Time series analysis with updated window definition

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Select varible of interests

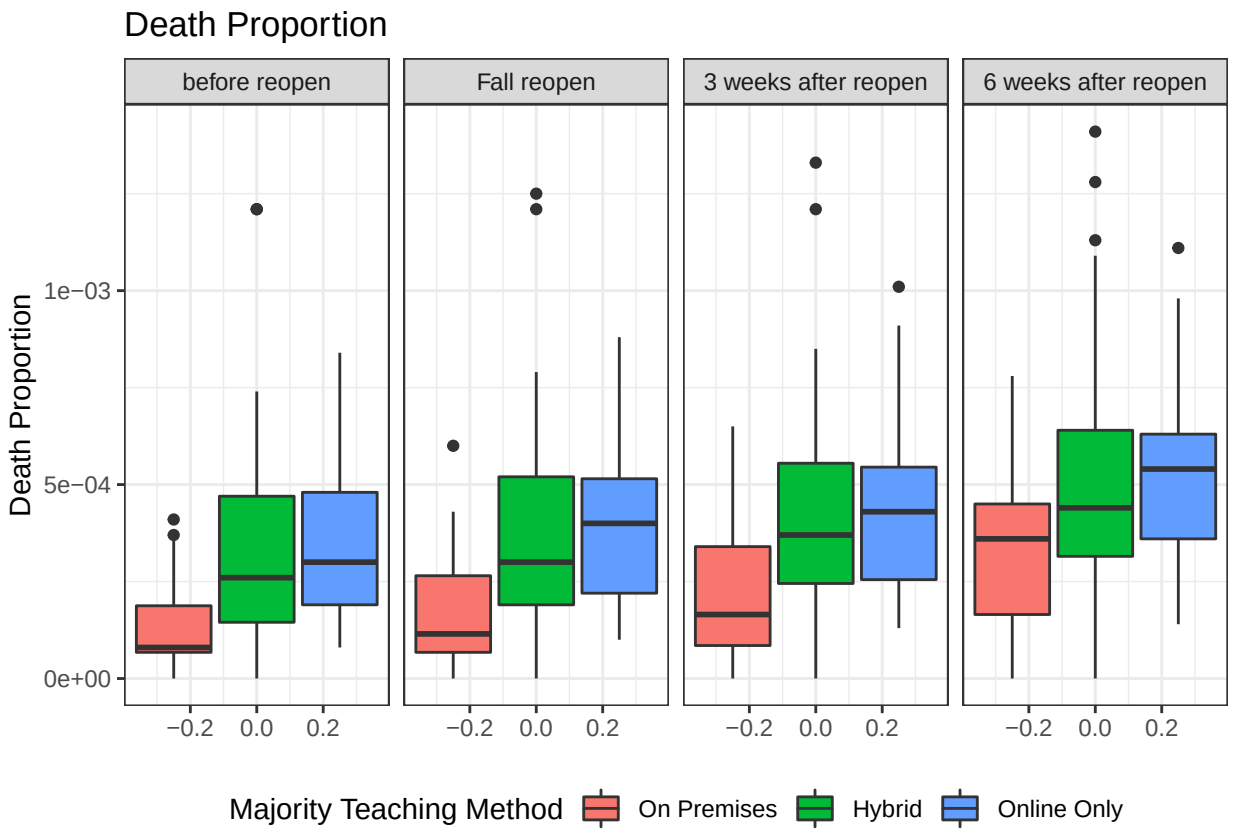
```
## If you don't have the covidcast package, run following line

#devtools::install_github("cmu-delphi/covidcast", ref = "main", subdir = "R-packages/covidcast",depende
```

```
source("step2_data_wrangle.R")
################### school reopen dates ###################
district_policies <- OH_K12 %>%
  distinct(county,county_enroll,leaid,district_enroll,schooltemporaryshutdown,opendategrouped,teachingm
# Calculate the proportion and generate date brackets
prop_opendate <- district_policies%>%
  filter(!schooltemporaryshutdown %in% c('Closed indefinitely','Pending','Unknown'))%>%
  group_by(county,county_enroll,opendategrouped)%>%
  summarise(n_opendate = sum(district_enroll))%>% # number of students under certain date for each coun
  mutate(prop_opendate = round(n_opendate/county_enroll,2))%>% # proportion
  group_by(county)%>%
  #filter(prop_opendate>0.6)%>%
  slice(which.max(prop_opendate))%>% # filter large proportions of students with same reopen dates #can
  mutate(threeweeks_lag_open = opendategrouped+21,sixweeks_lag_open = opendategrouped+42,twomonths_lag_
  select(-n_opendate)
```

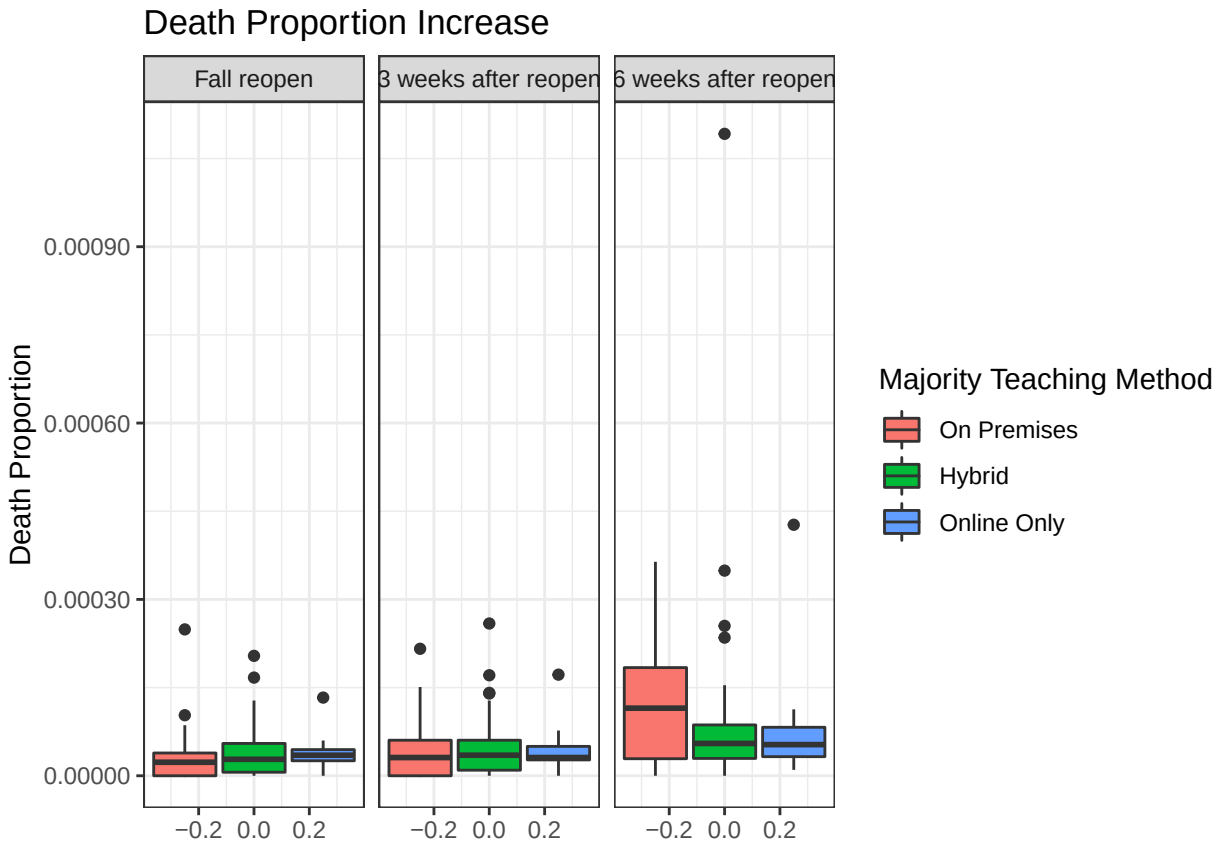
```
opendate_cases <- case_mobility%>%
  inner_join(prop_opendate,by=c('COUNTY'='county'))%>%
  group_by(COUNTY)%>%
  filter(DATE>=opendategrouped & DATE<=beforechristmas)%>%
  mutate(window_id = case_when(DATE<threeweeks_lag_open~"fall_reopento21d",
    DATE>=threeweeks_lag_open & DATE<sixweeks_lag_open~'reopen_21dto42d',
    DATE>= sixweeks_lag_open & DATE<twomonths_lag_open ~ 'reopen_42dto63d',
    TRUE ~ 'before_christmas'
  ))%>%
  mutate(death_prop = round(CUMDEATHS/POPULATION,5),
         window_id = as.factor(window_id))%>%
  left_join(wide_teaching_enroll,by=c('COUNTY'='county','county_enroll'))
# select the start date and end date data for each window of time

start_of_window <- opendate_cases%>%
  group_by(COUNTY,window_id)%>%
  arrange(DATE)%>%
  filter(row_number()==1)%>%
  ungroup()%>%
  mutate(y_label = case_when(window_id == "fall_reopento21d"~'before reopen',
```

```
    window_id == "reopen_21dto42d" ~ 'Fall reopen',
    window_id == "reopen_42dto63d" ~ '3 weeks after reopen',
    window_id == "before_christmas" ~ '6 weeks after reopen'
  ))%>%
  select(-opendategrouped,-threeweeks_lag_open,-sixweeks_lag_open,-twomonths_lag_open,-beforechristmas,
```

```
start_of_window$y_label <- factor(start_of_window$y_label,
         levels = c("before reopen",
         "Fall reopen",
         "3 weeks after reopen",
         "6 weeks after reopen"))

start_of_window$major_teaching <- factor(start_of_window$major_teaching,
         levels = c("On Premises",
         "Hybrid",
         "Online Only"))

start_of_window %>%
  ggplot(aes(y = death_prop,
             fill = major_teaching))+
  geom_boxplot(na.rm = T) +
  facet_grid(~y_label)+
  theme_bw()+
  labs(y = "Death Proportion",
       fill = "Majority Teaching Method",
       title = "Death Proportion")+theme(legend.position = "bottom")
```



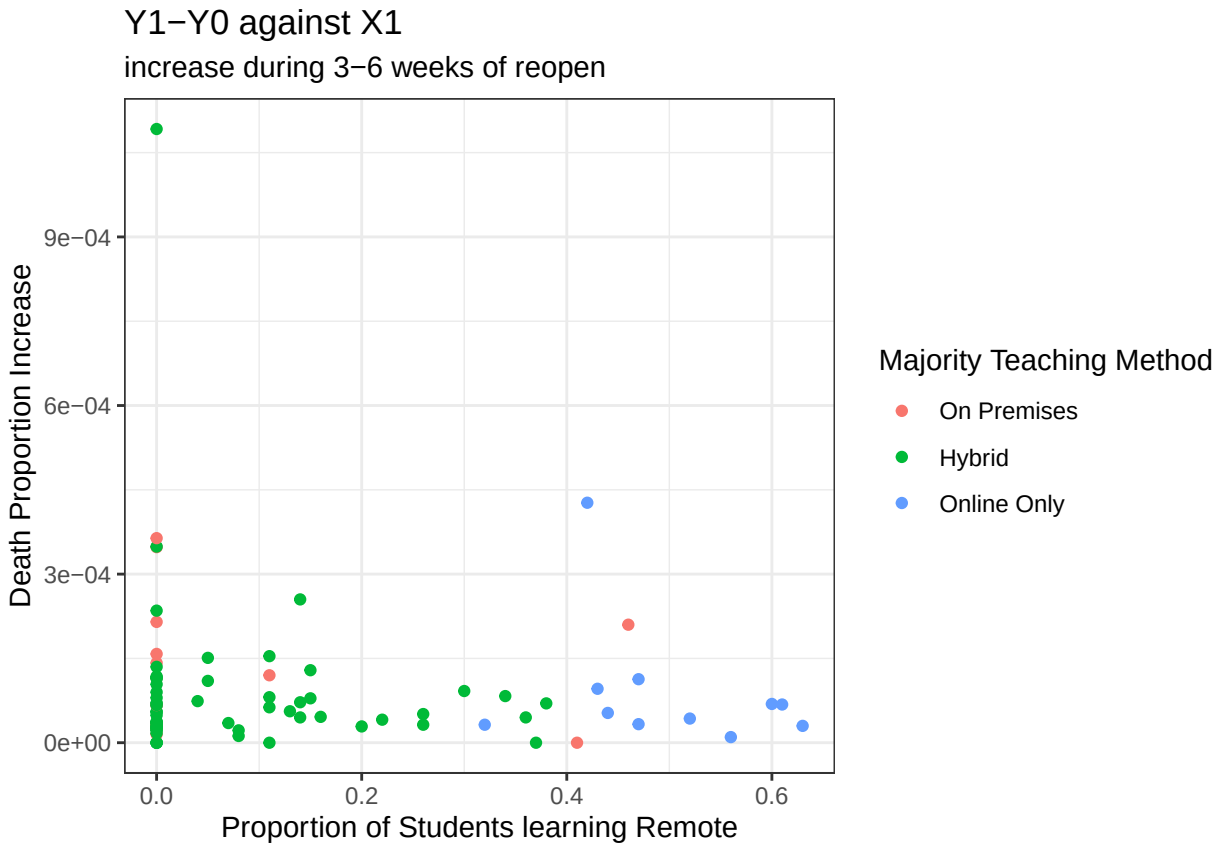
```
#ggsave("Deathprop_box.jpg", width = 8.5, height = 5)

require(scales)
start_of_window %>%
  group_by(COUNTY)%>%
  mutate(death_inc = CUMDEATHS-lag(CUMDEATHS))%>%
  drop_na(death_inc)%>%
  mutate(death_prop_inc = round(death_inc/POPULATION,6))%>%
  ggplot(aes(y = death_prop_inc,
             fill = major_teaching))+
  geom_boxplot(na.rm = T) +
  theme_bw()+
  labs(y = "Death Proportion",
       fill = "Majority Teaching Method",
       title = "Death Proportion Increase") +
  facet_grid(~y_label)+
  scale_y_continuous(labels = comma)
```




```
#ggsave("Deathpropinc_box.jpg", width = 8.5, height = 5)
```

```
start_of_window %>%
  group_by(COUNTY)%>%
  mutate(death_inc = CUMDEATHS-lag(CUMDEATHS))%>%
  drop_na(death_inc)%>%
  mutate(death_prop_inc = round(death_inc/POPULATION,6))%>%
  filter(y_label == "6 weeks after reopen") %>%
  ggplot(aes(x = Online_Only, y = death_prop_inc, color = major_teaching)) +
```

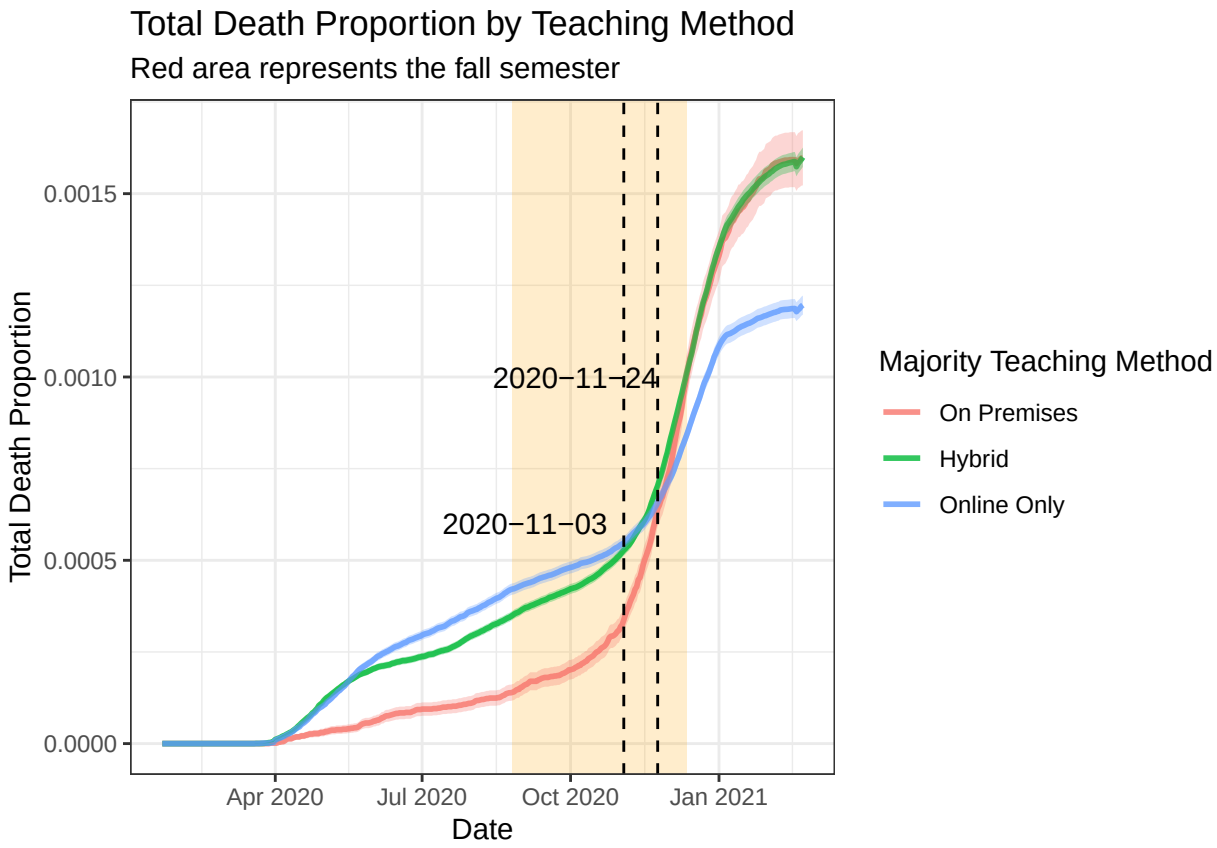
```
  geom_point()+
  theme_bw() +
  labs(x = "Proportion of Students learning Remote",
       y = "Death Proportion Increase",
       title = "Y1-Y0 against X1",
       subtitle = "increase during 3-6 weeks of reopen",
       color = "Majority Teaching Method")
```




```
ggsave("y1x1.jpg", width = 7, height = 5)
```

```
county_policy_wide$major_teaching <- factor(county_policy_wide$major_teaching,
         levels = c("On Premises",
         "Hybrid",
         "Online Only"))
# see when the intesection happens
date.intercept <- as.Date("2020-11-24")

# add 95% confidence bans
confidence_level <- .95
z_cl <- qnorm(confidence_level)

# case_policy_wide
case_policy_wide <- case_mobility %>%
  left_join(county_policy_wide[,c("county","major_teaching","Online_Only","Hybrid","On_Premises")],by =
  mutate(death_prop = CUMDEATHS/POPULATION)

# plot
```

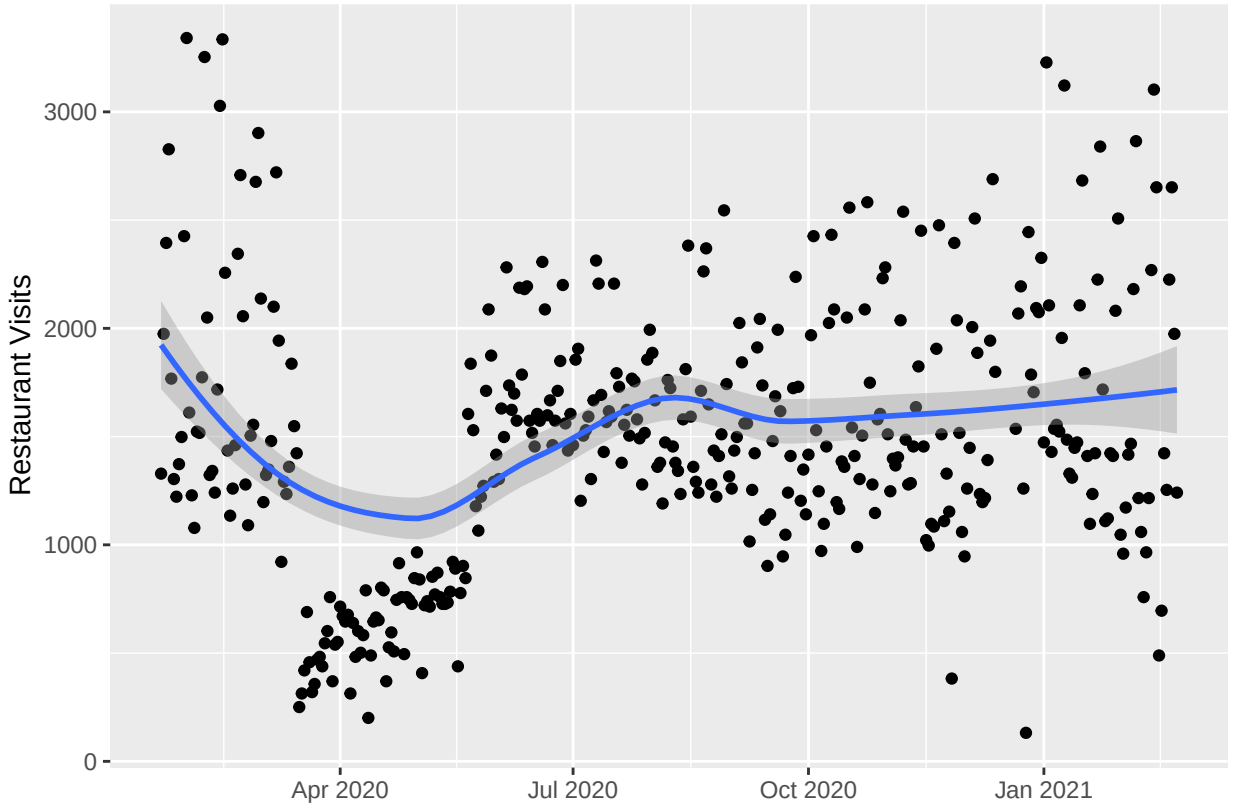
```r
case_policy_wide%>%
  group_by(DATE, major_teaching) %>%
  drop_na(major_teaching)%>%
  summarise(total_deaths = sum(CUMDEATHS),
            total_pop = sum(POPULATION),
            death_prop = total_deaths/total_pop,
            death_prop_upper = death_prop + z_cl*sqrt(death_prop*(1 - death_prop)/total_pop),
            death_prop_lower = death_prop - z_cl*sqrt(death_prop*(1 - death_prop)/total_pop),
            .groups = "drop") %>%
  ggplot(aes(x = DATE, y = death_prop, group = major_teaching))+
    geom_rect(data=opendate_cases[1,],
            aes(xmin=as.Date("2020/08/26"), xmax=as.Date("2020/12/12"),
                ymin=-Inf,ymax=Inf),
            color = NA,alpha=0.2, show.legend = F, fill = "orange") +
    geom_line(aes(color = major_teaching),size = 1, alpha = .8) +
    geom_ribbon(aes(ymin = death_prop_lower, ymax = death_prop_upper,
                    fill= major_teaching),
                alpha = .3, show.legend = F)+
    geom_vline(xintercept = date.intercept, linetype = "dashed") +
    annotate("text",x = date.intercept,y = .001,
             label = date.intercept,
             hjust = 1.0) +
    geom_vline(xintercept = as.Date('2020/11/03'), linetype = "dashed") +
    annotate("text",x = as.Date('2020/11/03'),y = .0006,
              label =as.Date('2020/11/03'),
              hjust = 1.1) +
    theme_bw() +
    labs(x = "Date", y = "Total Death Proportion",
         title = "Total Death Proportion by Teaching Method",
         subtitle = "Red area represents the fall semester",
         color = "Majority Teaching Method")
```




```
# +
#   scale_x_date(date_breaks = "2 month", date_labels = "%b-%y")
```

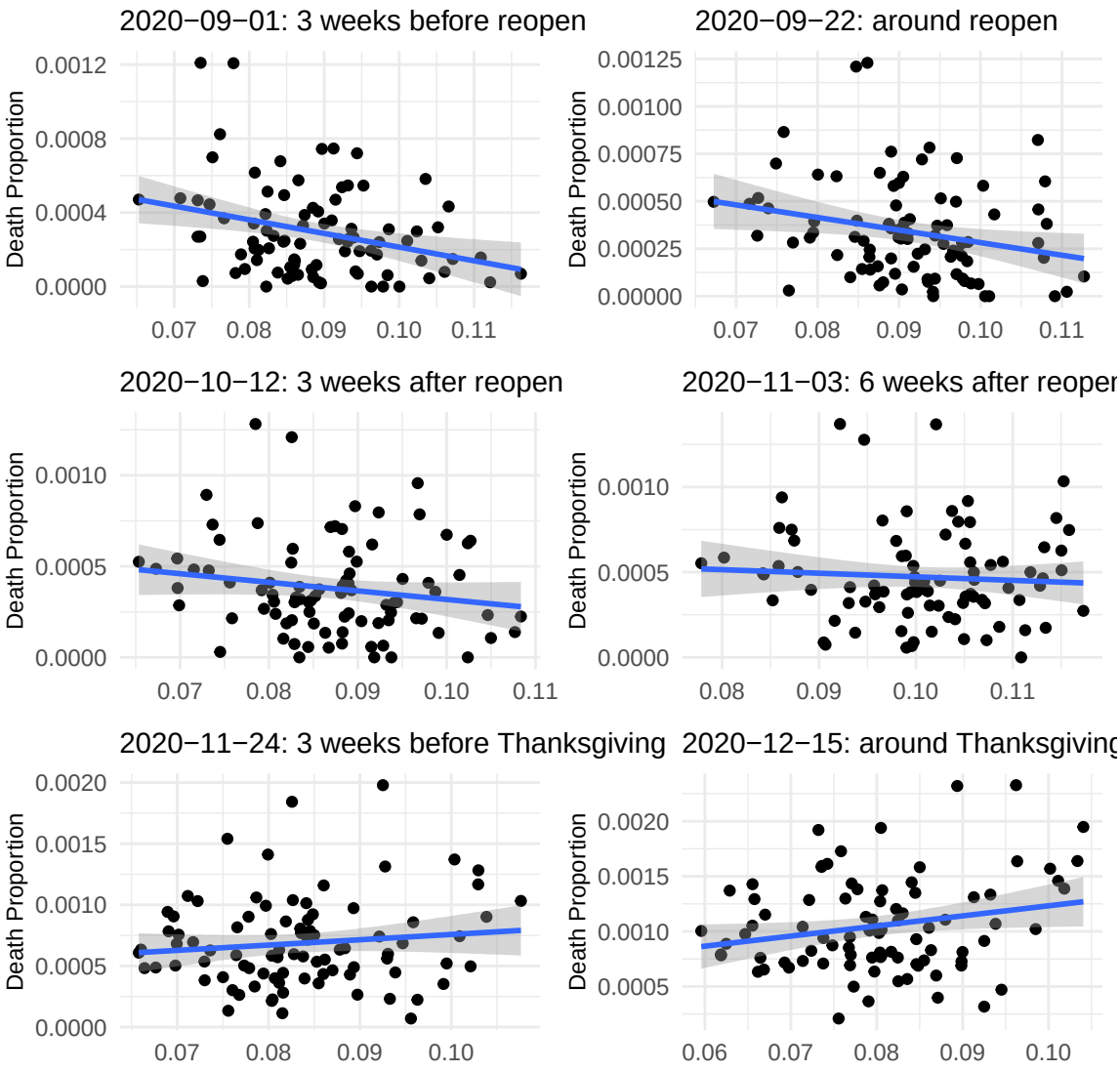
```
case_mobility%>%
  filter(COUNTY=="HARRISON")%>%
  mutate(death_prop = CUMDEATHS/POPULATION)%>%
  ggplot(aes(x=DATE,y=res_visit_prop))+geom_point()+geom_smooth()+labs(x="",y="Restaurant Visits")
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'

## Warning: Removed 7 rows containing non-finite values (stat_smooth).

## Warning: Removed 7 rows containing missing values (geom_point).
```

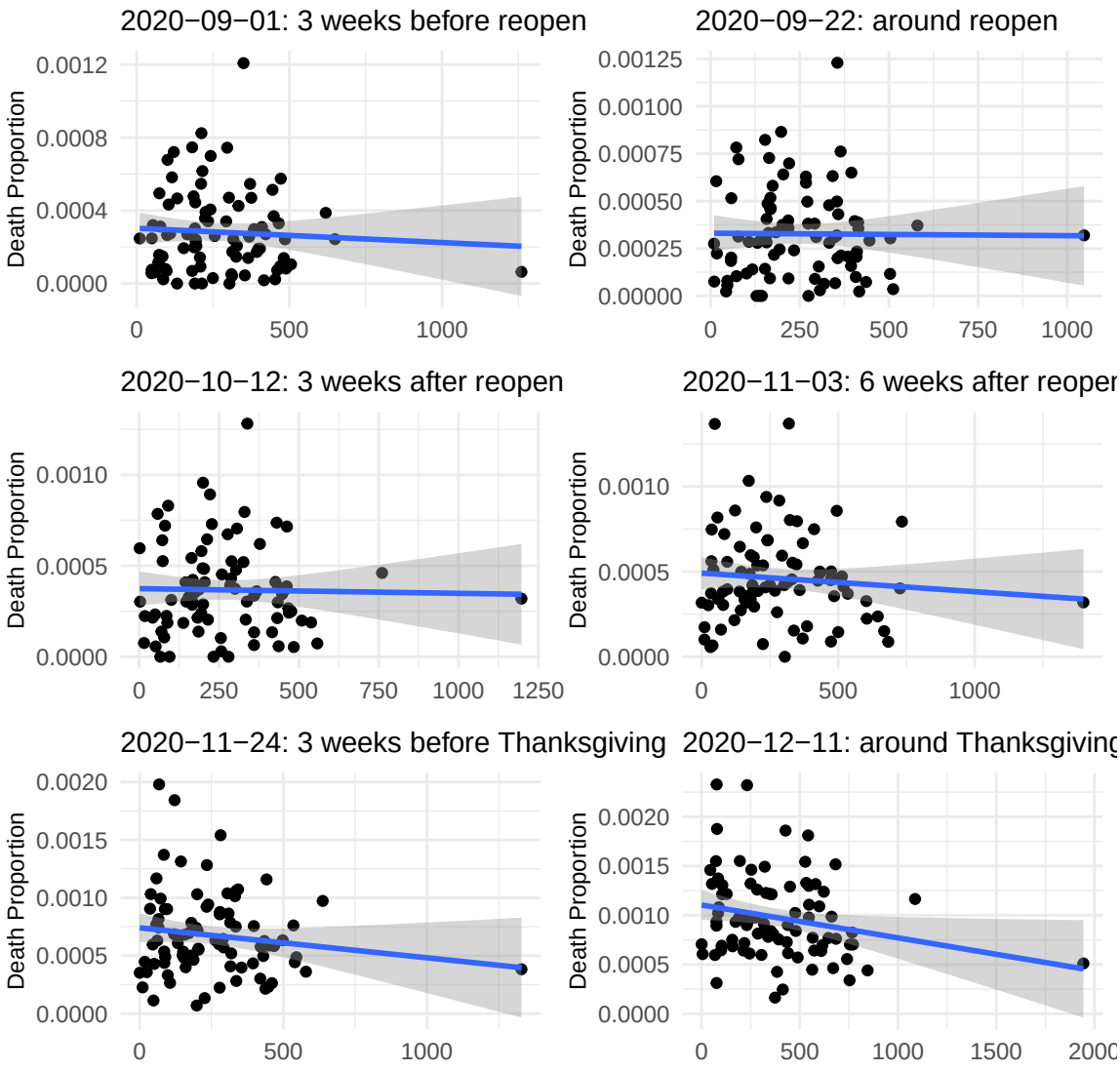



```
library(gridExtra)

date_plot <- function(date,var,title_text){
  p <- case_mobility%>%
  filter(DATE == date)%>%
  mutate(death_prop = CUMDEATHS/POPULATION)%>%
  ggplot(aes(x= get(var),y = death_prop))+theme_minimal()+
  labs(x=NULL,y="Death Proportion",title=paste0(date,": ",title_text))+geom_point()+geom_smooth(method=
return(p)
}

p11 <- date_plot(date = '2020-09-01',var = "work_prop_7d",title_text = "3 weeks before reopen")

p12 <- date_plot(date = '2020-09-01',var = "res_visit_prop",title_text = "3 weeks before reopen")

p13 <- date_plot(date = '2020-09-01',var = "bar_visit_prop",title_text = "3 weeks before reopen")

#############################################################################
p21 <- date_plot(date = '2020-09-22',var = "work_prop_7d",title_text = "around reopen")

p22 <- date_plot(date = '2020-09-22',var = "res_visit_prop",title_text = "around reopen")

p23 <- date_plot(date = '2020-09-22',var = "bar_visit_prop",title_text = "around reopen")

#############################################################################
p31 <- date_plot(date = '2020-10-12',var = "work_prop_7d",title_text = "3 weeks after reopen")

p32 <- date_plot(date = '2020-10-12',var = "res_visit_prop",title_text = "3 weeks after reopen")
```

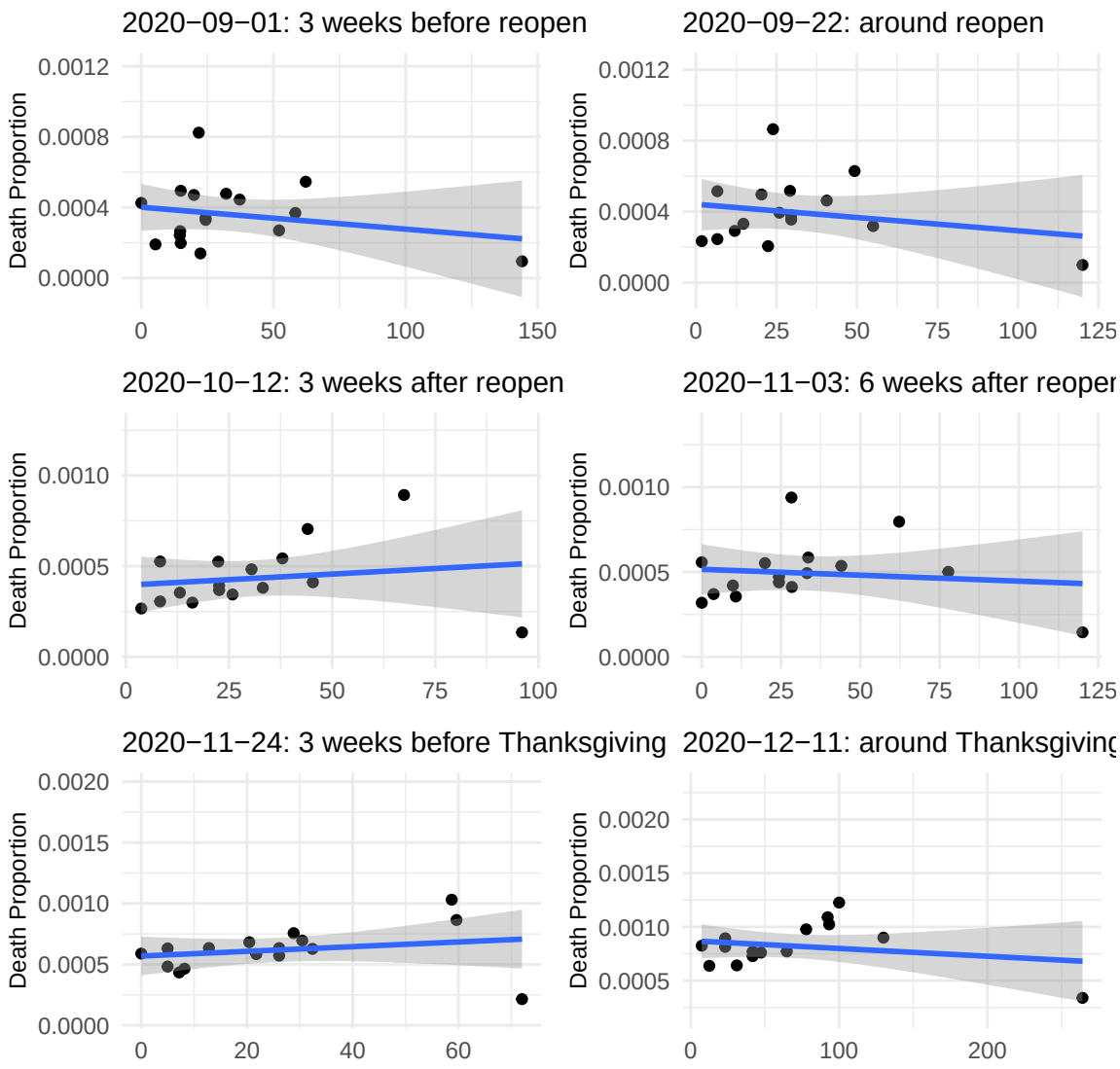
```r
p33 <- date_plot(date = '2020-10-12',var = "bar_visit_prop",title_text = "3 weeks after reopen")

##############################################################################
p41 <- date_plot(date = '2020-11-03',var = "work_prop_7d",title_text = "6 weeks after reopen")

p42 <- date_plot(date = '2020-11-03',var = "res_visit_prop",title_text = "6 weeks after reopen")

p43 <- date_plot(date = '2020-11-03',var = "bar_visit_prop",title_text = "6 weeks after reopen")

##############################################################################
p51 <- date_plot(date = '2020-11-24',var = "work_prop_7d",title_text = "3 weeks before Thanksgiving")

p52 <- date_plot(date = '2020-11-24',var = "res_visit_prop",title_text = "3 weeks before Thanksgiving")

p53 <- date_plot(date = '2020-11-24',var = "bar_visit_prop",title_text = "3 weeks before Thanksgiving")
##############################################################################
p61 <- date_plot(date = '2020-12-15',var = "work_prop_7d",title_text = "around Thanksgiving")

p62 <- date_plot(date = '2020-12-11',var = "res_visit_prop",title_text = "around Thanksgiving")

p63 <- date_plot(date = '2020-12-11',var = "bar_visit_prop",title_text = "around Thanksgiving")

##############################################################################
p71 <- date_plot(date = '2021-02-22',var = "work_prop_7d",title_text = "")

p72 <- date_plot(date = '2021-02-22',var = "res_visit_prop",title_text = "")

p73 <- date_plot(date = '2021-02-22',var = "bar_visit_prop",title_text = "")

##############################################################################
options(scipen=10000)
grid.arrange(p11, p21, p31,p41,p51,p61,nrow = 3,ncol=2,widths = c(5,5),heights = c(3,3,3),bottom= "Frac
```




```
grid.arrange(p12, p22, p32,p42,p52,p62,nrow = 3,ncol=2,widths = c(5,5),heights = c(3,3,3),bottom="Resta
```




```
grid.arrange(p13,p23,p33,p43,p53,p63,nrow = 3,ncol=2,widths = c(5,5),heights = c(3,3,3),bottom="Bar visi
```



Bar visits by population

```
avg_work <- case_policy_wide %>%
  drop_na(major_teaching)%>%
  group_by(DATE, major_teaching) %>%
  summarise(avg_ptwork_prop_7d = mean(work_prop_7d))
```

```
## `summarise()` regrouping output by 'DATE' (override with `.groups` argument)
```

```
avg_work%>%
  ggplot(aes(x = DATE, y = avg_ptwork_prop_7d, color = major_teaching))+
    geom_rect(data = avg_work[1,],
              aes(xmin=as.Date("2020/08/26"), xmax=as.Date("2020/12/12")),
                  ymin=-Inf,ymax=Inf,color = NA,alpha=0.3,show.legend = F, fill = "orange") +
    geom_line(aes(color = major_teaching),size = 1, alpha = .8) +
        geom_vline(xintercept = date.intercept, linetype = "dashed") +
    annotate("text",x = date.intercept,y = .06,
             label = date.intercept,
             hjust = 1.0) +
    geom_vline(xintercept = as.Date('2020/11/03'), linetype = "dashed") +
```

```r
    annotate("text",x = as.Date('2020/11/03'),y = .11,
             label =as.Date('2020/11/03'),
             hjust = 1.1) +
    theme_bw() +
    labs(x = "Date", y = "Average Mobility Porportion",
         title = "Average Mobility Proportion by Teaching Method",
         subtitle = "Red area represents the fall semester",
         color = "Majority Teaching Method",
         caption = "The fraction of devices that spent between 3 and 6 hours at a location other than th
  theme(legend.position = "bottom")
```

```
## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
## hours at a location other than their home during the daytime (SafeGraph’s)' in
## 'mbcsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
## hours at a location other than their home during the daytime (SafeGraph’s)' in
## 'mbcsToSbcs': dot substituted for <80>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
## hours at a location other than their home during the daytime (SafeGraph’s)' in
## 'mbcsToSbcs': dot substituted for <99>

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## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
```

```
## hours at a location other than their home during the daytime (SafeGraph’s)' in
## 'mbcsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
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## 'mbcsToSbcs': dot substituted for <e2>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
## hours at a location other than their home during the daytime (SafeGraph’s)' in
## 'mbcsToSbcs': dot substituted for <80>

## Warning in grid.Call(C_textBounds, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
## hours at a location other than their home during the daytime (SafeGraph’s)' in
## 'mbcsToSbcs': dot substituted for <99>

## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
```

```
## hours at a location other than their home during the daytime (SafeGraph's)' in
## 'mbcsToSbcs': dot substituted for <e2>
```

```
## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
## hours at a location other than their home during the daytime (SafeGraph's)' in
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```
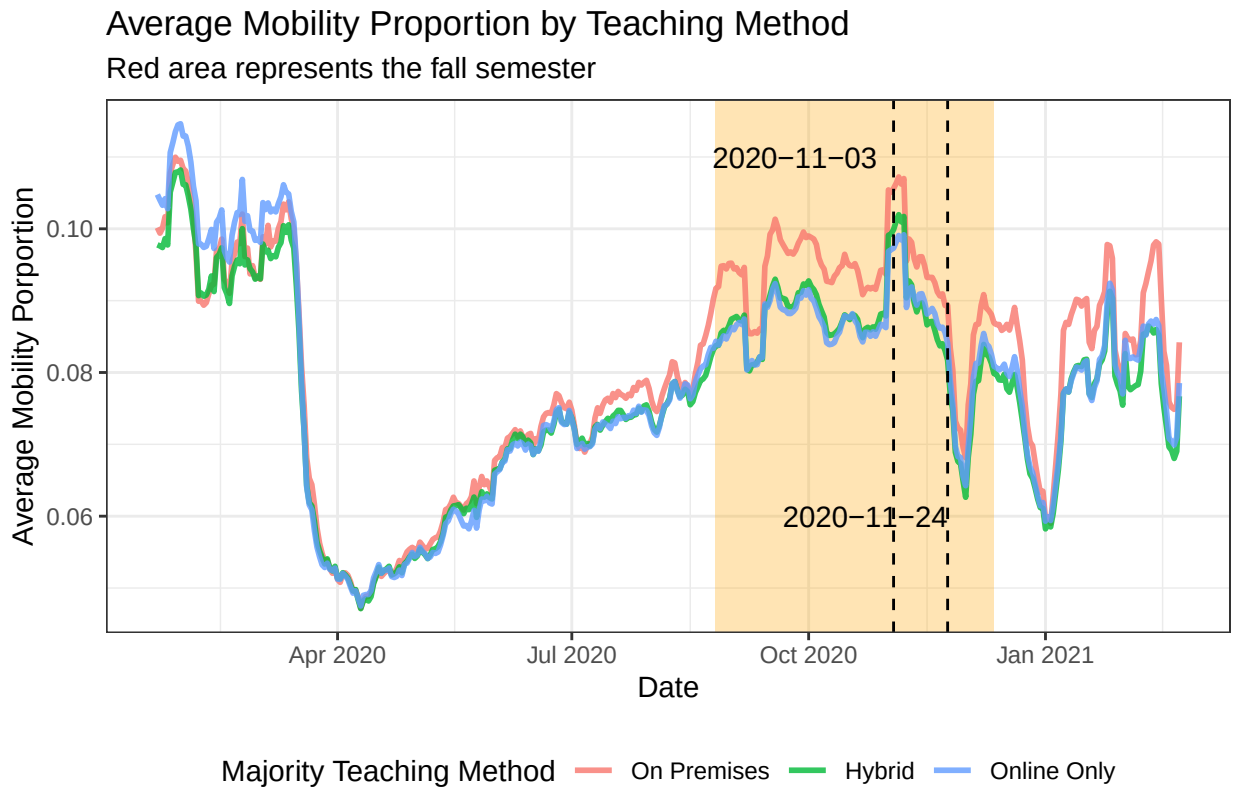

```
## Warning in grid.Call.graphics(C_text, as.graphicsAnnot(x$label), x$x, x$y, :
## conversion failure on 'The fraction of devices that spent between 3 and 6
## hours at a location other than their home during the daytime (SafeGraph's)' in
## 'mbcsToSbcs': dot substituted for <99>
```



n of devices that spent between 3 and 6 hours at a location other than their home during the daytime (SafeGraph...s)

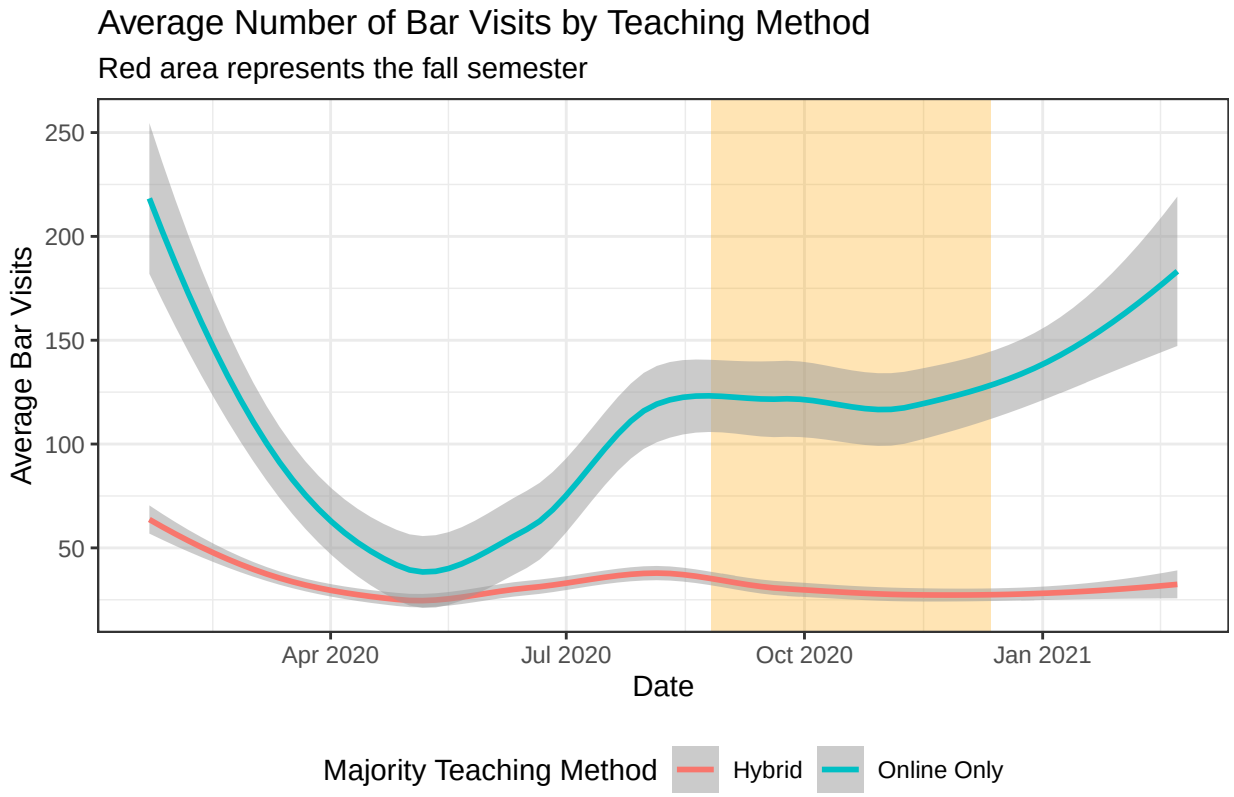
```
avg_bar_visit <- case_policy_wide %>%
  drop_na(bar_visit_prop)%>%
  group_by(DATE, major_teaching) %>%
  summarise(avg_bar_visit = mean(bar_visit_prop))
```

```
## `summarise()` regrouping output by 'DATE' (override with `.groups` argument)
```

```
avg_bar_visit%>%
  ggplot(aes(x = DATE, y = avg_bar_visit, color = major_teaching))+
    geom_rect(data = avg_bar_visit[1,],
              aes(xmin=as.Date("2020/08/26"), xmax=as.Date("2020/12/12")),
                  ymin=-Inf,ymax=Inf,color = NA,alpha=0.3, show.legend = F, fill = "orange") +
    #geom_point(size = 2, alpha = .8)+
    geom_smooth(size = 1, alpha = .5) +
    theme_bw() +
    labs(x = "Date", y = "Average Bar Visits",
```

```
        title = "Average Number of Bar Visits by Teaching Method",
        subtitle = "Red area represents the fall semester",
        color = "Majority Teaching Method",
        caption = "Weekly counts of visits and normalized by population size (SafeGraph)")+
  theme(legend.position = "bottom")
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



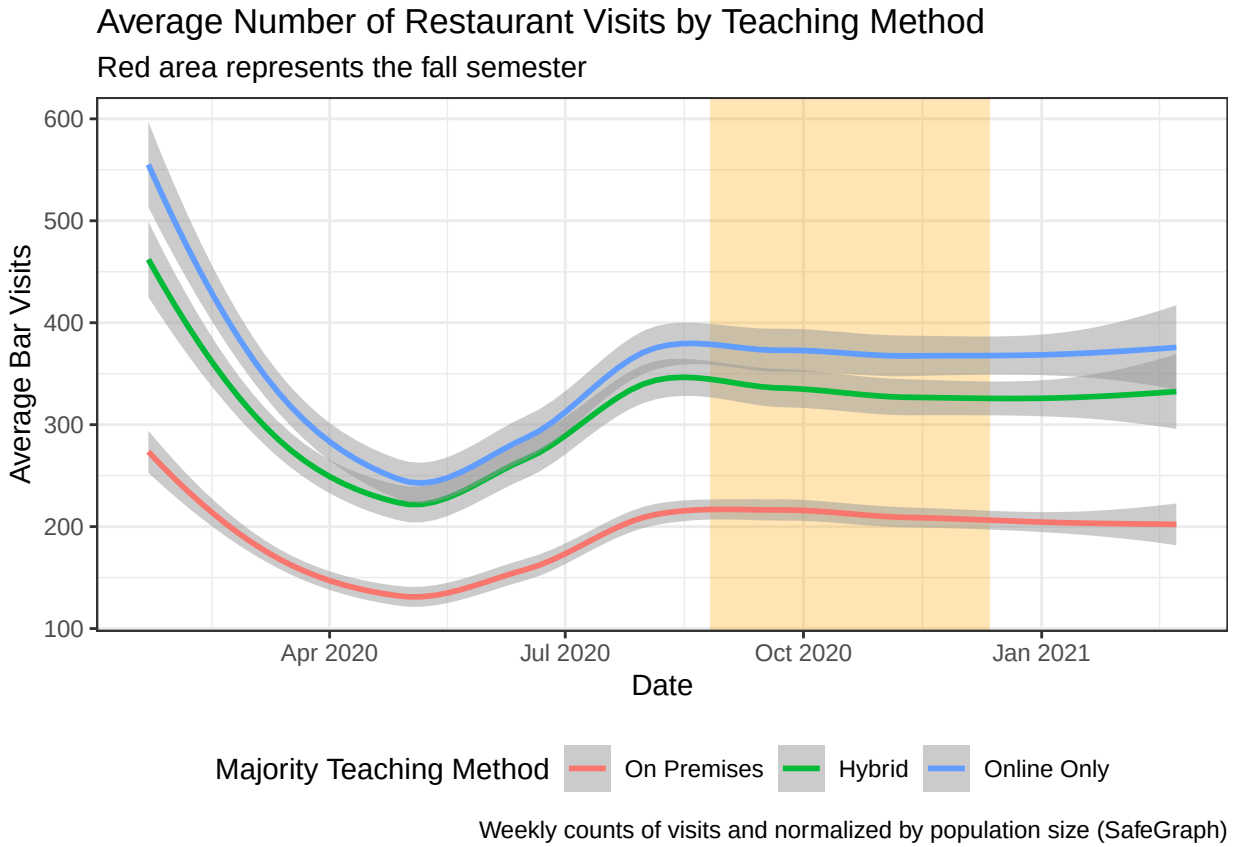

```
avg_res_visit <- case_policy_wide %>%
  drop_na(res_visit_prop)%>%
  group_by(DATE, major_teaching) %>%
  summarise(avg_res_visit = mean(res_visit_prop))
```

```
## `summarise()` regrouping output by 'DATE' (override with `.groups` argument)
```

```
avg_res_visit%>%
  drop_na(major_teaching)%>%
  ggplot(aes(x = DATE, y = avg_res_visit, color = major_teaching))+
    geom_rect(data = avg_res_visit[1,],
            aes(xmin=as.Date("2020/08/26"), xmax=as.Date("2020/12/12")),
                ymin=-Inf,ymax=Inf,color = NA,alpha=0.3, show.legend = F, fill = "orange") +
    #geom_point(size = 1, alpha = .8)+
    geom_smooth(size = 1, alpha = .5) +
    theme_bw() +
    labs(x = "Date", y = "Average Bar Visits",
         title = "Average Number of Restaurant Visits by Teaching Method",
         subtitle = "Red area represents the fall semester",
         color = "Majority Teaching Method",
```

```
        caption = "Weekly counts of visits and normalized by population size (SafeGraph)")+
  theme(legend.position = "bottom")
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



Notice

After removing missing values in each of the mobility measures, we end up with different sample size for each linear regression

NOTES:

Considering the lagging deaths, if we want to know the part-time work effects on the deaths, we should fit

y1 death after 3 weeks ~ y0 death today + work_prop_7d today

Check y0_label and y1_label for what window it is

```
y1y0 <- start_of_window %>%
  rename(y0_label = y_label)%>%
  group_by(COUNTY)%>%
  arrange(DATE)%>%
  mutate(y0= death_prop,y1 = lead(y0,n=1))%>%
  mutate(y1_label = lead(y0_label,n=1))%>%
  drop_na(y1)

summary(lm(y1~y0+work_prop_7d,na.action='na.omit',data = y1y0))
```

```
##
```

```
## Call:
## lm(formula = y1 ~ y0 + work_prop_7d, data = y1y0, na.action = "na.omit")
##
## Residuals:
##         Min          1Q      Median          3Q         Max
## -0.00009719 -0.00004274 -0.00001658  0.00001322  0.00102021
##
## Coefficients:
##                 Estimate  Std. Error t value             Pr(>|t|)
## (Intercept)  -0.00011443  0.00005342  -2.142             0.033156 *
## y0            1.01107722  0.02214861  45.650 < 0.0000000000000002 ***
## work_prop_7d  0.00192568  0.00057410   3.354             0.000917 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00009029 on 254 degrees of freedom
## Multiple R-squared:  0.8937, Adjusted R-squared:  0.8929
## F-statistic:  1068 on 2 and 254 DF,  p-value: < 0.00000000000000022
```

```
summary(lm(y1~y0+res_visit_prop,na.action='na.omit',data = y1y0))
```

```
##
## Call:
## lm(formula = y1 ~ y0 + res_visit_prop, data = y1y0, na.action = "na.omit")
##
## Residuals:
##         Min          1Q      Median          3Q         Max
## -0.00006329 -0.00004695 -0.00002166  0.00001133  0.00102853
##
## Coefficients:
##                       Estimate      Std. Error t value             Pr(>|t|)
## (Intercept)     0.000063523571  0.000014546476   4.367            0.0000185 ***
## y0              0.999059737847  0.024127807465  41.407 < 0.0000000000000002 ***
## res_visit_prop -0.000000009785  0.000000038388  -0.255                0.799
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00009337 on 247 degrees of freedom
##   (7 observations deleted due to missingness)
## Multiple R-squared:  0.8745, Adjusted R-squared:  0.8735
## F-statistic: 860.4 on 2 and 247 DF,  p-value: < 0.00000000000000022
```

```
summary(lm(y1~y0+bar_visit_prop,na.action='na.omit',data = y1y0))
```

```
##
## Call:
## lm(formula = y1 ~ y0 + bar_visit_prop, data = y1y0, na.action = "na.omit")
##
## Residuals:
##          Min           1Q       Median           3Q          Max
## -0.000041198 -0.000019574 -0.000006836  0.000012816  0.000080356
##
## Coefficients:
##                      Estimate     Std. Error t value             Pr(>|t|)
## (Intercept)     0.00004402219  0.00001079212   4.079             0.000174 ***
```

```
## y0              1.01466856193  0.02260236689  44.892 < 0.0000000000000002 ***
## bar_visit_prop -0.00000006807  0.00000007062  -0.964             0.339991
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00002811 on 47 degrees of freedom
##   (207 observations deleted due to missingness)
## Multiple R-squared:  0.9785, Adjusted R-squared:  0.9776
## F-statistic:  1070 on 2 and 47 DF,  p-value: < 0.00000000000000022
```

```
summary(lm(y1~y0+Hybrid,data = y1y0))
```

```
##
## Call:
## lm(formula = y1 ~ y0 + Hybrid, data = y1y0)
##
## Residuals:
##         Min          1Q      Median          3Q         Max
## -0.00006619 -0.00004703 -0.00002094  0.00001140  0.00103106
##
## Coefficients:
##                Estimate  Std. Error t value             Pr(>|t|)
## (Intercept)  0.00006619  0.00001497   4.421            0.0000146 ***
## y0           0.99367816  0.02208399  44.995 < 0.0000000000000002 ***
## Hybrid      -0.00000725  0.00002036  -0.356                0.722
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00009225 on 254 degrees of freedom
## Multiple R-squared:  0.8891, Adjusted R-squared:  0.8882
## F-statistic:  1018 on 2 and 254 DF,  p-value: < 0.00000000000000022
```

```
summary(lm(y1~y0+On_Premises,data = y1y0))
```

```
##
## Call:
## lm(formula = y1 ~ y0 + On_Premises, data = y1y0)
##
## Residuals:
##         Min          1Q      Median          3Q         Max
## -0.00009171 -0.00004445 -0.00001991  0.00001497  0.00103879
##
## Coefficients:
##               Estimate Std. Error t value             Pr(>|t|)
## (Intercept) 0.00005121 0.00001131   4.529           0.00000913 ***
## y0          1.00033661 0.02219894  45.062 < 0.0000000000000002 ***
## On_Premises 0.00004050 0.00002342   1.729               0.0849 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00009173 on 254 degrees of freedom
## Multiple R-squared:  0.8903, Adjusted R-squared:  0.8894
## F-statistic:  1031 on 2 and 254 DF,  p-value: < 0.00000000000000022
```

```
summary(lm(y1~y0+Online_Only,data = y1y0))
```

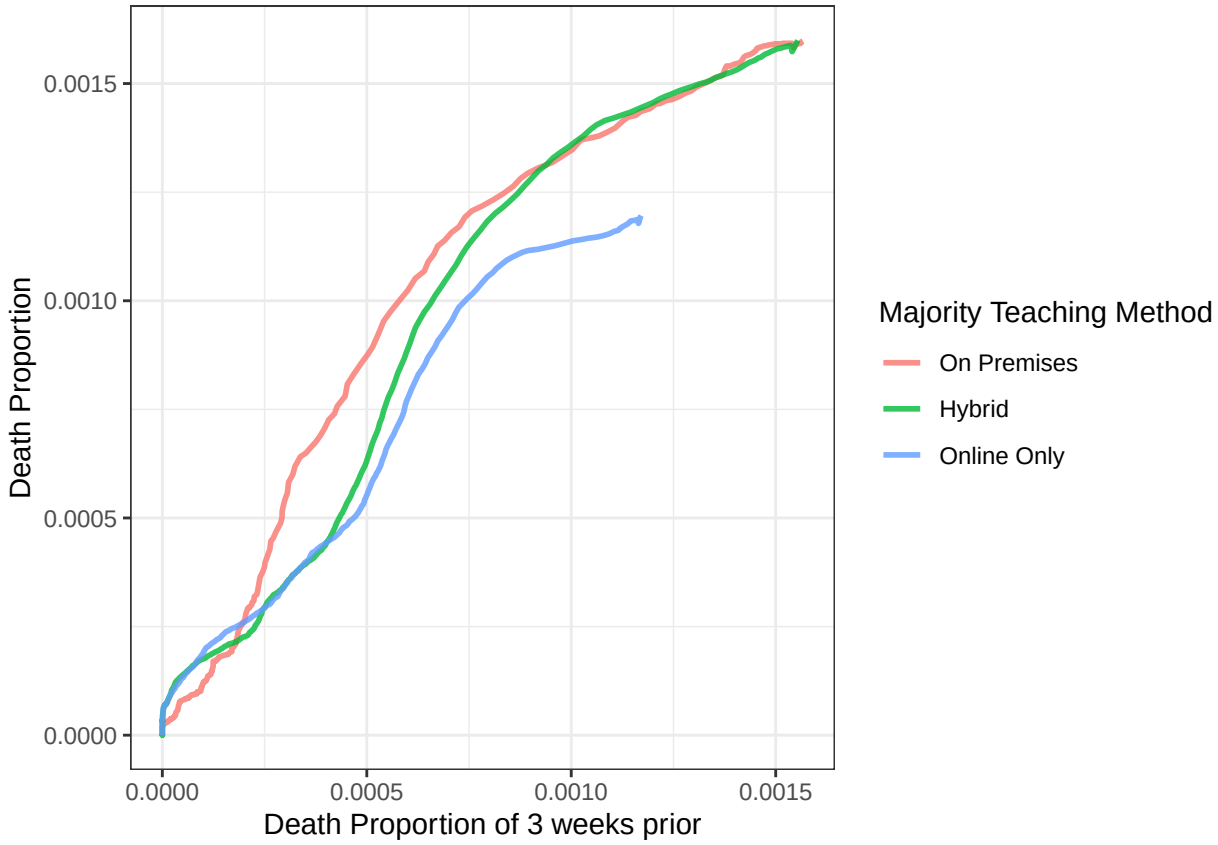
```
##
## Call:
## lm(formula = y1 ~ y0 + Online_Only, data = y1y0)
##
## Residuals:
##         Min          1Q      Median          3Q         Max
## -0.00006469 -0.00004435 -0.00002163  0.00001457  0.00102531
##
## Coefficients:
##                Estimate  Std. Error t value             Pr(>|t|)
## (Intercept)  0.00006469  0.00001011   6.395       0.000000000764 ***
## y0           0.99514259  0.02205641  45.118 < 0.0000000000000002 ***
## Online_Only -0.00002309  0.00003152  -0.733                0.464
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00009217 on 254 degrees of freedom
## Multiple R-squared:  0.8892, Adjusted R-squared:  0.8884
## F-statistic:  1020 on 2 and 254 DF,  p-value: < 0.00000000000000022
```

```
summary(lm(y1~y0+work_prop_7d+On_Premises,na.action='na.omit',data = y1y0))
```

```
##
## Call:
## lm(formula = y1 ~ y0 + work_prop_7d + On_Premises, data = y1y0,
##     na.action = "na.omit")
##
## Residuals:
##         Min          1Q      Median          3Q         Max
## -0.00010331 -0.00004081 -0.00001667  0.00001352  0.00102364
##
## Coefficients:
##                 Estimate  Std. Error t value             Pr(>|t|)
## (Intercept)  -0.00010716  0.00005598  -1.914              0.05674 .
## y0            1.01178568  0.02224176  45.490 < 0.0000000000000002 ***
## work_prop_7d  0.00181384  0.00062834   2.887              0.00423 **
## On_Premises   0.00001114  0.00002523   0.441              0.65923
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.00009043 on 253 degrees of freedom
## Multiple R-squared:  0.8938, Adjusted R-squared:  0.8925
## F-statistic: 709.8 on 3 and 253 DF,  p-value: < 0.00000000000000022
```

```
lag_cases <- case_mobility %>%
  left_join(county_policy_wide[,c("county","major_teaching")],
            by = c("COUNTY" = "county")) %>%
  drop_na(major_teaching)%>%
  select(COUNTY,DATE,CUMDEATHS,POPULATION,major_teaching)%>%
  group_by(COUNTY) %>%
  mutate(lag_total_deaths = lag(CUMDEATHS,21)) %>%
  ungroup()%>%
  group_by(DATE,major_teaching) %>%
  summarise(total_deaths = sum(CUMDEATHS),
            total_deaths_lag = sum(lag_total_deaths),
```

```
            total_pop = sum(POPULATION),
            death_prop = total_deaths/total_pop,
            lag_death_prop = total_deaths_lag/total_pop,
            death_prop_inc = (total_deaths-total_deaths_lag)/total_pop,
            .groups = "drop")

ggplot(lag_cases, aes(x = lag_death_prop, y = death_prop, color = major_teaching)) +
    geom_line(size = 1,alpha = .8, na.rm=T)+
  theme_bw() +
  labs(x = "Death Proportion of 3 weeks prior", y  = "Death Proportion",
       color = "Majority Teaching Method")
```




```
peak.date <- as.Date("2020-12-23")
ggplot(lag_cases,aes(x = DATE, y = death_prop_inc,
                     color = major_teaching,
                     fill = "red")) +
    geom_line(na.rm = T) +
    geom_rect(data = lag_cases[1,],
              aes(xmin=as.Date("2020/08/26"), xmax=as.Date("2020/12/12"),
                  ymin=-Inf,ymax=Inf),
              color = NA,alpha=0.2, show.legend = F) +
    geom_vline(xintercept = peak.date, linetype = "dashed")+
    annotate("text",x = peak.date,y = .0005,
             label = peak.date,
             hjust = 1.2)  +
  theme_bw() +
  labs(x = "Date",
```

```
      y = "Death Proportion Increase",
      title = "Death Proportion Increase by Teaching Method",
      subtitle = "Increase compared to 3 Week Lag \nRed area represents Fall Semester",
      color = "Majority Teaching Method") +
scale_y_continuous(labels = comma)
```