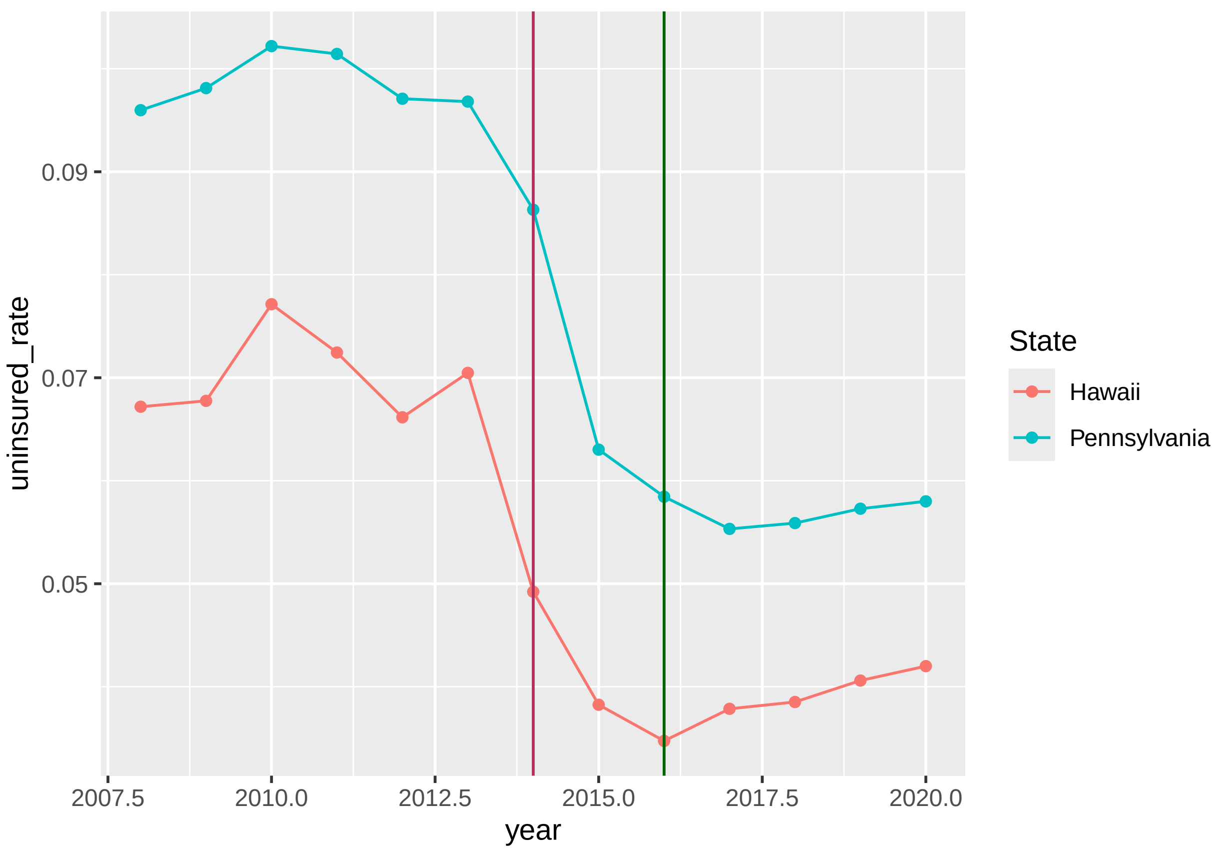
- Choose a state that adopted the Medicaid expansion on January 1, 2014 and a state that did not. **Hint**: Do not pick Massachusetts as it passed a universal healthcare law in 2006, and also avoid picking a state that adopted the Medicaid expansion between 2014 and 2015.
- Assess the parallel trends assumption for your choices using a plot. If you are not satisfied that the assumption has been met, pick another state and try again (but detail the states you tried).

```r
head(medicaid_expansion, n = 60)
```

```
## # A tibble: 60 x 5
##    State                Date_Adopted  year uninsured_rate population
##    <chr>                <date>       <dbl>          <dbl>      <dbl>
##  1 Alabama              NA            2008          0.140    4849377
##  2 Alaska               2015-09-01    2008          0.208     737732
##  3 Arizona              2014-01-01    2008          0.187    6731484
```

```
##   4 Arkansas             2014-01-01    2008          0.179      2994079
##   5 California           2014-01-01    2008          0.178     38802500
##   6 Colorado             2014-01-01    2008          0.170      5355856
##   7 Connecticut          2014-01-01    2008          0.0891     3596677
##   8 Delaware             2014-01-01    2008          0.108       935614
##   9 District of Columbia 2014-01-01    2008          0.0805          NA
##  10 Florida              NA            2008          0.209     19893297
## # i 50 more rows
```

```r
# Parallel Trends plotting
medicaid_expansion %>%
  # process
  # ---------
  filter(State %in% c("Hawaii", "Pennsylvania")) %>%
  # north dakota, kentucky, nevada, arizona, Date_Adopted %in% c("2016-01-01") |
  # plot
  # ---------
  ggplot() +
  geom_point(aes(x = year,
                 y = uninsured_rate,
                 color = State)) +
  geom_line(aes(x = year,
                y = uninsured_rate,
                color = State)) +
  geom_vline(xintercept = 2014, color = "maroon") +
  geom_vline(xintercept = 2016, color = "darkgreen")
```



```r
# themes
theme_fivethirtyeight() +
theme(axis.title = element_text()) +

# labels
ggtitle('States Enrolled on Jan 1, 2014 and Jan 1, 2016, \nbefore/after Enrollment') +
xlab('Year') +
ylab('Uninsured Rate')
```

```
## List of 138
##  $ line                            :List of 6
##   ..$ colour       : chr "black"
##   ..$ linewidth    : num 0.545
##   ..$ linetype     : num 1
##   ..$ lineend      : chr "butt"
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ rect                            :List of 5
##   ..$ fill         : Named chr "#F0F0F0"
##   .. ..- attr(*, "names")= chr "Light Gray"
##   ..$ colour       : logi NA
##   ..$ linewidth    : num 0.545
##   ..$ linetype     : num 0
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ text                            :List of 11
##   ..$ family       : chr "sans"
##   ..$ face         : chr "plain"
##   ..$ colour       : Named chr "#3C3C3C"
##   .. ..- attr(*, "names")= chr "Dark Gray"
##   ..$ size         : num 12
##   ..$ hjust        : num 0.5
##   ..$ vjust        : num 0.5
##   ..$ angle        : num 0
##   ..$ lineheight   : num 0.9
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : logi FALSE
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ title                           : chr "States Enrolled on Jan 1, 2014 and Jan 1, 2016, \nbefore/a
##  $ aspect.ratio                    : NULL
##  $ axis.title                      :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
```

```
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.x                    :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 3points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.x.top                :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 3points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.x.bottom             : NULL
##  $ axis.title.y                    :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : num 90
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 3points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.title.y.left               : NULL
##  $ axis.title.y.right              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : num -90
```

```
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 3points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text                     :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x                   :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 1
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 2.4points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x.top               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : num 0
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 2.4points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.x.bottom            : NULL
##  $ axis.text.y                   :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 1
```

```
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 2.4points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.y.left                : NULL
##  $ axis.text.y.right               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 2.4points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.text.theta                 : NULL
##  $ axis.text.r                     :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0.5
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 2.4points 0points 2.4points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ axis.ticks                      : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ axis.ticks.x                    : NULL
##  $ axis.ticks.x.top                : NULL
##  $ axis.ticks.x.bottom             : NULL
##  $ axis.ticks.y                    : NULL
##  $ axis.ticks.y.left               : NULL
##  $ axis.ticks.y.right              : NULL
##  $ axis.ticks.theta                : NULL
##  $ axis.ticks.r                    : NULL
##  $ axis.minor.ticks.x.top          : NULL
##  $ axis.minor.ticks.x.bottom       : NULL
##  $ axis.minor.ticks.y.left         : NULL
##  $ axis.minor.ticks.y.right        : NULL
##  $ axis.minor.ticks.theta          : NULL
##  $ axis.minor.ticks.r              : NULL
```

```
##  $ axis.ticks.length               : 'simpleUnit' num 3points
##   ..- attr(*, "unit")= int 8
##  $ axis.ticks.length.x             : NULL
##  $ axis.ticks.length.x.top         : NULL
##  $ axis.ticks.length.x.bottom      : NULL
##  $ axis.ticks.length.y             : NULL
##  $ axis.ticks.length.y.left        : NULL
##  $ axis.ticks.length.y.right       : NULL
##  $ axis.ticks.length.theta         : NULL
##  $ axis.ticks.length.r             : NULL
##  $ axis.minor.ticks.length         : 'rel' num 0.75
##  $ axis.minor.ticks.length.x       : NULL
##  $ axis.minor.ticks.length.x.top   : NULL
##  $ axis.minor.ticks.length.x.bottom: NULL
##  $ axis.minor.ticks.length.y       : NULL
##  $ axis.minor.ticks.length.y.left  : NULL
##  $ axis.minor.ticks.length.y.right : NULL
##  $ axis.minor.ticks.length.theta   : NULL
##  $ axis.minor.ticks.length.r       : NULL
##  $ axis.line                       : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ axis.line.x                     : NULL
##  $ axis.line.x.top                 : NULL
##  $ axis.line.x.bottom              : NULL
##  $ axis.line.y                     : NULL
##  $ axis.line.y.left                : NULL
##  $ axis.line.y.right               : NULL
##  $ axis.line.theta                 : NULL
##  $ axis.line.r                     : NULL
##  $ legend.background               :List of 5
##   ..$ fill         : NULL
##   ..$ colour       : logi NA
##   ..$ linewidth    : NULL
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ legend.margin                   : 'margin' num [1:4] 6points 6points 6points 6points
##   ..- attr(*, "unit")= int 8
##  $ legend.spacing                  : 'simpleUnit' num 12points
##   ..- attr(*, "unit")= int 8
##  $ legend.spacing.x                : NULL
##  $ legend.spacing.y                : NULL
##  $ legend.key                      : NULL
##  $ legend.key.size                 : 'simpleUnit' num 1.2lines
##   ..- attr(*, "unit")= int 3
##  $ legend.key.height               : NULL
##  $ legend.key.width                : NULL
##  $ legend.key.spacing              : 'simpleUnit' num 6points
##   ..- attr(*, "unit")= int 8
##  $ legend.key.spacing.x            : NULL
##  $ legend.key.spacing.y            : NULL
##  $ legend.frame                    : NULL
##  $ legend.ticks                    : NULL
##  $ legend.ticks.length             : 'rel' num 0.2
```

```
##  $ legend.axis.line                : NULL
##  $ legend.text                     :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ legend.text.position            : NULL
##  $ legend.title                    :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ legend.title.position           : NULL
##  $ legend.position                 : chr "bottom"
##  $ legend.position.inside          : NULL
##  $ legend.direction                : chr "horizontal"
##  $ legend.byrow                    : NULL
##  $ legend.justification            : chr "center"
##  $ legend.justification.top        : NULL
##  $ legend.justification.bottom     : NULL
##  $ legend.justification.left       : NULL
##  $ legend.justification.right      : NULL
##  $ legend.justification.inside     : NULL
##  $ legend.location                 : NULL
##  $ legend.box                      : chr "vertical"
##  $ legend.box.just                 : NULL
##  $ legend.box.margin               : 'margin' num [1:4] 0cm 0cm 0cm 0cm
##   ..- attr(*, "unit")= int 1
##  $ legend.box.background           : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ legend.box.spacing              : 'simpleUnit' num 12points
##   ..- attr(*, "unit")= int 8
##   [list output truncated]
##  - attr(*, "class")= chr [1:2] "theme" "gg"
##  - attr(*, "complete")= logi TRUE
##  - attr(*, "validate")= logi TRUE
```

Assessment: Very difficult to find two states that are parallel but opted in to Medicaid at different times more than a year apart. I found that Hawaii (adopted Jan 1, 2014) and Pennsylvania (adopted Jan 1, 2015) are *somewhat* similar but definitely still have differences. Concerningly, in 2013, Hawaii's rates spike while Pennsylvania's remaini the same.

- Estimates a difference-in-differences estimate of the effect of the Medicaid expansion on the uninsured share of the population. You may follow the lab example where we estimate the differences in one pre-treatment and one post-treatment period, or take an average of the pre-treatment and post-treatment outcomes

```
# Difference-in-Differences estimation

# create a dataset for kansas and colorado
HI_PA <-
  medicaid_expansion %>%
  filter(State %in% c("Pennsylvania","Hawaii")) %>%
  filter(year >= 2014 & year <= 2015)

# pre-treatment difference
# ----------
pre_diff <-
  HI_PA %>%
  # filter out only the year we want
  filter(year == 2014) %>%
  # subset to select only vars we want
  select(State,
         uninsured_rate) %>%
  # make the data wide
  pivot_wider(names_from = State,
              values_from = uninsured_rate) %>%
  # subtract to make calculation
  summarise(Pennsylvania - Hawaii)

# post-treatment difference
# ----------
post_diff <-
  HI_PA %>%
  # filter out only the quarter we want
  filter(year == 2015) %>%
  # subset to select only vars we want
  select(State,
         uninsured_rate) %>%
  # make the data wide
  pivot_wider(names_from = State,
              values_from = uninsured_rate) %>%
  # subtract to make calculation
  summarise(Pennsylvania - Hawaii)

# diff-in-diffs
# ----------
diff_in_diffs <- post_diff - pre_diff
diff_in_diffs
```

```
##   Pennsylvania - Hawaii
## 1              -0.01232
```

Discussion Questions

- Card/Krueger's original piece utilized the fact that towns on either side of the Delaware river are likely to be quite similar to one another in terms of demographics, economics, etc. Why is that intuition harder to replicate with this data?
- **Answer**:
  - On one hand, due to the geographic similarities of the two cities the shared economies are likely to be much stronger. People can and do physically move between the two and intertwine across multiple dimensions. Should that study have been done at the statewide level, differences across the states likely would have resulted in divergent trends and an inappropriate diff-in-diff to assess a counterfactual. Further, how states responded to A) the passing of the ACA, and B) the judicial decision differ across the nation and are not inherently geographically bound.
- What are the strengths and weaknesses of using the parallel trends assumption in difference-in-differences estimates?
- **Answer**:
  - Identifying and assuming parallel trends allows for estimating the average treatment effect on the treated given that we can "reasonably" say that the control groups share similar properties that allows us to isolate the effect of treatment. It can be useful when comparing treatment between two distinct yet similar groups in natural experiments. However, the assumption may not hold robustly. There may be other confounders at the time of treatment that violate the assumption that the control group is similar to/the same as the treatment group through the full time of analysis. And of course a parallel trend may not exist or not be perfectly parallel.

Synthetic Control

Estimate Synthetic Control

Although several states did not expand Medicaid on January 1, 2014, many did later on. In some cases, a Democratic governor was elected and pushed for a state budget that included the Medicaid expansion, whereas in others voters approved expansion via a ballot initiative. The 2018 election was a watershed moment where several Republican-leaning states elected Democratic governors and approved Medicaid expansion. In cases with a ballot initiative, the state legislature and governor still must implement the results via legislation. For instance, Idaho voters approved a Medicaid expansion in the 2018 election, but it was not implemented in the state budget until late 2019, with enrollment beginning in 2020.

Do the following:

- Choose a state that adopted the Medicaid expansion after January 1, 2014. Construct a non-augmented synthetic control and plot the results (both pre-treatment fit and post-treatment differences). Also report the average ATT and L2 imbalance.

First, pick a state that adopted Medicaid after Jan 1, 2014. From above, we can see that Virginia adopted on January 1, 2019.

```
colnames(medicaid_expansion)
```

```
## [1] "State"          "Date_Adopted"   "year"           "uninsured_rate"
## [5] "population"
```

```
# add treatment effect
medicaid_expansion <-
  medicaid_expansion %>%
  # create new treatment flag just to see
  mutate(treatment = case_when(State == "Virginia" & year >= 2019 ~ 1, # note this adds treatment in 20
                               TRUE ~ 0))
```

```r
# view head
head(medicaid_expansion)
```

```
## # A tibble: 6 x 6
##   State      Date_Adopted  year uninsured_rate population treatment
##   <chr>      <date>       <dbl>          <dbl>      <dbl>     <dbl>
## 1 Alabama    NA            2008          0.140    4849377         0
## 2 Alaska     2015-09-01    2008          0.208     737732         0
## 3 Arizona    2014-01-01    2008          0.187    6731484         0
## 4 Arkansas   2014-01-01    2008          0.179    2994079         0
## 5 California 2014-01-01    2008          0.178   38802500         0
## 6 Colorado   2014-01-01    2008          0.170    5355856         0
```

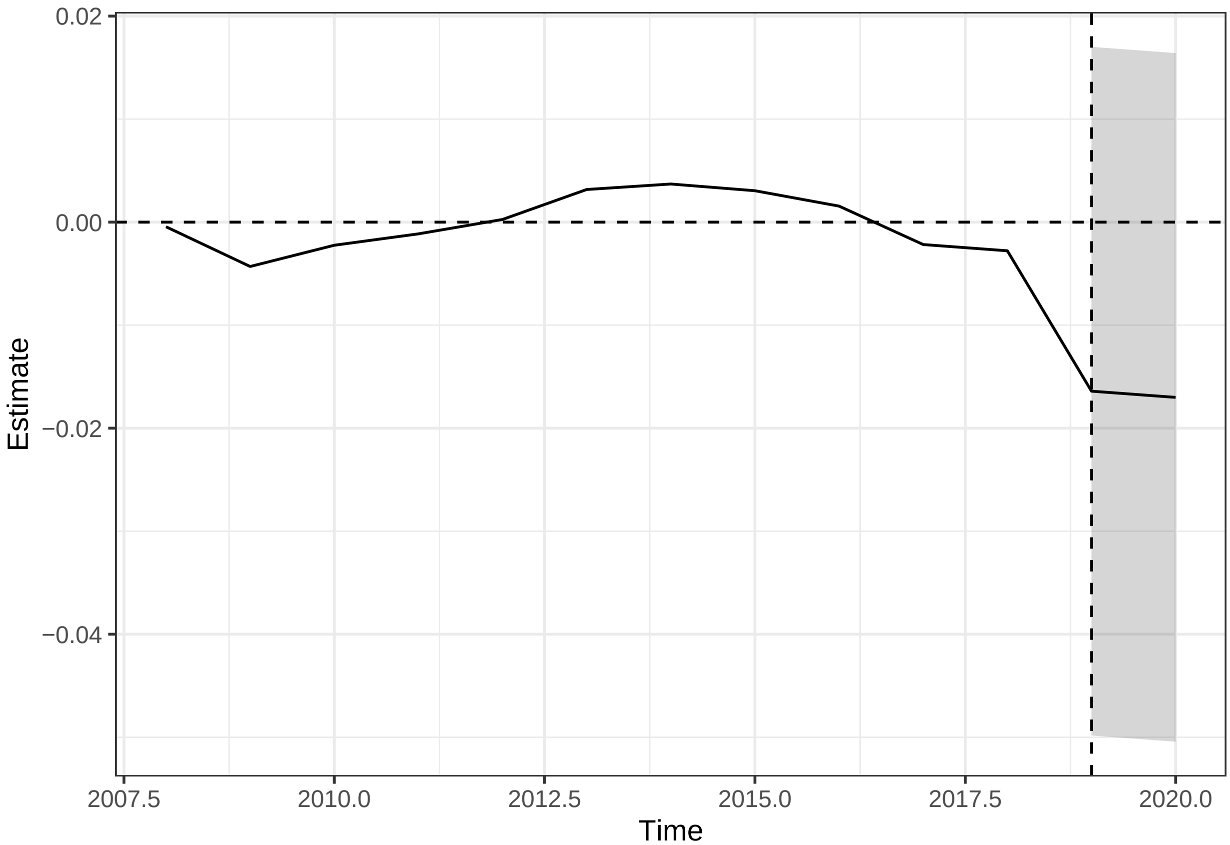
```r
# non-augmented synthetic control

syn <-                              # save object
  augsynth(uninsured_rate ~ treatment, # treatment - use instead of treated bc latter codes 2012.25 as
                         State,     # unit
                         year,  # time
                         medicaid_expansion,    # data
           progfunc = "None",       # plain syn control
           scm = T)                 # synthetic control
```

```
## One outcome and one treatment time found. Running single_augsynth.
```

```r
# summary to show average ATT and L2 imbalance
summary(syn)
```

```
##
## Call:
## single_augsynth(form = form, unit = !!enquo(unit), time = !!enquo(time),
##     t_int = t_int, data = data, progfunc = "None", scm = ..2)
##
## Average ATT Estimate (p Value for Joint Null):  -0.0167   ( 0.095 )
## L2 Imbalance: 0.009
## Percent improvement from uniform weights: 88.9%
##
## Avg Estimated Bias: NA
##
## Inference type: Conformal inference
##
##  Time Estimate 95% CI Lower Bound 95% CI Upper Bound p Value
##  2019   -0.016              -0.05              0.017   0.079
##  2020   -0.017              -0.05              0.016   0.081
```

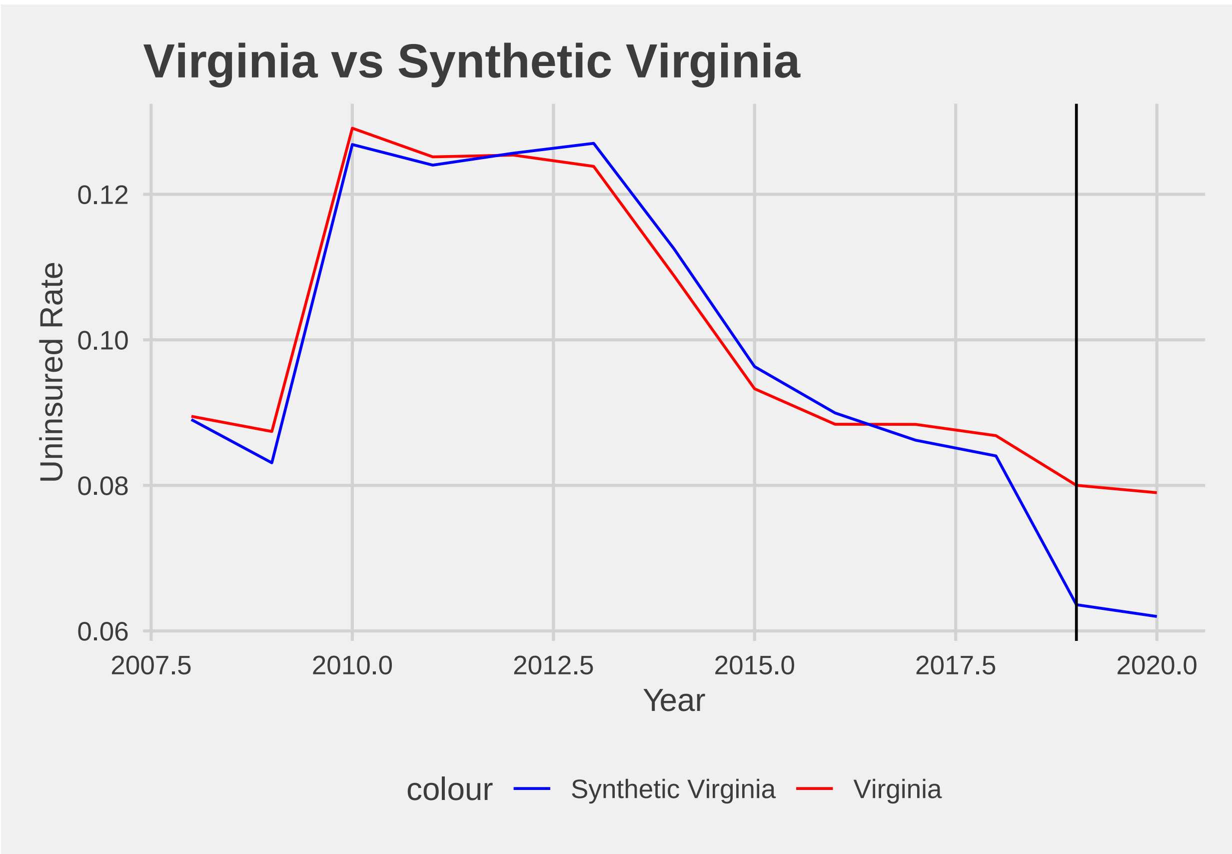
```r
# Plot differences
plot(syn)
```




```
# virginia_synvirginia %>% filter((State == 'Virginia' ) & (year >= 2019))
```

```
syn_sum <- summary(syn)

# create synthetic Virginia
# ---------
virginia_synvirginia <-
  # data
  medicaid_expansion %>%
  # filter just Kansas
  filter(State == "Virginia") %>%
  # bind columns
  bind_cols(difference = syn_sum$att$Estimate) %>%# add in estimate
  # calculate synthetic Virginia
  mutate(synthetic_virginia = uninsured_rate + difference) # adds the estimate to the observed Kansas t


# plot
# ---------
virginia_synvirginia %>%
  ggplot() +
  # ---------
  geom_line(aes(x = year,
                y = uninsured_rate,
                color = 'Virginia')) +
  # synthetic Virginia
  # ---------
```

```r
  geom_line(aes(x = year,
                y = synthetic_virginia,
                color = 'Synthetic Virginia')) +
  scale_color_manual(values = c('Virginia' = 'red', 'Synthetic Virginia' = 'blue')) +
  geom_vline(aes(xintercept = 2019)) +
  theme_fivethirtyeight() +
  theme(axis.title = element_text()) +
  ggtitle('Virginia vs Synthetic Virginia') +
  xlab('Year') +
  ylab('Uninsured Rate')
```



- Re-run the same analysis but this time use an augmentation (default choices are Ridge, Matrix Completion, and GSynth). Create the same plot and report the average ATT and L2 imbalance.

```r
# augmented synthetic control
ridge_syn <-
  augsynth(uninsured_rate ~ treatment,
                       State,
                       year,
                       medicaid_expansion,
           progfunc = "ridge",  # specify
           scm = T)
```

```
## One outcome and one treatment time found. Running single_augsynth.
```

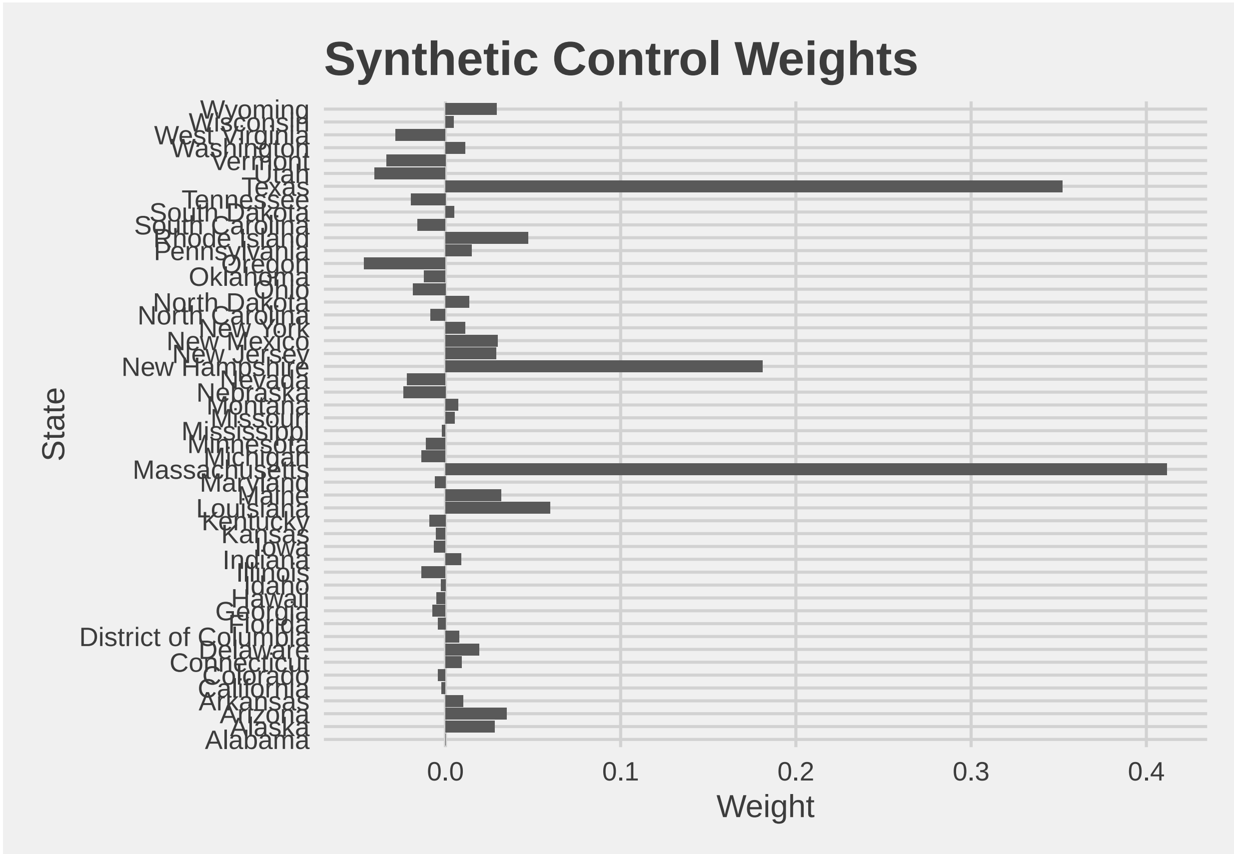
```r
summary(ridge_syn)
```

```
##
```

```
## Call:
## single_augsynth(form = form, unit = !!enquo(unit), time = !!enquo(time),
##     t_int = t_int, data = data, progfunc = "ridge", scm = ..2)
##
## Average ATT Estimate (p Value for Joint Null):  -0.0143   ( 0.061 )
## L2 Imbalance: 0.001
## Percent improvement from uniform weights: 99.2%
##
## Avg Estimated Bias: -0.002
##
## Inference type: Conformal inference
##
##  Time Estimate 95% CI Lower Bound 95% CI Upper Bound p Value
##  2019   -0.014              -0.043              0.015   0.070
##  2020   -0.015              -0.043              0.014   0.079
```

- Plot barplots to visualize the weights of the donors.

```r
# barplots of weights
# ----------------------------------------------------------------
data.frame(ridge_syn$weights) %>%
  tibble::rownames_to_column('State') %>%
  ggplot() +
  geom_bar(aes(x = State, y = ridge_syn.weights),
           stat = 'identity') +
  coord_flip() + # coord flip
  theme_fivethirtyeight() +
  theme(axis.title = element_text()) +
  ggtitle('Synthetic Control Weights') +
  xlab('State') +
  ylab('Weight')
```



HINT: Is there any preprocessing you need to do before you allow the program to automatically find weights for donor states?

- We may want to remove states that adopted a form of universal healthcare prior to or separate from the medicaid expansion. Massachusetts is the obvious example here by adopting their own healthcare system in 2006.

Discussion Questions

- What are the advantages and disadvantages of synthetic control compared to difference-in-differences estimators?
- **Answer**:
  - Synthetic control allows for much closer matching as it takes data from all other controls in the dataset, rather than tryingi to make an educated guess. However, diff-in-diff may allow for drawing conclusions beyond the specific unit analysis. In other words, doing a diff-in-diff between two states may give a broader insight into how medicaid adoption affected uninsured rates elsewhere, whereas synthetic control will tell us more about the effects of medicaid adoption in the state we synthesize but not elsewhere.
- One of the benefits of synthetic control is that the weights are bounded between [0,1] and the weights must sum to 1. Augmentation might relax this assumption by allowing for negative weights. Does this create an interpretation problem, and how should we balance this consideration against the improvements augmentation offers in terms of imbalance in the pre-treatment period?
- **Answer**:
  - Allowing negative weights can complicate the interpretation that each donor contributes "X%" to

the synthetic set. It suugests that some control units might effectively "counteract" others, which can be harder to justify or explain in a causal inference context.

Staggered Adoption Synthetic Control

Estimate Multisynth

Do the following:

- Estimate a multisynth model that treats each state individually. Choose a fraction of states that you can fit on a plot and examine their treatment effects.

```
# multisynth model states
# Removing Massachusetts & add new treatment variable
medicaid_expansion_clean <- medicaid_expansion %>%
  filter(!State == "Massachusetts") %>%

    # create "treatment" - year collective bargaining was adopted
    mutate(Date_Adopted = ifelse(is.na(Date_Adopted),
                                 Inf, Date_Adopted),

           adopted = 1 * (year >= as.numeric(format(as.Date(Date_Adopted, format = "%Y-%m-%d"), "%Y")))

medicaid_expansion_clean
```

```
## # A tibble: 650 x 7
##    State          Date_Adopted  year uninsured_rate population treatment adopted
##    <chr>                 <dbl> <dbl>          <dbl>      <dbl>     <dbl>   <dbl>
##  1 Alabama                 Inf  2008         0.140     4849377         0       0
##  2 Alaska                16679  2008         0.208      737732         0       0
##  3 Arizona               16071  2008         0.187     6731484         0       0
##  4 Arkansas              16071  2008         0.179     2994079         0       0
##  5 California            16071  2008         0.178    38802500         0       0
##  6 Colorado              16071  2008         0.170     5355856         0       0
##  7 Connecticut           16071  2008         0.0891    3596677         0       0
##  8 Delaware              16071  2008         0.108      935614         0       0
##  9 District of C~        16071  2008         0.0805         NA         0       0
## 10 Florida                 Inf  2008         0.209    19893297         0       0
## # i 640 more rows
```

```
# Multisynth model states
# ---------
# Setting nu to 0 to treat each state individually
no_pool_syn <- multisynth(uninsured_rate ~ adopted,
                          State,                       # unit
                          year,                        # time
                          nu = 0,                    # no pooling
                          medicaid_expansion_clean, # data
                          n_leads = 2)
```

```
no_pool_synsum <- summary(no_pool_syn)
```

```
no_pool_synsum$att
```

```
##     Time                 Level      Estimate   Std.Error   lower_bound
## 1    -12               Average  1.025101e-02 0.037957396 -0.0648191846
```

```
## 2    -11              Average  1.160478e-02 0.026734532 -0.0425560692
## 3    -10              Average  3.432105e-03 0.011716643 -0.0190546194
## 4     -9              Average -5.185198e-04 0.007580385 -0.0158867256
## 5     -8              Average -1.848474e-03 0.008369585 -0.0156006257
## 6     -7              Average -1.163056e-03 0.007227458 -0.0124020708
## 7     -6              Average -1.136448e-04 0.007167483 -0.0126611594
## 8     -5              Average -7.142314e-04 0.006064815 -0.0120605201
## 9     -4              Average  2.720578e-04 0.003258371 -0.0062644474
## 10    -3              Average -3.903377e-04 0.003605776 -0.0077116302
## 11    -2              Average -8.841279e-04 0.003892036 -0.0087190759
## 12    -1              Average -9.166283e-05 0.003466892 -0.0074552654
## 13     0              Average -1.173916e-02 0.004748010 -0.0212930770
## 14     1              Average -1.817259e-02 0.006550081 -0.0309284125
## 15    NA              Average -1.440935e-02 0.005159329 -0.0246273620
## 16   -12               Alaska            NA         NaN            NA
## 17   -11               Alaska            NA         NaN            NA
## 18   -10               Alaska            NA         NaN            NA
## 19    -9               Alaska            NA         NaN            NA
## 20    -8               Alaska            NA         NaN            NA
## 21    -7               Alaska  1.027723e-03 0.023082311 -0.0402930653
## 22    -6               Alaska  7.243849e-04 0.017800827 -0.0313787810
## 23    -5               Alaska -1.195273e-02 0.024951418 -0.0461080769
## 24    -4               Alaska  4.610996e-03 0.007427316 -0.0104625804
## 25    -3               Alaska  6.778125e-03 0.008352612 -0.0130776303
## 26    -2               Alaska -2.317406e-03 0.010999430 -0.0183712245
## 27    -1               Alaska  1.128911e-03 0.004954784 -0.0091367641
## 28     0               Alaska -1.065096e-02 0.012512980 -0.0278209506
## 29     1               Alaska -4.996361e-03 0.005882979 -0.0159787189
## 30    NA               Alaska -7.823663e-03 0.008904028 -0.0217715106
## 31   -12              Arizona            NA         NaN            NA
## 32   -11              Arizona            NA         NaN            NA
## 33   -10              Arizona            NA         NaN            NA
## 34    -9              Arizona            NA         NaN            NA
## 35    -8              Arizona            NA         NaN            NA
## 36    -7              Arizona            NA         NaN            NA
## 37    -6              Arizona  2.625765e-03 0.024122081 -0.0414435148
## 38    -5              Arizona -2.946809e-03 0.013306461 -0.0219916454
## 39    -4              Arizona -3.901417e-03 0.015042918 -0.0302540513
## 40    -3              Arizona -2.336919e-03 0.011427891 -0.0227669765
## 41    -2              Arizona  3.943136e-03 0.007575458 -0.0113743321
## 42    -1              Arizona  2.616243e-03 0.007384575 -0.0118825809
## 43     0              Arizona -2.067609e-02 0.016629048 -0.0453036983
## 44     1              Arizona -3.170106e-02 0.025456749 -0.0658238817
## 45    NA              Arizona -2.618858e-02 0.020990629 -0.0555618953
## 46   -12             Arkansas            NA         NaN            NA
## 47   -11             Arkansas            NA         NaN            NA
## 48   -10             Arkansas            NA         NaN            NA
## 49    -9             Arkansas            NA         NaN            NA
## 50    -8             Arkansas            NA         NaN            NA
## 51    -7             Arkansas            NA         NaN            NA
## 52    -6             Arkansas  2.488362e-03 0.026397683 -0.0530609294
## 53    -5             Arkansas -2.706397e-03 0.016905364 -0.0321668602
## 54    -4             Arkansas  9.865953e-04 0.010700928 -0.0184076346
## 55    -3             Arkansas  1.429651e-03 0.011251309 -0.0212821890
```

```
## 56    -2          Arkansas -1.852202e-03 0.010558665 -0.0222650232
## 57    -1          Arkansas -3.460092e-04 0.010432431 -0.0222419245
## 58     0          Arkansas -2.147545e-02 0.028360010 -0.0571013614
## 59     1          Arkansas -2.998838e-02 0.034564757 -0.0692828948
## 60    NA          Arkansas -2.573191e-02 0.031410668 -0.0627754024
## 61   -12        California            NA         NaN            NA
## 62   -11        California            NA         NaN            NA
## 63   -10        California            NA         NaN            NA
## 64    -9        California            NA         NaN            NA
## 65    -8        California            NA         NaN            NA
## 66    -7        California            NA         NaN            NA
## 67    -6        California -6.332163e-11 0.014405867 -0.0224134074
## 68    -5        California  7.062909e-11 0.014506824 -0.0243288263
## 69    -4        California  1.736669e-11 0.005972630 -0.0119335181
## 70    -3        California -1.434475e-10 0.006797815 -0.0138460683
## 71    -2        California  9.116377e-11 0.007865408 -0.0156675535
## 72    -1        California  2.760953e-11 0.009310717 -0.0171304255
## 73     0        California -2.939468e-02 0.031418116 -0.0651908786
## 74     1        California -5.028501e-02 0.053606829 -0.1086660456
## 75    NA        California -3.983985e-02 0.042474614 -0.0862674978
## 76   -12          Colorado            NA         NaN            NA
## 77   -11          Colorado            NA         NaN            NA
## 78   -10          Colorado            NA         NaN            NA
## 79    -9          Colorado            NA         NaN            NA
## 80    -8          Colorado            NA         NaN            NA
## 81    -7          Colorado            NA         NaN            NA
## 82    -6          Colorado  3.411354e-03 0.024422341 -0.0435058608
## 83    -5          Colorado -3.552840e-03 0.011742331 -0.0254621896
## 84    -4          Colorado  1.924324e-03 0.004496013 -0.0068610794
## 85    -3          Colorado  1.918107e-03 0.007762177 -0.0132755616
## 86    -2          Colorado -2.129560e-03 0.010151124 -0.0186619499
## 87    -1          Colorado -1.571385e-03 0.013825769 -0.0254236111
## 88     0          Colorado -1.172853e-02 0.025550407 -0.0482160634
## 89     1          Colorado -2.533451e-02 0.031699363 -0.0616749252
## 90    NA          Colorado -1.853152e-02 0.028404387 -0.0546806722
## 91   -12       Connecticut            NA         NaN            NA
## 92   -11       Connecticut            NA         NaN            NA
## 93   -10       Connecticut            NA         NaN            NA
## 94    -9       Connecticut            NA         NaN            NA
## 95    -8       Connecticut            NA         NaN            NA
## 96    -7       Connecticut            NA         NaN            NA
## 97    -6       Connecticut -1.263251e-04 0.012137355 -0.0236993332
## 98    -5       Connecticut  6.919339e-05 0.012035450 -0.0241210088
## 99    -4       Connecticut -1.432031e-03 0.009699305 -0.0212071322
## 100   -3       Connecticut -5.046973e-03 0.010594551 -0.0216127063
## 101   -2       Connecticut  3.190982e-03 0.007938451 -0.0140109987
## 102   -1       Connecticut  3.345153e-03 0.007493652 -0.0109025191
## 103    0       Connecticut -2.165019e-03 0.008322045 -0.0176710793
## 104    1       Connecticut -1.438232e-03 0.013844942 -0.0272391587
## 105   NA       Connecticut -1.801626e-03 0.010338623 -0.0198092130
## 106  -12          Delaware            NA         NaN            NA
## 107  -11          Delaware            NA         NaN            NA
## 108  -10          Delaware            NA         NaN            NA
## 109   -9          Delaware            NA         NaN            NA
```

```
## 110   -8             Delaware            NA         NaN            NA
## 111   -7             Delaware            NA         NaN            NA
## 112   -6             Delaware  4.698354e-04 0.029996603 -0.0587071395
## 113   -5             Delaware -1.178458e-03 0.026209084 -0.0499331342
## 114   -4             Delaware  6.165954e-04 0.015084691 -0.0282647479
## 115   -3             Delaware -3.182807e-03 0.019093283 -0.0398788617
## 116   -2             Delaware -1.628232e-03 0.020983492 -0.0406741094
## 117   -1             Delaware  4.903066e-03 0.008243953 -0.0128257460
## 118    0             Delaware  4.390070e-03 0.007071538 -0.0099835986
## 119    1             Delaware -1.210016e-02 0.011174822 -0.0271201112
## 120   NA             Delaware -3.855047e-03 0.004314982 -0.0115922257
## 121  -12 District of Columbia            NA         NaN            NA
## 122  -11 District of Columbia            NA         NaN            NA
## 123  -10 District of Columbia            NA         NaN            NA
## 124   -9 District of Columbia            NA         NaN            NA
## 125   -8 District of Columbia            NA         NaN            NA
## 126   -7 District of Columbia            NA         NaN            NA
## 127   -6 District of Columbia  4.078235e-03 0.016014620 -0.0269985117
## 128   -5 District of Columbia -4.334165e-03 0.007672711 -0.0191184809
## 129   -4 District of Columbia  1.799168e-03 0.002103907 -0.0023576950
## 130   -3 District of Columbia  5.574322e-03 0.002789504 -0.0004376945
## 131   -2 District of Columbia -6.438455e-03 0.016267403 -0.0270339205
## 132   -1 District of Columbia -6.791057e-04 0.005990714 -0.0104579049
## 133    0 District of Columbia  1.517938e-02 0.010410561 -0.0088493345
## 134    1 District of Columbia  2.024933e-02 0.013720273 -0.0102343129
## 135   NA District of Columbia  1.771435e-02 0.011828290 -0.0095418663
## 136  -12               Hawaii            NA         NaN            NA
## 137  -11               Hawaii            NA         NaN            NA
## 138  -10               Hawaii            NA         NaN            NA
## 139   -9               Hawaii            NA         NaN            NA
## 140   -8               Hawaii            NA         NaN            NA
## 141   -7               Hawaii            NA         NaN            NA
## 142   -6               Hawaii  8.876372e-12 0.013876650 -0.0243373512
## 143   -5               Hawaii -9.900775e-12 0.012693241 -0.0222781599
## 144   -4               Hawaii -2.434455e-12 0.007543233 -0.0137734088
## 145   -3               Hawaii  2.010841e-11 0.007491924 -0.0148432835
## 146   -2               Hawaii -1.277931e-11 0.009222890 -0.0178335297
## 147   -1               Hawaii -3.870293e-12 0.004824954 -0.0098095764
## 148    0               Hawaii  2.364820e-03 0.005044671 -0.0086941364
## 149    1               Hawaii  2.551249e-03 0.010249761 -0.0180143050
## 150   NA               Hawaii  2.458034e-03 0.006528840 -0.0107350098
## 151  -12                Idaho  2.304296e-03 0.025621375 -0.0452442623
## 152  -11                Idaho -2.183838e-03 0.018519826 -0.0358393418
## 153  -10                Idaho  7.250498e-03 0.013489748 -0.0183518116
## 154   -9                Idaho -8.595266e-03 0.009659612 -0.0230998701
## 155   -8                Idaho  1.218516e-03 0.004714972 -0.0075943815
## 156   -7                Idaho  1.150191e-03 0.006882804 -0.0110816597
## 157   -6                Idaho -8.992386e-04 0.002423652 -0.0055600867
## 158   -5                Idaho  9.360247e-04 0.010353644 -0.0174682181
## 159   -4                Idaho -9.584729e-05 0.011271906 -0.0187820549
## 160   -3                Idaho  1.291580e-03 0.011597018 -0.0185581780
## 161   -2                Idaho  1.776667e-03 0.008875529 -0.0148169600
## 162   -1                Idaho -4.153583e-03 0.018226299 -0.0312936817
## 163    0                Idaho -1.308111e-03 0.015204043 -0.0246980155
```

```
## 164   1              Idaho            NA          NaN            NA
## 165  NA              Idaho -1.308111e-03 0.015204043 -0.0246980155
## 166 -12           Illinois            NA          NaN            NA
## 167 -11           Illinois            NA          NaN            NA
## 168 -10           Illinois            NA          NaN            NA
## 169  -9           Illinois            NA          NaN            NA
## 170  -8           Illinois            NA          NaN            NA
## 171  -7           Illinois            NA          NaN            NA
## 172  -6           Illinois -5.280943e-04 0.009117789 -0.0177887747
## 173  -5           Illinois  6.320909e-04 0.008224401 -0.0155319688
## 174  -4           Illinois  1.955541e-04 0.002596658 -0.0050591150
## 175  -3           Illinois -9.334521e-04 0.009839738 -0.0187340634
## 176  -2           Illinois  8.370655e-04 0.004407576 -0.0083806640
## 177  -1           Illinois -2.031641e-04 0.003264849 -0.0069192964
## 178   0           Illinois -6.831126e-03 0.010437168 -0.0223328338
## 179   1           Illinois -1.585249e-02 0.021484688 -0.0434655010
## 180  NA           Illinois -1.134181e-02 0.015918376 -0.0327273008
## 181 -12            Indiana            NA          NaN            NA
## 182 -11            Indiana            NA          NaN            NA
## 183 -10            Indiana            NA          NaN            NA
## 184  -9            Indiana            NA          NaN            NA
## 185  -8            Indiana            NA          NaN            NA
## 186  -7            Indiana -4.746103e-06 0.005371382 -0.0100454270
## 187  -6            Indiana  4.391358e-06 0.004690898 -0.0089796921
## 188  -5            Indiana -1.361134e-05 0.003216849 -0.0068858666
## 189  -4            Indiana -2.374178e-05 0.003626045 -0.0068430475
## 190  -3            Indiana  2.861172e-05 0.002780322 -0.0059971685
## 191  -2            Indiana  2.471800e-05 0.001394227 -0.0025072834
## 192  -1            Indiana -1.562186e-05 0.002722789 -0.0052480355
## 193   0            Indiana -4.896250e-03 0.005356414 -0.0136661302
## 194   1            Indiana -1.351991e-02 0.014351836 -0.0293953708
## 195  NA            Indiana -9.208082e-03 0.009637716 -0.0215334003
## 196 -12               Iowa            NA          NaN            NA
## 197 -11               Iowa            NA          NaN            NA
## 198 -10               Iowa            NA          NaN            NA
## 199  -9               Iowa            NA          NaN            NA
## 200  -8               Iowa            NA          NaN            NA
## 201  -7               Iowa            NA          NaN            NA
## 202  -6               Iowa -8.297807e-12 0.012056002 -0.0222593421
## 203  -5               Iowa  9.255346e-12 0.011047411 -0.0199070372
## 204  -4               Iowa  2.275749e-12 0.006536528 -0.0127020241
## 205  -3               Iowa -1.879763e-11 0.006654507 -0.0131486914
## 206  -2               Iowa  1.194625e-11 0.008355326 -0.0162566145
## 207  -1               Iowa  3.617995e-12 0.003588018 -0.0071473272
## 208   0               Iowa -8.208280e-03 0.008224082 -0.0204803918
## 209   1               Iowa -6.110681e-03 0.005512971 -0.0151989572
## 210  NA               Iowa -7.159481e-03 0.004582164 -0.0142071568
## 211 -12           Kentucky            NA          NaN            NA
## 212 -11           Kentucky            NA          NaN            NA
## 213 -10           Kentucky            NA          NaN            NA
## 214  -9           Kentucky            NA          NaN            NA
## 215  -8           Kentucky            NA          NaN            NA
## 216  -7           Kentucky            NA          NaN            NA
## 217  -6           Kentucky -7.023438e-04 0.016341901 -0.0312420578
```

```
## 218   -5              Kentucky  6.916848e-04 0.015588950 -0.0304324043
## 219   -4              Kentucky  1.579115e-03 0.008902969 -0.0154682476
## 220   -3              Kentucky  5.145222e-06 0.009319635 -0.0206768182
## 221   -2              Kentucky -2.042224e-03 0.012248156 -0.0243631717
## 222   -1              Kentucky  4.686232e-04 0.005662458 -0.0099847390
## 223    0              Kentucky -3.270426e-02 0.033109319 -0.0688873318
## 224    1              Kentucky -4.939311e-02 0.042455409 -0.0955079142
## 225   NA              Kentucky -4.104869e-02 0.037552129 -0.0800108723
## 226  -12             Louisiana            NA         NaN            NA
## 227  -11             Louisiana            NA         NaN            NA
## 228  -10             Louisiana            NA         NaN            NA
## 229   -9             Louisiana            NA         NaN            NA
## 230   -8             Louisiana  1.401961e-03 0.016968885 -0.0331798173
## 231   -7             Louisiana -1.546136e-03 0.010906510 -0.0227186906
## 232   -6             Louisiana  3.544046e-04 0.004863799 -0.0093989099
## 233   -5             Louisiana  1.164666e-03 0.004041927 -0.0067123430
## 234   -4             Louisiana -9.895302e-04 0.005984501 -0.0112737923
## 235   -3             Louisiana -7.468527e-04 0.003193174 -0.0072158816
## 236   -2             Louisiana  8.391783e-04 0.006171535 -0.0121464554
## 237   -1             Louisiana -4.776909e-04 0.015762755 -0.0298702249
## 238    0             Louisiana -1.205470e-02 0.023758324 -0.0486219719
## 239    1             Louisiana -3.358185e-02 0.044601062 -0.0904330820
## 240   NA             Louisiana -2.281828e-02 0.033908527 -0.0691393266
## 241  -12              Maryland            NA         NaN            NA
## 242  -11              Maryland            NA         NaN            NA
## 243  -10              Maryland            NA         NaN            NA
## 244   -9              Maryland            NA         NaN            NA
## 245   -8              Maryland            NA         NaN            NA
## 246   -7              Maryland            NA         NaN            NA
## 247   -6              Maryland -4.145015e-07 0.012601479 -0.0251743438
## 248   -5              Maryland  4.968849e-07 0.009936815 -0.0194324752
## 249   -4              Maryland  5.656665e-08 0.002984425 -0.0056677373
## 250   -3              Maryland -9.219880e-07 0.011667553 -0.0198305372
## 251   -2              Maryland  7.423690e-07 0.006926076 -0.0125681301
## 252   -1              Maryland  4.066901e-08 0.003627199 -0.0060971590
## 253    0              Maryland -4.179886e-04 0.006582224 -0.0118813943
## 254    1              Maryland  3.877541e-03 0.006785955 -0.0090555028
## 255   NA              Maryland  1.729776e-03 0.006062285 -0.0097009208
## 256  -12              Michigan            NA         NaN            NA
## 257  -11              Michigan            NA         NaN            NA
## 258  -10              Michigan            NA         NaN            NA
## 259   -9              Michigan            NA         NaN            NA
## 260   -8              Michigan            NA         NaN            NA
## 261   -7              Michigan            NA         NaN            NA
## 262   -6              Michigan -4.896385e-04 0.013882882 -0.0258723169
## 263   -5              Michigan  5.485453e-04 0.014999760 -0.0292649700
## 264   -4              Michigan  4.250109e-04 0.004649377 -0.0089648506
## 265   -3              Michigan -6.605248e-04 0.008113365 -0.0160016349
## 266   -2              Michigan  5.226093e-04 0.007264238 -0.0144985720
## 267   -1              Michigan -3.460021e-04 0.008130494 -0.0153335829
## 268    0              Michigan -8.025371e-03 0.011718151 -0.0258322918
## 269    1              Michigan -1.369117e-02 0.018357711 -0.0386203790
## 270   NA              Michigan -1.085827e-02 0.014980936 -0.0321255508
## 271  -12             Minnesota            NA         NaN            NA
```

```
## 272  -11            Minnesota            NA         NaN            NA
## 273  -10            Minnesota            NA         NaN            NA
## 274   -9            Minnesota            NA         NaN            NA
## 275   -8            Minnesota            NA         NaN            NA
## 276   -7            Minnesota            NA         NaN            NA
## 277   -6            Minnesota -4.920693e-11 0.009536900 -0.0193760101
## 278   -5            Minnesota  5.488555e-11 0.010424074 -0.0201529325
## 279   -4            Minnesota  1.349559e-11 0.005812529 -0.0102571421
## 280   -3            Minnesota -1.114724e-10 0.005828003 -0.0106502504
## 281   -2            Minnesota  7.084297e-11 0.005898739 -0.0111188630
## 282   -1            Minnesota  2.145525e-11 0.002374266 -0.0045822493
## 283    0            Minnesota -3.542872e-03 0.004392798 -0.0110345730
## 284    1            Minnesota -5.321175e-03 0.003841413 -0.0120440162
## 285   NA            Minnesota -4.432024e-03 0.003321594 -0.0101020421
## 286  -12              Montana            NA         NaN            NA
## 287  -11              Montana            NA         NaN            NA
## 288  -10              Montana            NA         NaN            NA
## 289   -9              Montana            NA         NaN            NA
## 290   -8              Montana  4.453454e-04 0.029038431 -0.0601861821
## 291   -7              Montana  1.703790e-03 0.028551405 -0.0579397392
## 292   -6              Montana -1.267496e-02 0.014696409 -0.0342975599
## 293   -5              Montana  7.908725e-03 0.009947414 -0.0157753465
## 294   -4              Montana  9.668764e-03 0.011652496 -0.0171816507
## 295   -3              Montana  1.325011e-03 0.010194842 -0.0173875686
## 296   -2              Montana -6.278959e-03 0.016733460 -0.0360458672
## 297   -1              Montana -2.097720e-03 0.024327259 -0.0475064507
## 298    0              Montana -2.522622e-02 0.045286249 -0.0945912018
## 299    1              Montana -2.396532e-02 0.042868213 -0.0910784056
## 300   NA              Montana -2.459577e-02 0.044058709 -0.0921605116
## 301  -12             Nebraska -3.667427e-03 0.015938296 -0.0354921988
## 302  -11             Nebraska  5.059002e-03 0.013386758 -0.0220773866
## 303  -10             Nebraska  2.174985e-03 0.010248508 -0.0161709495
## 304   -9             Nebraska  8.734972e-04 0.006247963 -0.0119717650
## 305   -8             Nebraska -4.222909e-03 0.010975336 -0.0228426888
## 306   -7             Nebraska -3.552310e-03 0.009902128 -0.0181326515
## 307   -6             Nebraska -4.880591e-03 0.003813757 -0.0112468922
## 308   -5             Nebraska -5.260393e-03 0.004126885 -0.0111957917
## 309   -4             Nebraska  1.049622e-02 0.018844819 -0.0260195092
## 310   -3             Nebraska  4.305912e-03 0.012950707 -0.0213678018
## 311   -2             Nebraska  4.564940e-03 0.009400277 -0.0139345947
## 312   -1             Nebraska -5.890924e-03 0.005357478 -0.0133802159
## 313    0             Nebraska -2.017920e-03 0.006286162 -0.0135549649
## 314    1             Nebraska            NA         NaN            NA
## 315   NA             Nebraska -2.017920e-03 0.006286162 -0.0135549649
## 316  -12               Nevada            NA         NaN            NA
## 317  -11               Nevada            NA         NaN            NA
## 318  -10               Nevada            NA         NaN            NA
## 319   -9               Nevada            NA         NaN            NA
## 320   -8               Nevada            NA         NaN            NA
## 321   -7               Nevada            NA         NaN            NA
## 322   -6               Nevada -7.968625e-04 0.023971909 -0.0403928429
## 323   -5               Nevada  8.873256e-04 0.023334149 -0.0355196315
## 324   -4               Nevada  7.379966e-04 0.009615545 -0.0178017221
## 325   -3               Nevada -1.008670e-03 0.012152249 -0.0273241545
```

```
## 326   -2             Nevada  7.938569e-04 0.014875611 -0.0264499159
## 327   -1             Nevada -6.136469e-04 0.015595864 -0.0284044216
## 328    0             Nevada -3.877113e-02 0.042771102 -0.0904363417
## 329    1             Nevada -4.845291e-02 0.056069919 -0.1101445300
## 330   NA             Nevada -4.361202e-02 0.049379270 -0.1004788579
## 331  -12      New Hampshire            NA         NaN            NA
## 332  -11      New Hampshire            NA         NaN            NA
## 333  -10      New Hampshire            NA         NaN            NA
## 334   -9      New Hampshire            NA         NaN            NA
## 335   -8      New Hampshire            NA         NaN            NA
## 336   -7      New Hampshire            NA         NaN            NA
## 337   -6      New Hampshire  6.607513e-04 0.011684446 -0.0252807959
## 338   -5      New Hampshire -7.057918e-04 0.007588740 -0.0167499950
## 339   -4      New Hampshire -1.860400e-03 0.005309921 -0.0110031569
## 340   -3      New Hampshire -5.562685e-03 0.013791658 -0.0267204098
## 341   -2      New Hampshire  3.964452e-03 0.005734285 -0.0069371988
## 342   -1      New Hampshire  3.503674e-03 0.005095872 -0.0062446672
## 343    0      New Hampshire  7.535342e-03 0.010960706 -0.0153440217
## 344    1      New Hampshire  1.736218e-03 0.007794391 -0.0119136790
## 345   NA      New Hampshire  4.635780e-03 0.008637148 -0.0134602504
## 346  -12         New Jersey            NA         NaN            NA
## 347  -11         New Jersey            NA         NaN            NA
## 348  -10         New Jersey            NA         NaN            NA
## 349   -9         New Jersey            NA         NaN            NA
## 350   -8         New Jersey            NA         NaN            NA
## 351   -7         New Jersey            NA         NaN            NA
## 352   -6         New Jersey -5.790568e-04 0.017211443 -0.0287722502
## 353   -5         New Jersey  4.180303e-04 0.017300978 -0.0291163987
## 354   -4         New Jersey -9.176344e-04 0.009260094 -0.0181476291
## 355   -3         New Jersey -1.113657e-03 0.008987226 -0.0183712079
## 356   -2         New Jersey  4.185996e-04 0.011133042 -0.0194704844
## 357   -1         New Jersey  1.773718e-03 0.010563371 -0.0179053643
## 358    0         New Jersey -3.417452e-03 0.012382814 -0.0233459233
## 359    1         New Jersey -1.862684e-02 0.012790361 -0.0348138348
## 360   NA         New Jersey -1.102215e-02 0.011459970 -0.0243348428
## 361  -12         New Mexico            NA         NaN            NA
## 362  -11         New Mexico            NA         NaN            NA
## 363  -10         New Mexico            NA         NaN            NA
## 364   -9         New Mexico            NA         NaN            NA
## 365   -8         New Mexico            NA         NaN            NA
## 366   -7         New Mexico            NA         NaN            NA
## 367   -6         New Mexico  3.267756e-03 0.024513702 -0.0417373459
## 368   -5         New Mexico -3.495510e-03 0.011722245 -0.0234306109
## 369   -4         New Mexico  1.055547e-03 0.009200518 -0.0156298335
## 370   -3         New Mexico  2.933805e-03 0.007413261 -0.0103411305
## 371   -2         New Mexico -3.047410e-03 0.013313685 -0.0214979628
## 372   -1         New Mexico -7.141884e-04 0.007112820 -0.0132599062
## 373    0         New Mexico -2.495741e-02 0.028713792 -0.0576269526
## 374    1         New Mexico -4.559683e-02 0.051110576 -0.1014023976
## 375   NA         New Mexico -3.527712e-02 0.039892787 -0.0798167339
## 376  -12           New York            NA         NaN            NA
## 377  -11           New York            NA         NaN            NA
## 378  -10           New York            NA         NaN            NA
## 379   -9           New York            NA         NaN            NA
```

```
## 380  -8          New York            NA         NaN            NA
## 381  -7          New York            NA         NaN            NA
## 382  -6          New York  1.598151e-05 0.013493518 -0.0294342557
## 383  -5          New York -1.726374e-05 0.009917406 -0.0221723111
## 384  -4          New York  4.526955e-06 0.005245284 -0.0105340530
## 385  -3          New York  1.177596e-05 0.006016599 -0.0116981625
## 386  -2          New York -8.287400e-06 0.006920581 -0.0124980117
## 387  -1          New York -6.733288e-06 0.005735612 -0.0116738175
## 388   0          New York  4.465051e-04 0.006162014 -0.0103689703
## 389   1          New York  3.426964e-03 0.005945348 -0.0080912295
## 390  NA          New York  1.936735e-03 0.005944418 -0.0091903337
## 391 -12      North Dakota            NA         NaN            NA
## 392 -11      North Dakota            NA         NaN            NA
## 393 -10      North Dakota            NA         NaN            NA
## 394  -9      North Dakota            NA         NaN            NA
## 395  -8      North Dakota            NA         NaN            NA
## 396  -7      North Dakota            NA         NaN            NA
## 397  -6      North Dakota  7.365070e-04 0.007246470 -0.0137676375
## 398  -5      North Dakota -7.978633e-04 0.007549573 -0.0162675441
## 399  -4      North Dakota -1.998166e-03 0.010348618 -0.0208266728
## 400  -3      North Dakota -4.367890e-03 0.007376853 -0.0153331026
## 401  -2      North Dakota  3.184796e-03 0.007240797 -0.0133216337
## 402  -1      North Dakota  3.242616e-03 0.005511497 -0.0070590245
## 403   0      North Dakota -2.870206e-03 0.006812089 -0.0152837077
## 404   1      North Dakota  1.265383e-02 0.022229363 -0.0303284726
## 405  NA      North Dakota  4.891811e-03 0.013736269 -0.0210987196
## 406 -12              Ohio            NA         NaN            NA
## 407 -11              Ohio            NA         NaN            NA
## 408 -10              Ohio            NA         NaN            NA
## 409  -9              Ohio            NA         NaN            NA
## 410  -8              Ohio            NA         NaN            NA
## 411  -7              Ohio            NA         NaN            NA
## 412  -6              Ohio -3.226225e-12 0.016279129 -0.0252939590
## 413  -5              Ohio  3.598524e-12 0.016866537 -0.0297760388
## 414  -4              Ohio  8.848200e-13 0.006943526 -0.0141409548
## 415  -3              Ohio -7.308612e-12 0.007178005 -0.0146949327
## 416  -2              Ohio  4.644771e-12 0.008957145 -0.0182001926
## 417  -1              Ohio  1.406694e-12 0.010554963 -0.0191638308
## 418   0              Ohio -8.337684e-03 0.012993919 -0.0282133400
## 419   1              Ohio -9.242049e-03 0.015196338 -0.0306901723
## 420  NA              Ohio -8.789867e-03 0.014071500 -0.0293180063
## 421 -12            Oregon            NA         NaN            NA
## 422 -11            Oregon            NA         NaN            NA
## 423 -10            Oregon            NA         NaN            NA
## 424  -9            Oregon            NA         NaN            NA
## 425  -8            Oregon            NA         NaN            NA
## 426  -7            Oregon            NA         NaN            NA
## 427  -6            Oregon -3.095536e-03 0.026571843 -0.0497216028
## 428  -5            Oregon  3.177208e-03 0.029730464 -0.0556878514
## 429  -4            Oregon  6.465552e-03 0.011359646 -0.0178610101
## 430  -3            Oregon -4.548286e-04 0.014603499 -0.0296717140
## 431  -2            Oregon -5.597237e-03 0.019667765 -0.0396354337
## 432  -1            Oregon -4.951587e-04 0.016309612 -0.0296994206
## 433   0            Oregon -2.984363e-02 0.039722088 -0.0776775203
```

```
## 434    1           Oregon -3.869174e-02 0.050587751 -0.0963807442
## 435   NA           Oregon -3.426769e-02 0.045136355 -0.0870291323
## 436  -12     Pennsylvania            NA         NaN            NA
## 437  -11     Pennsylvania            NA         NaN            NA
## 438  -10     Pennsylvania            NA         NaN            NA
## 439   -9     Pennsylvania            NA         NaN            NA
## 440   -8     Pennsylvania            NA         NaN            NA
## 441   -7     Pennsylvania -9.303645e-04 0.011159970 -0.0189361032
## 442   -6     Pennsylvania  9.710774e-04 0.011064714 -0.0179873658
## 443   -5     Pennsylvania  3.626142e-04 0.007510738 -0.0155957316
## 444   -4     Pennsylvania -1.502775e-03 0.004977692 -0.0112624592
## 445   -3     Pennsylvania  1.319086e-04 0.006549635 -0.0151928358
## 446   -2     Pennsylvania -1.228539e-03 0.005561617 -0.0123705837
## 447   -1     Pennsylvania  2.196078e-03 0.012433473 -0.0235655713
## 448    0     Pennsylvania -6.346238e-03 0.009687319 -0.0237993944
## 449    1     Pennsylvania -2.522150e-03 0.012912656 -0.0294041852
## 450   NA     Pennsylvania -4.434194e-03 0.011208744 -0.0267264954
## 451  -12     Rhode Island            NA         NaN            NA
## 452  -11     Rhode Island            NA         NaN            NA
## 453  -10     Rhode Island            NA         NaN            NA
## 454   -9     Rhode Island            NA         NaN            NA
## 455   -8     Rhode Island            NA         NaN            NA
## 456   -7     Rhode Island            NA         NaN            NA
## 457   -6     Rhode Island  1.873017e-03 0.019369247 -0.0322376132
## 458   -5     Rhode Island -2.649163e-03 0.025996277 -0.0448520205
## 459   -4     Rhode Island  1.767065e-05 0.010277599 -0.0172814253
## 460   -3     Rhode Island -4.244557e-03 0.006689052 -0.0130208775
## 461   -2     Rhode Island -7.050353e-04 0.012378842 -0.0212488324
## 462   -1     Rhode Island  5.708068e-03 0.018799777 -0.0275397825
## 463    0     Rhode Island -2.607626e-02 0.019984596 -0.0524884136
## 464    1     Rhode Island -2.878355e-02 0.022421602 -0.0579378707
## 465   NA     Rhode Island -2.742990e-02 0.021192551 -0.0552131419
## 466  -12             Utah  3.211616e-02 0.100993411 -0.1536692820
## 467  -11             Utah  4.427464e-02 0.092692149 -0.1321134313
## 468  -10             Utah  6.203015e-03 0.018205328 -0.0272444973
## 469   -9             Utah  5.657675e-03 0.019739808 -0.0301444876
## 470   -8             Utah -5.031201e-03 0.021569954 -0.0388729470
## 471   -7             Utah -9.093646e-03 0.023855427 -0.0447586818
## 472   -6             Utah -3.626450e-03 0.011809243 -0.0217460775
## 473   -5             Utah -3.927796e-03 0.012006250 -0.0222283280
## 474   -4             Utah -1.989720e-02 0.023573720 -0.0463838164
## 475   -3             Utah -1.404148e-02 0.024017913 -0.0467222927
## 476   -2             Utah -1.840027e-02 0.024023333 -0.0473244307
## 477   -1             Utah -1.423345e-02 0.022398220 -0.0438129164
## 478    0             Utah -1.293536e-02 0.021724185 -0.0423158386
## 479    1             Utah            NA         NaN            NA
## 480   NA             Utah -1.293536e-02 0.021724185 -0.0423158386
## 481  -12          Vermont            NA         NaN            NA
## 482  -11          Vermont            NA         NaN            NA
## 483  -10          Vermont            NA         NaN            NA
## 484   -9          Vermont            NA         NaN            NA
## 485   -8          Vermont            NA         NaN            NA
## 486   -7          Vermont            NA         NaN            NA
## 487   -6          Vermont  1.644172e-03 0.068223087 -0.1287258935
```

```
## 488   -5              Vermont -5.973458e-04 0.061428399 -0.1165527025
## 489   -4              Vermont -8.107928e-05 0.029970926 -0.0486734371
## 490   -3              Vermont -2.335120e-03 0.032960025 -0.0547381424
## 491   -2              Vermont -6.393527e-05 0.036297602 -0.0613657562
## 492   -1              Vermont  1.433308e-03 0.031129420 -0.0506322169
## 493    0              Vermont -6.342753e-03 0.030015054 -0.0528626602
## 494    1              Vermont -5.839137e-03 0.023023210 -0.0481325395
## 495   NA              Vermont -6.090945e-03 0.025919488 -0.0484204287
## 496  -12             Virginia            NA         NaN            NA
## 497  -11             Virginia -7.306868e-04 0.034724219 -0.0591293489
## 498  -10             Virginia -1.900077e-03 0.036246623 -0.0575939380
## 499   -9             Virginia -9.985294e-06 0.011581062 -0.0184420762
## 500   -8             Virginia -4.902555e-03 0.007971018 -0.0182597925
## 501   -7             Virginia  7.779925e-04 0.009491652 -0.0187839299
## 502   -6             Virginia  8.975205e-04 0.006493561 -0.0099748318
## 503   -5             Virginia  2.685063e-03 0.011000633 -0.0182783849
## 504   -4             Virginia  3.326303e-03 0.012867846 -0.0201730783
## 505   -3             Virginia  2.600563e-03 0.016660026 -0.0289633426
## 506   -2             Virginia -1.284143e-03 0.012263720 -0.0252922079
## 507   -1             Virginia -1.459996e-03 0.010043907 -0.0206759271
## 508    0             Virginia -1.401384e-02 0.007154205 -0.0246454268
## 509    1             Virginia -1.472141e-02 0.007497121 -0.0258703843
## 510   NA             Virginia -1.436762e-02 0.007314591 -0.0252486658
## 511  -12           Washington            NA         NaN            NA
## 512  -11           Washington            NA         NaN            NA
## 513  -10           Washington            NA         NaN            NA
## 514   -9           Washington            NA         NaN            NA
## 515   -8           Washington            NA         NaN            NA
## 516   -7           Washington            NA         NaN            NA
## 517   -6           Washington -2.101208e-04 0.014059299 -0.0263769983
## 518   -5           Washington  1.225242e-04 0.015213856 -0.0280590028
## 519   -4           Washington -1.670990e-04 0.005428772 -0.0085319667
## 520   -3           Washington -3.650552e-04 0.005410329 -0.0100435511
## 521   -2           Washington -6.773906e-05 0.007612819 -0.0128304500
## 522   -1           Washington  6.874899e-04 0.012227161 -0.0209373272
## 523    0           Washington -3.232985e-02 0.021058752 -0.0595313031
## 524    1           Washington -4.561742e-02 0.030208607 -0.0830792813
## 525   NA           Washington -3.897364e-02 0.025555946 -0.0709795283
## 526  -12        West Virginia            NA         NaN            NA
## 527  -11        West Virginia            NA         NaN            NA
## 528  -10        West Virginia            NA         NaN            NA
## 529   -9        West Virginia            NA         NaN            NA
## 530   -8        West Virginia            NA         NaN            NA
## 531   -7        West Virginia            NA         NaN            NA
## 532   -6        West Virginia  4.085459e-04 0.009212959 -0.0187415148
## 533   -5        West Virginia -4.661518e-04 0.008713304 -0.0170232486
## 534   -4        West Virginia -1.521051e-03 0.004088859 -0.0085984538
## 535   -3        West Virginia  4.406058e-03 0.009969879 -0.0148652084
## 536   -2        West Virginia -1.916591e-03 0.007539303 -0.0117903657
## 537   -1        West Virginia -9.108102e-04 0.004739824 -0.0097393180
## 538    0        West Virginia -3.322117e-02 0.028565260 -0.0649126802
## 539    1        West Virginia -5.064441e-02 0.045456050 -0.0992161580
## 540   NA        West Virginia -4.193279e-02 0.036984567 -0.0818675903
##      upper_bound
```

```
## 1    0.078134387
## 2    0.059022215
## 3    0.026859978
## 4    0.012964496
## 5    0.016818169
## 6    0.014407099
## 7    0.015015184
## 8    0.011916145
## 9    0.006332432
## 10   0.006205907
## 11   0.005825194
## 12   0.006073928
## 13  -0.002682828
## 14  -0.005366612
## 15  -0.004522737
## 16            NA
## 17            NA
## 18            NA
## 19            NA
## 20            NA
## 21   0.041346130
## 22   0.032073580
## 23   0.035407328
## 24   0.016185006
## 25   0.021513585
## 26   0.017600165
## 27   0.011281682
## 28   0.013393484
## 29   0.006467355
## 30   0.009827969
## 31            NA
## 32            NA
## 33            NA
## 34            NA
## 35            NA
## 36            NA
## 37   0.044461138
## 38   0.023310869
## 39   0.025768368
## 40   0.017839550
## 41   0.015485512
## 42   0.014924099
## 43   0.014535866
## 44   0.021268720
## 45   0.018219981
## 46            NA
## 47            NA
## 48            NA
## 49            NA
## 50            NA
## 51            NA
## 52   0.055363551
## 53   0.028722839
## 54   0.019453151
```

```
## 55   0.023344153
## 56   0.020428427
## 57   0.021989787
## 58   0.034048055
## 59   0.036551788
## 60   0.034806507
## 61            NA
## 62            NA
## 63            NA
## 64            NA
## 65            NA
## 66            NA
## 67   0.029132225
## 68   0.029351267
## 69   0.009965563
## 70   0.011690605
## 71   0.013429691
## 72   0.016027577
## 73   0.030327259
## 74   0.051547429
## 75   0.040363514
## 76            NA
## 77            NA
## 78            NA
## 79            NA
## 80            NA
## 81            NA
## 82   0.044361598
## 83   0.019712538
## 84   0.010212072
## 85   0.016682901
## 86   0.017379918
## 87   0.024766921
## 88   0.036951259
## 89   0.034478288
## 90   0.035714775
## 91            NA
## 92            NA
## 93            NA
## 94            NA
## 95            NA
## 96            NA
## 97   0.022615344
## 98   0.023738098
## 99   0.019458350
## 100  0.016446014
## 101  0.017974565
## 102  0.015614759
## 103  0.015535827
## 104  0.022500010
## 105  0.016340144
## 106           NA
## 107           NA
## 108           NA
```

```
## 109          NA
## 110          NA
## 111          NA
## 112 0.059277850
## 113 0.048804708
## 114 0.026623412
## 115 0.036621099
## 116 0.038858355
## 117 0.019720521
## 118 0.015705571
## 119 0.010533047
## 120 0.005191573
## 121          NA
## 122          NA
## 123          NA
## 124          NA
## 125          NA
## 126          NA
## 127 0.025269953
## 128 0.010080263
## 129 0.004433351
## 130 0.010152380
## 131 0.025090702
## 132 0.010459459
## 133 0.030373122
## 134 0.038344361
## 135 0.034572175
## 136          NA
## 137          NA
## 138          NA
## 139          NA
## 140          NA
## 141          NA
## 142 0.026528406
## 143 0.024184110
## 144 0.012869536
## 145 0.014176792
## 146 0.017549034
## 147 0.009334280
## 148 0.011622956
## 149 0.019531143
## 150 0.012422131
## 151 0.044478385
## 152 0.030903072
## 153 0.027635350
## 154 0.014587792
## 155 0.009812186
## 156 0.013794201
## 157 0.004553078
## 158 0.017671366
## 159 0.018431367
## 160 0.020369904
## 161 0.016445118
## 162 0.028457640
```

```
## 163  0.025213222
## 164           NA
## 165  0.025213222
## 166           NA
## 167           NA
## 168           NA
## 169           NA
## 170           NA
## 171           NA
## 172  0.018847866
## 173  0.013407066
## 174  0.005372952
## 175  0.017780085
## 176  0.008944414
## 177  0.007236378
## 178  0.013458823
## 179  0.024504782
## 180  0.018770426
## 181           NA
## 182           NA
## 183           NA
## 184           NA
## 185           NA
## 186  0.010329582
## 187  0.008815106
## 188  0.005506764
## 189  0.007002527
## 190  0.005173870
## 191  0.002819800
## 192  0.005439442
## 193  0.006334092
## 194  0.014000117
## 195  0.010303897
## 196           NA
## 197           NA
## 198           NA
## 199           NA
## 200           NA
## 201           NA
## 202  0.024216874
## 203  0.022006591
## 204  0.011782865
## 205  0.012626003
## 206  0.015560167
## 207  0.006908200
## 208  0.009387154
## 209  0.005502900
## 210  0.003287005
## 211           NA
## 212           NA
## 213           NA
## 214           NA
## 215           NA
## 216           NA
```

```
## 217  0.031818311
## 218  0.029304177
## 219  0.017281736
## 220  0.018775130
## 221  0.023834757
## 222  0.012232355
## 223  0.030608312
## 224  0.031305354
## 225  0.029821972
## 226           NA
## 227           NA
## 228           NA
## 229           NA
## 230  0.035761288
## 231  0.023260248
## 232  0.009746053
## 233  0.008208953
## 234  0.011090323
## 235  0.004698703
## 236  0.011026488
## 237  0.027770672
## 238  0.032340656
## 239  0.052097329
## 240  0.041434817
## 241           NA
## 242           NA
## 243           NA
## 244           NA
## 245           NA
## 246           NA
## 247  0.022689668
## 248  0.015967688
## 249  0.005712041
## 250  0.021535635
## 251  0.013408693
## 252  0.007285044
## 253  0.011770163
## 254  0.012715760
## 255  0.010856996
## 256           NA
## 257           NA
## 258           NA
## 259           NA
## 260           NA
## 261           NA
## 262  0.025311960
## 263  0.027469693
## 264  0.006908501
## 265  0.014425531
## 266  0.015023630
## 267  0.014915291
## 268  0.015988968
## 269  0.022918538
## 270  0.019456250
```

```
## 271          NA
## 272          NA
## 273          NA
## 274          NA
## 275          NA
## 276          NA
## 277 0.019411754
## 278 0.017718114
## 279 0.011167041
## 280 0.011685826
## 281 0.010766910
## 282 0.004880455
## 283 0.005649917
## 284 0.002751088
## 285 0.002670764
## 286          NA
## 287          NA
## 288          NA
## 289          NA
## 290 0.060699405
## 291 0.059903213
## 292 0.017206487
## 293 0.024864220
## 294 0.030390790
## 295 0.018827764
## 296 0.028809898
## 297 0.045089006
## 298 0.063971465
## 299 0.063460395
## 300 0.063704578
## 301 0.028832779
## 302 0.028086323
## 303 0.021562226
## 304 0.014025620
## 305 0.019861003
## 306 0.015843243
## 307 0.003101641
## 308 0.003434026
## 309 0.035930877
## 310 0.025946031
## 311 0.017204807
## 312 0.005637100
## 313 0.010949751
## 314          NA
## 315 0.010949751
## 316          NA
## 317          NA
## 318          NA
## 319          NA
## 320          NA
## 321          NA
## 322 0.048773383
## 323 0.047808348
## 324 0.017631029
```

```
## 325  0.020219342
## 326  0.030303265
## 327  0.026801666
## 328  0.044087920
## 329  0.057171245
## 330  0.050297387
## 331           NA
## 332           NA
## 333           NA
## 334           NA
## 335           NA
## 336           NA
## 337  0.024974180
## 338  0.013287017
## 339  0.008981010
## 340  0.021687191
## 341  0.015190771
## 342  0.013272527
## 343  0.025904094
## 344  0.016452813
## 345  0.020944668
## 346           NA
## 347           NA
## 348           NA
## 349           NA
## 350           NA
## 351           NA
## 352  0.029513766
## 353  0.029650892
## 354  0.017023197
## 355  0.015466803
## 356  0.019512161
## 357  0.020173250
## 358  0.020060400
## 359  0.008700856
## 360  0.010423563
## 361           NA
## 362           NA
## 363           NA
## 364           NA
## 365           NA
## 366           NA
## 367  0.039934894
## 368  0.016914412
## 369  0.017567666
## 370  0.015252767
## 371  0.022296467
## 372  0.013415540
## 373  0.030680730
## 374  0.051359055
## 375  0.041139401
## 376           NA
## 377           NA
## 378           NA
```

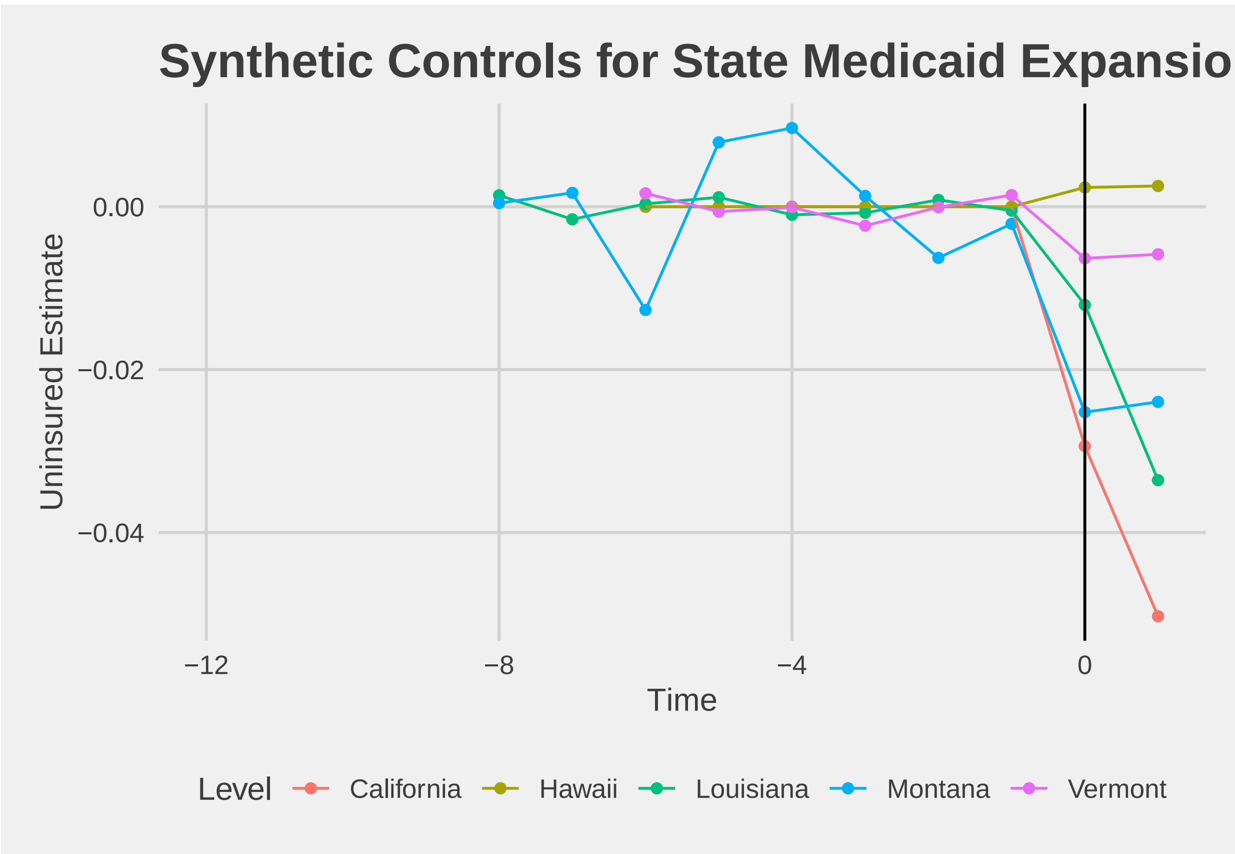
```
## 379          NA
## 380          NA
## 381          NA
## 382  0.025919399
## 383  0.020737037
## 384  0.011394258
## 385  0.013221952
## 386  0.014814745
## 387  0.011940612
## 388  0.013017724
## 389  0.015153156
## 390  0.013923056
## 391          NA
## 392          NA
## 393          NA
## 394          NA
## 395          NA
## 396          NA
## 397  0.014430121
## 398  0.015174543
## 399  0.019039339
## 400  0.010862182
## 401  0.017190587
## 402  0.011993532
## 403  0.012347530
## 404  0.039792746
## 405  0.025713117
## 406          NA
## 407          NA
## 408          NA
## 409          NA
## 410          NA
## 411          NA
## 412  0.033305410
## 413  0.032944633
## 414  0.011697036
## 415  0.011840466
## 416  0.015890432
## 417  0.017517170
## 418  0.017118866
## 419  0.020048810
## 420  0.018601262
## 421          NA
## 422          NA
## 423          NA
## 424          NA
## 425          NA
## 426          NA
## 427  0.047350747
## 428  0.057606456
## 429  0.025716653
## 430  0.029087267
## 431  0.033907525
## 432  0.029063150
```

```
## 433  0.044784373
## 434  0.056749460
## 435  0.050990444
## 436           NA
## 437           NA
## 438           NA
## 439           NA
## 440           NA
## 441  0.020608802
## 442  0.022048040
## 443  0.015599868
## 444  0.008088038
## 445  0.013159929
## 446  0.008535682
## 447  0.025746359
## 448  0.016022580
## 449  0.025664740
## 450  0.020907135
## 451           NA
## 452           NA
## 453           NA
## 454           NA
## 455           NA
## 456           NA
## 457  0.033914460
## 458  0.041295571
## 459  0.017297247
## 460  0.008136164
## 461  0.020617640
## 462  0.034636697
## 463  0.019149175
## 464  0.022571882
## 465  0.020860528
## 466  0.186525375
## 467  0.177409073
## 468  0.033990494
## 469  0.036296763
## 470  0.033725217
## 471  0.035453791
## 472  0.018036996
## 473  0.018209079
## 474  0.026027332
## 475  0.032358508
## 476  0.028499108
## 477  0.029250937
## 478  0.029081826
## 479           NA
## 480  0.029081826
## 481           NA
## 482           NA
## 483           NA
## 484           NA
## 485           NA
## 486           NA
```

```
## 487  0.110723919
## 488  0.101778665
## 489  0.057728247
## 490  0.061435385
## 491  0.069222936
## 492  0.057052234
## 493  0.050489999
## 494  0.041422082
## 495  0.041420582
## 496           NA
## 497  0.060665978
## 498  0.064928561
## 499  0.018389838
## 500  0.010860700
## 501  0.019628311
## 502  0.012534444
## 503  0.018582771
## 504  0.022142179
## 505  0.026226049
## 506  0.015884485
## 507  0.016186055
## 508  0.002078094
## 509  0.002508740
## 510  0.002105746
## 511           NA
## 512           NA
## 513           NA
## 514           NA
## 515           NA
## 516           NA
## 517  0.026111207
## 518  0.027128900
## 519  0.011602160
## 520  0.009522832
## 521  0.015042443
## 522  0.020203797
## 523  0.014192372
## 524  0.017845801
## 525  0.015807247
## 526           NA
## 527           NA
## 528           NA
## 529           NA
## 530           NA
## 531           NA
## 532  0.017261121
## 533  0.015182772
## 534  0.008005999
## 535  0.020101524
## 536  0.012862472
## 537  0.008056480
## 538  0.021470530
## 539  0.035984751
## 540  0.028022682
```

```r
# ---------
no_pool_synsum_filt_att <- as.data.frame(no_pool_synsum$att) %>% filter(Level %in% c("Hawaii", "Califor

no_pool_synsum_filt_att %>%
  ggplot(aes(x = Time, y = Estimate, color = Level)) +
  geom_point() +
  geom_line() +
  geom_vline(xintercept = 0) +
  theme_fivethirtyeight() +
  theme(axis.title = element_text(),
        legend.position = "bottom") +
  ggtitle('Synthetic Controls for State Medicaid Expansion') +
  xlab('Time') +
  ylab('Uninsured Estimate')
```

```
## Warning: Removed 31 rows containing missing values or values outside the scale range
## (`geom_point()`).

## Warning: Removed 31 rows containing missing values or values outside the scale range
## (`geom_line()`).
```



- Estimate a multisynth model using time cohorts. For the purpose of this exercise, you can simplify the treatment time so that states that adopted Medicaid expansion within the same year (i.e. all states that adopted epxansion in 2016) count for the same cohort. Plot the treatment effects for these time cohorts.

```r
# multisynth model time cohorts
```

```r
# -----------------------------------------------------------------
ppool_syn_time <- multisynth(uninsured_rate ~ adopted,
                             State,
                             year,
                             medicaid_expansion_clean,
                             n_leads = 6,
                             time_cohort = TRUE)           # time cohort set to TRUE

# save summary
ppool_syn_time_summ <- summary(ppool_syn_time)

ppool_syn_time_summ
```

```
##
## Call:
## multisynth(form = uninsured_rate ~ adopted, unit = State, time = year,
##     data = medicaid_expansion_clean, n_leads = 6, time_cohort = TRUE)
##
## Average ATT Estimate (Std. Error): -0.016  (0.006)
##
## Global L2 Imbalance: 0.001
## Scaled Global L2 Imbalance: 0.008
## Percent improvement from uniform global weights: 99.2
##
## Individual L2 Imbalance: 0.005
## Scaled Individual L2 Imbalance: 0.018
## Percent improvement from uniform individual weights: 98.2
##
##  Time Since Treatment   Level    Estimate   Std.Error lower_bound  upper_bound
##                     0 Average -0.01039793 0.004731448 -0.02038151 -0.001681147
##                     1 Average -0.01864128 0.005918010 -0.03017164 -0.006974274
##                     2 Average -0.01674715 0.005971125 -0.02819730 -0.005390146
##                     3 Average -0.01971271 0.006150733 -0.03181973 -0.008017841
##                     4 Average -0.02100310 0.006051889 -0.03298715 -0.009754213
##                     5 Average -0.02033303 0.005577805 -0.03088554 -0.009006378
```

```r
ppool_syn_time_summ$att %>%
  ggplot(aes(x = Time, y = Estimate, color = Level)) +
  geom_point() +
  geom_line() +
  geom_vline(xintercept = 0) +
  theme_fivethirtyeight() +
  theme(axis.title = element_text(),
        legend.position = 'None') +
  ggtitle('Synthetic Controls for State Adoption of Medicare') +
  xlab('Time') +
  ylab('Uninsured Estimate') +
  facet_wrap(~Level)
```

```
## Warning: Removed 32 rows containing missing values or values outside the scale range
## (`geom_point()`).
```

```
## Warning: Removed 32 rows containing missing values or values outside the scale range
## (`geom_line()`).
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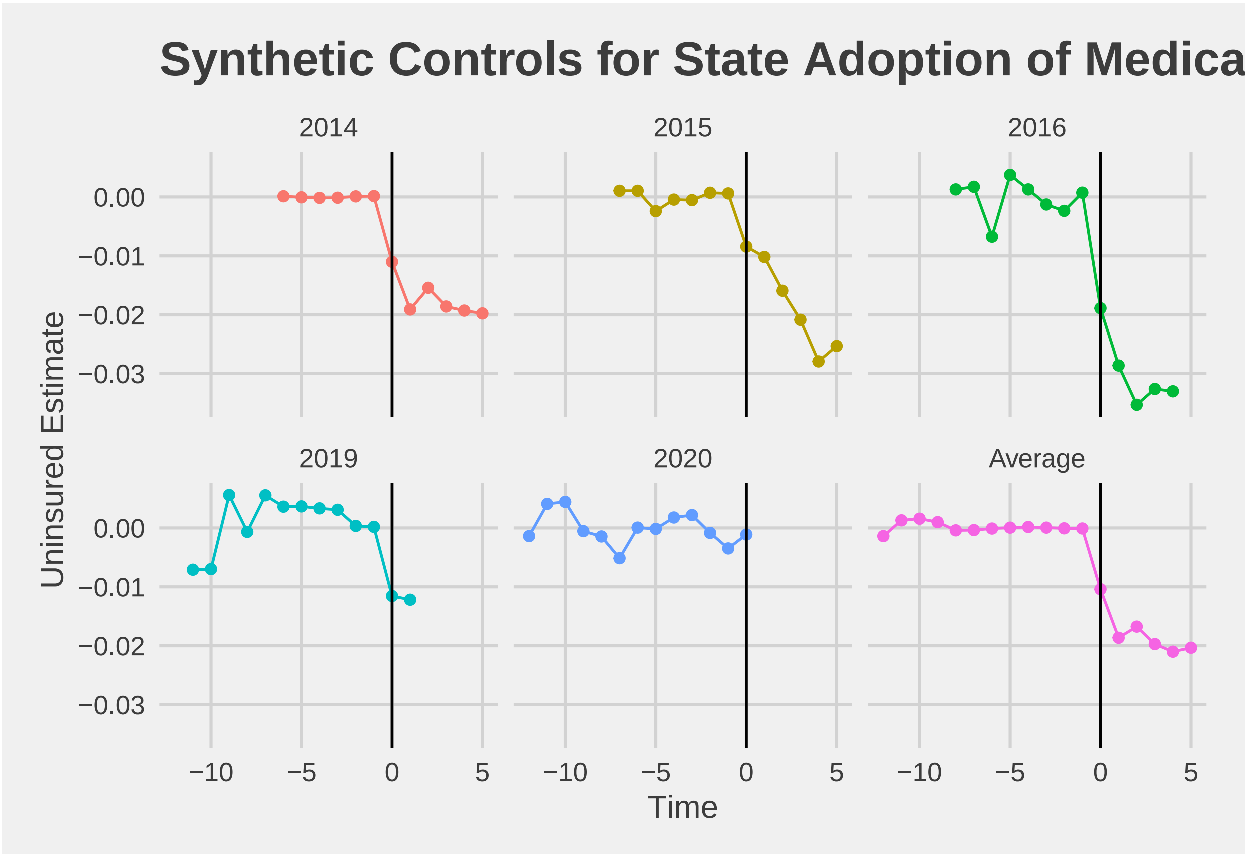

Discussion Questions

- One feature of Medicaid is that it is jointly administered by the federal government and the states, and states have some flexibility in how they implement Medicaid. For example, during the Trump administration, several states applied for waivers where they could add work requirements to the eligibility standards (i.e. an individual needed to work for 80 hours/month to qualify for Medicaid). Given these differences, do you see evidence for the idea that different states had different treatment effect sizes?
- **Answer**:
  - When analyzing on a state-by-state basis there does seem to be a slight difference between treatment effect, with some states having a slightly positive ATT and others having an ATT of nearly -0.04. This somewhat dissolves when considering time cohorts, where each group falls between 0 and -0.02. Even here, the range of ATT is very small and not as large as I would have expected given the different conditions for treatment.
- Do you see evidence for the idea that early adopters of Medicaid expansion enjoyed a larger decrease in the uninsured population?
- **Answer**:
  - It can be difficult to assess this robustly given that there appears to be a continued decline in the uninsured population for some years after treatment in the early adopters. However, in the year of treatment there does not appear to be a significant difference in the treatment effect.

General Discussion Questions

- Why are DiD and synthetic control estimates well suited to studies of aggregated units like cities, states, countries, etc?
- **Answer**:
  - DiD can effectively control for unmeasured, time-invariant variables by comparing changes over time between treatment and control groups, assuming similar trends absent the treatment. It allows you to draw insights despite unknown confounders that are often present in natural experiments and thus are useful for large-scale policy changes that affect multiple regions. SCM allows for a similar analysis when the DiD assumption of pre-treatment similarities does not hold, making it easier to perform a treatment analysis at regional scales when multiple factors may influence the outcome.
- What role does selection into treatment play in DiD/synthetic control versus regression discontinuity? When would we want to use either method?
- **Answer**:
  - DiD and SCM handle nonrandom selection by assuming parallel trends or matching pretreatment characteristics, respectively, making them suitable for analyses with multiple periods. Regression discontinuity uses a sharp cutoff for treatment assignment,making it suitable for natural experiements where treatment is assigned by a specific threshold. DiD or SCM are more suitable for broader policy impacts across units whill regression discontinuity applies when precise cutoff-based treatment assignment allows for quasi-experimental conditions.