HITECH_Act_Case

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```r
HITECH <- read.csv(here::here("Data","Other_data","HITECH.csv"))
DUNS <- read.csv(here::here("Data","Other_data","DUNS_HITECH.csv"))

NAICS <- merge(HITECH, DUNS, by="clean_name", all=TRUE)

NAICS$DUNS_2 <- substr(NAICS$Primary.NAICS.Code, start=1, stop=2)
# colSums(!is.na(NAICS)) # 1740 resolved for Duns_2
# colSums(is.na(NAICS)) # 248 not resolved for Duns_2
NAICS <- NAICS[complete.cases(NAICS$firstdate),]

248/1740 # = 14.2% are not included
```

```
## [1] 0.1425287
```

```r
1740/(1740+248) # = 87.5% of incidents are resolved
```

```
## [1] 0.8752515
```

```r
write.csv(NAICS, here::here("Data","Other_data","NAICS_Clean.csv"))
```

Specifying Time Variables

```r
first_breach_date <- as.Date("2006-06-01") # doesn't change
data_start <- c(2006,6) # doesn't change
data_range <- c(2006,2011)
exp_start <- c(2008,4)
exp_range <- c(2008,2011)
first_pop_date <- as.Date("2000-04-01")
no_months_out <- 174

months_prior <- 6 # months before treatment start
months_after <- 6 # months after treatment start

# HIGH TECH Act regulations become effective on February 17, 2009
# Enforcement of HIGH TECH Act implement on May 27, 2009

treatment_start <- as.Date("02/17/2009", "%m/%d/%Y")-180 # Legislation H.B. 4144 becomes effective
treatment_end  <- as.Date("05/27/2009", "%m/%d/%Y")+180 # moving avg uses 30 days post treatment
```

Create Population Time Series for Matching with Incident Frequncy

```
# Population
pop <- read.csv(here::here("Data","Other_data","populations.csv")) # starts at 2000.04.01

datforpop <- data.frame(seq(first_pop_date, by="1 month", length.out=(length(pop)-1)))

names(datforpop) <- "yearmonth"
datforpop <- format(datforpop,  "%Y/%m")
datforpop <- rbind("yearmonth",datforpop)
row.names(datforpop) <- 1:nrow(datforpop)

datfull <- data.frame(seq(as.Date(first_breach_date), by="1 month", length.out=54))
names(datfull) <- "yearmonth"
datfull <- format(datfull,  "%Y/%m")

pop <- cbind(datforpop,t(pop))
colnames(pop) <- pop[1,]
pop <- pop[-1,]
rownames(pop) <- seq(1:nrow(pop))
pop <- as.data.frame(pop)

pop[2:ncol(pop)] <- sapply(pop[2:ncol(pop)],as.numeric)

# Create a new column for the total population across collecting states
pop$totpop <- rowSums(pop[ ,c('Massachusetts','South Carolina','North Carolina','New Hampshire','Hawaii
```

Create Monthly Frequency Accross Full Collected Time

```
NAICS$date_formatted <- format(as.Date(NAICS$firstdate, "%Y-%m-%d"), "%Y/%m") # Alternative is "%m/%d/%

NAICS_ts <- NAICS %>%
  dplyr::group_by(NAICS$date_formatted) %>%
  dplyr::summarise(frequency = n())
```

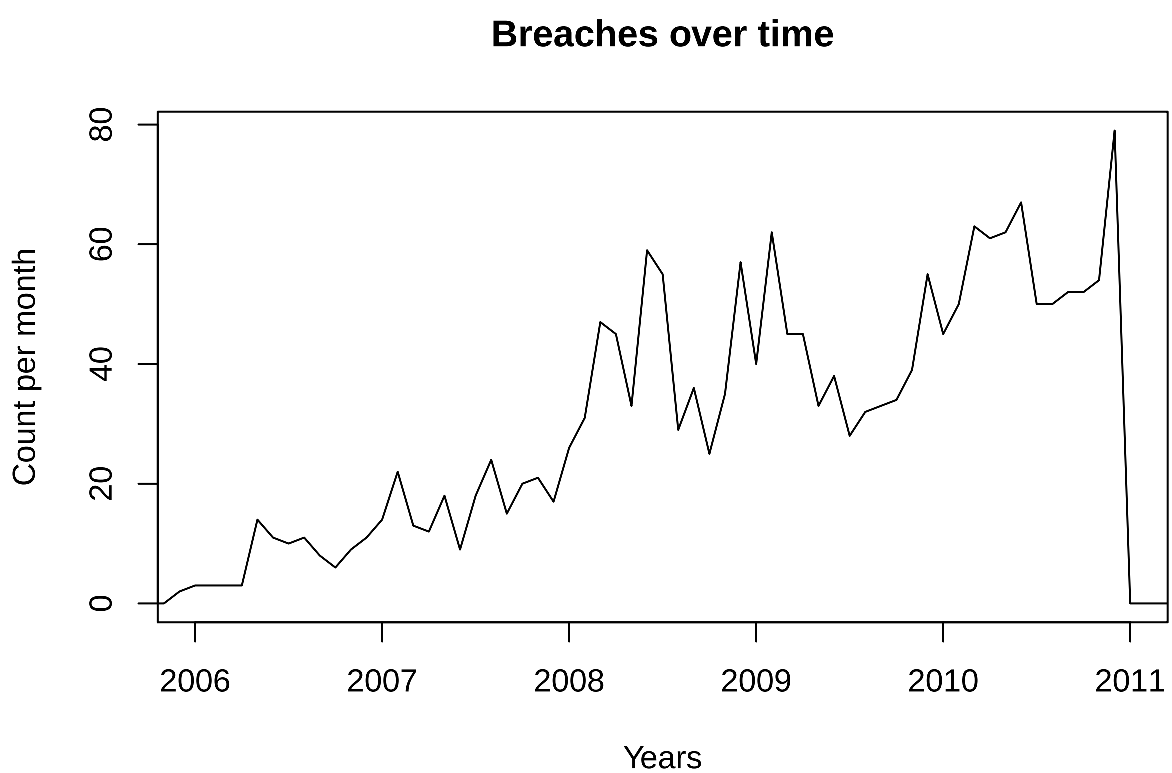
```
## `summarise()` ungrouping output (override with `.groups` argument)
```

```
NAICS_ts # Feb 2005 and Dec 2010
```

```
## # A tibble: 62 x 2
##    `NAICS$date_formatted` frequency
##    <chr>                      <int>
##  1 2005/02                        1
##  2 2005/12                        2
##  3 2006/01                        3
##  4 2006/02                        3
##  5 2006/03                        3
##  6 2006/04                        3
##  7 2006/05                       14
##  8 2006/06                       11
```

```
##  9 2006/07                      10
## 10 2006/08                      11
## # ... with 52 more rows
```

```
names(NAICS_ts)[1] <- "yearmonth"
NAICS_ts <- merge(NAICS_ts, pop, by="yearmonth", all.y=TRUE)
NAICS_ts$frequency[is.na(NAICS_ts$frequency)]<-0
# Look at Raw Frequency Counts

NAICS_ts <- ts(NAICS_ts$frequency, frequency = 12, start = c(2000,4))
ts.plot(NAICS_ts, main = "Breaches over time", xlim=data_range, gpars = list(col = c("black", "red")), :
```



Designate Treatment and Control groups

```
# Format control dates into months
NAICS$date_formatted <- format(as.Date(NAICS$firstdate, "%Y-%m-%d"), "%Y/%m") # Alternative is "%m/%d/%
NAICS <- NAICS[!is.na(NAICS$date_formatted),]

Health <- NAICS[grepl( "62", NAICS$DUNS_2), ]
Finance <- NAICS[grepl( "52", NAICS$DUNS_2), ]
Education <- NAICS[grepl( "61", NAICS$DUNS_2), ]
Information <- NAICS[grepl( "51", NAICS$DUNS_2), ]

Non_Health <- NAICS %>%
```

```r
                   filter(DUNS_2 != 62)

#Treat_Name <- 'Massachusetts'
#Ctrl_Name <- 'New Hampshire'

treatment <-  Health # This Must Be Filled in to Work Properly!
control <-  Finance  # This Must Be Filled in to Work Properly!
```

Experiment 1: Create control and treatment populations with Total Incidents

```r
# Format treatment dates into months
treatment$date_formatted <- format(as.Date(treatment$reported_date, "%Y-%m-%d"), "%Y/%m") # Alternative
treatment_freq <- treatment %>%
  dplyr::group_by(treatment$date_formatted) %>%
  dplyr::summarise(frequency = n(),)
```

```
## `summarise()` ungrouping output (override with `.groups` argument)
```

```r
names(treatment_freq)[1] <- "yearmonth"
treatment_freq<- merge(datfull,treatment_freq, by="yearmonth", all.x=TRUE) # WHAT IS THIS THING!!!!
treatment_freq$frequency[is.na(treatment_freq$frequency)]<-0

# Format control dates into months
control$date_formatted <- format(as.Date(control$reported_date, "%Y-%m-%d"), "%Y/%m") # Alternative is
control_freq <- control %>%
  dplyr::group_by(control$date_formatted) %>%
  dplyr::summarise(frequency = n())
```

```
## `summarise()` ungrouping output (override with `.groups` argument)
```

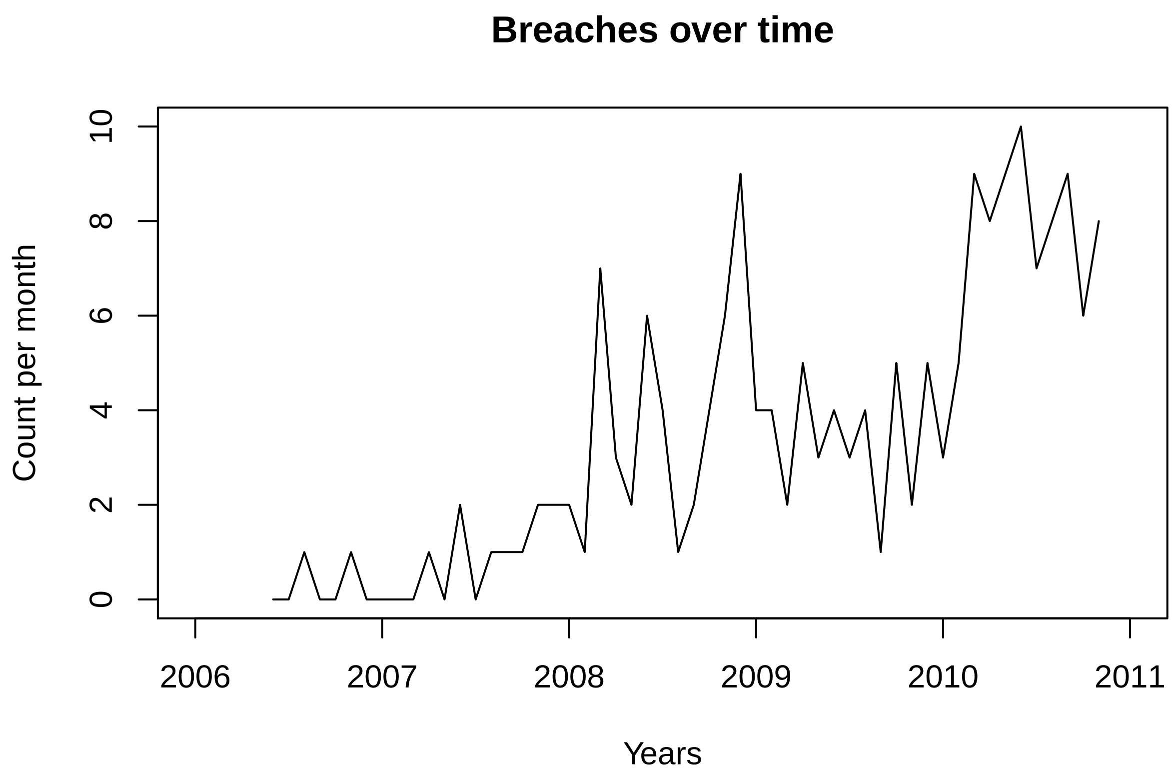
```r
names(control_freq)[1] <- "yearmonth"
control_freq<- merge(datfull,control_freq, by="yearmonth", all.x=TRUE)  # WHAT IS THIS THING!!!!
control_freq$frequency[is.na(control_freq$frequency)]<-0

ts(treatment_freq$frequency, frequency = 12, start = data_start)
```

```
##      Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
## 2006                       0   0   1   0   0   1   0
## 2007   0   0   0   1   0   2   0   1   1   1   2   2
## 2008   2   1   7   3   2   6   4   1   2   4   6   9
## 2009   4   4   2   5   3   4   3   4   1   5   2   5
## 2010   3   5   9   8   9  10   7   8   9   6   8
```

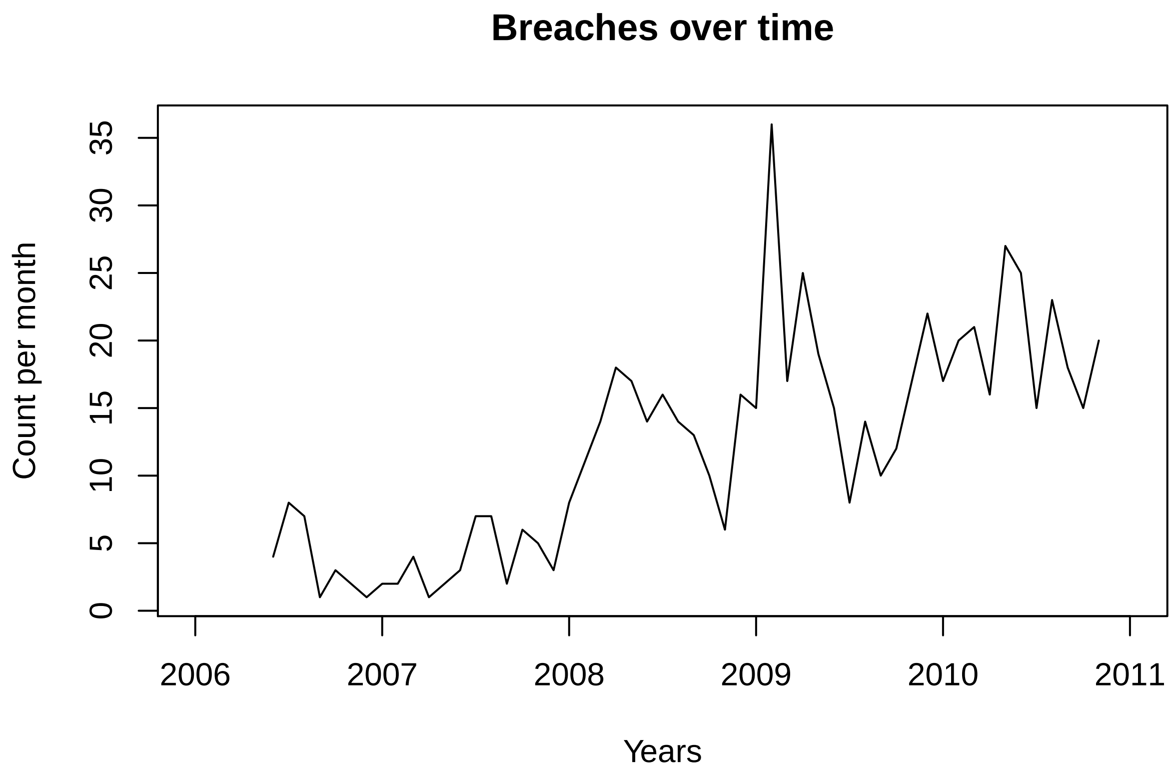
```r
ts(control_freq$frequency, frequency = 12, start = data_start)
```

```
##      Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
## 2006                       4   8   7   1   3   2   1
## 2007   2   2   4   1   2   3   7   7   2   6   5   3
## 2008   8  11  14  18  17  14  16  14  13  10   6  16
## 2009  15  36  17  25  19  15   8  14  10  12  17  22
## 2010  17  20  21  16  27  25  15  23  18  15  20
```

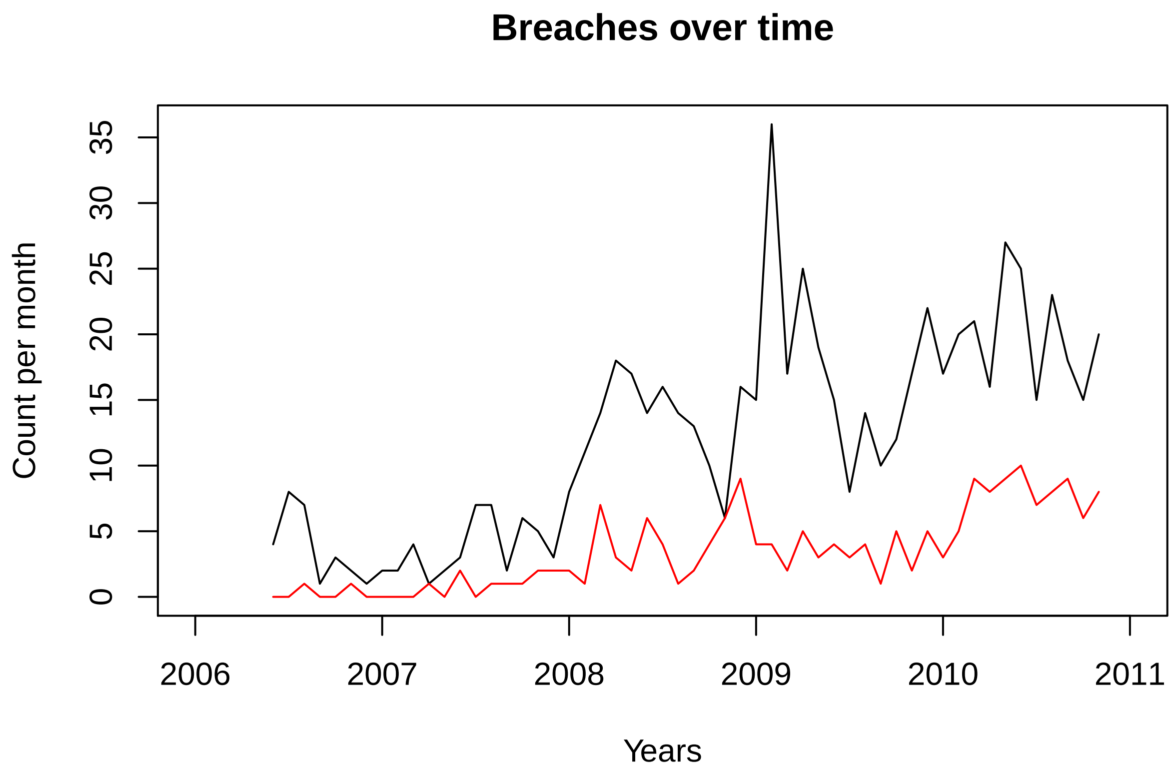
```
treatment_ts <- ts(treatment_freq$frequency, frequency = 12, start = data_start)
control_ts <- ts(control_freq$frequency, frequency = 12, start = data_start)

plot.ts(treatment_ts, main = "Breaches over time", xlim=data_range, xlab = "Years", ylab = "Count per mo
```




```
plot.ts(control_ts, main = "Breaches over time", xlim=data_range, xlab = "Years", ylab = "Count per mont
```




```
ts.plot(control_ts, treatment_ts, main = "Breaches over time", xlim=data_range, gpars = list(col = c("bl
```




```r
summary(treatment_ts)
```

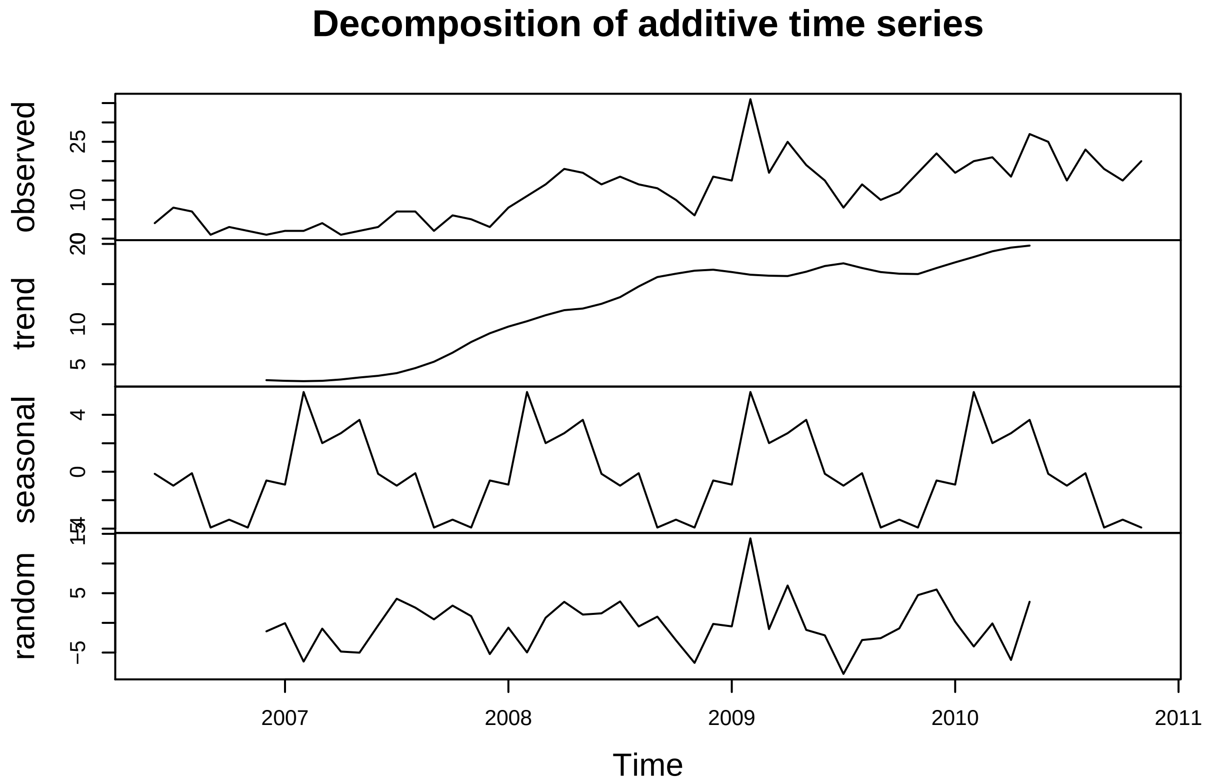
```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   0.000   1.000   2.500   3.389   5.000  10.000
```

```r
summary(control_ts)
```

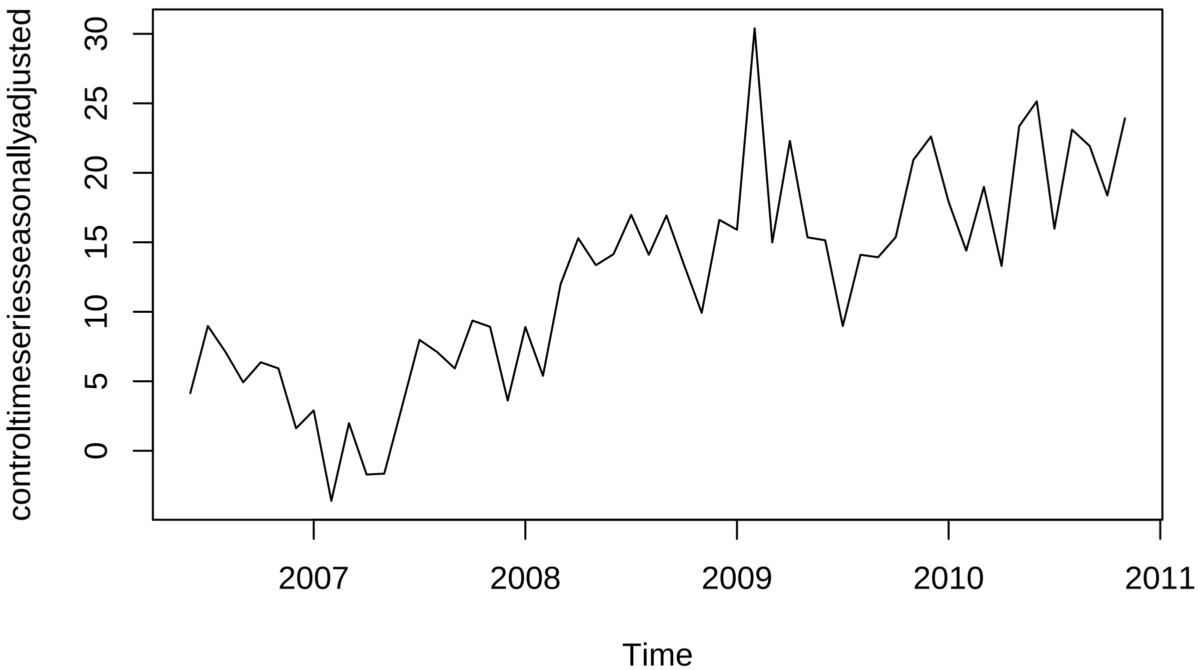
```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1.00    5.25   13.50   12.11   17.00   36.00
```

Decompose the Control to Find Seasonal Patterns

```r
controltimeseriescomponents <- decompose(control_ts)
plot(controltimeseriescomponents)
```

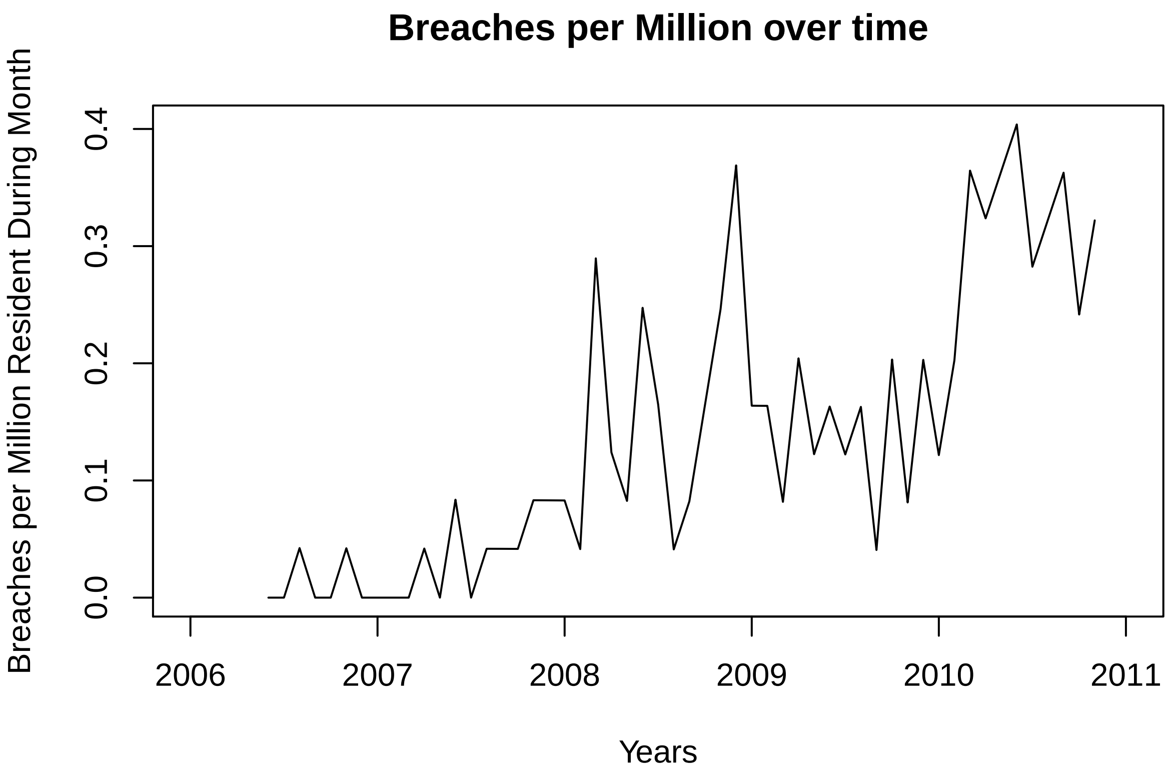



```
controltimeseriesseasonallyadjusted <- control_ts - controltimeseriescomponents$seasonal
plot(controltimeseriesseasonallyadjusted)
```

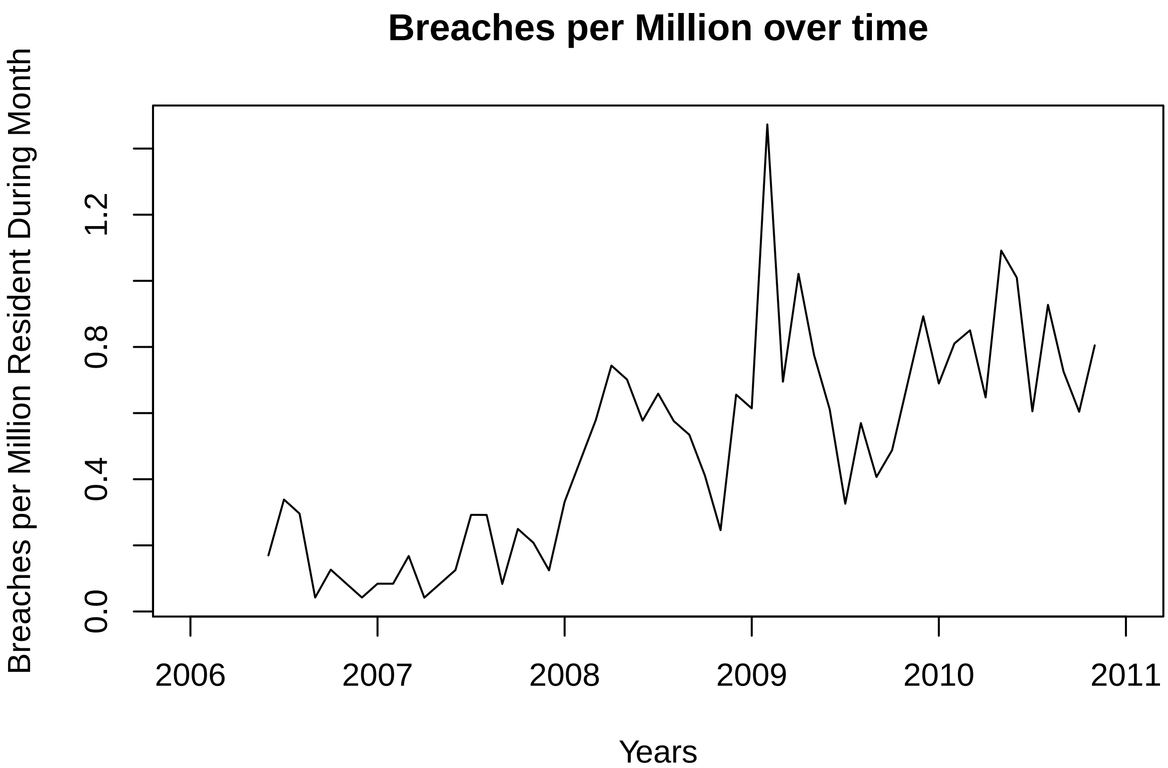


Create charts with breaches per million residents

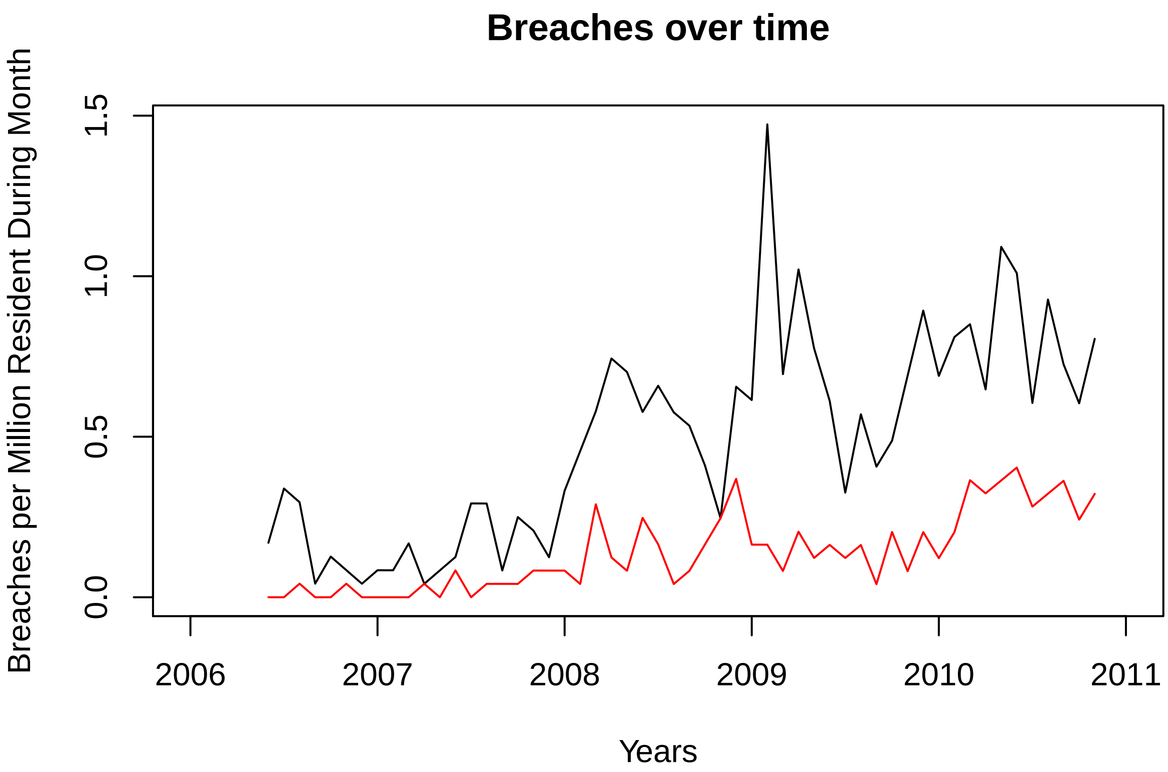
```
# Merge Treatment and Control Together
comb_ts <- merge(treatment_freq, control_freq, by="yearmonth", all=TRUE)

# Merge Combined Treatment and Control Together with Population Statistics
comb_ts <- merge(comb_ts, pop, by='yearmonth', all.x = TRUE)
comb_ts$frequency.x[is.na(comb_ts$frequency.x)]<-0
comb_ts$frequency.y[is.na(comb_ts$frequency.y)]<-0

# change class of columns to numeric
comb_ts[2:ncol(comb_ts)] <- sapply(comb_ts[2:ncol(comb_ts)],as.numeric)

comb_ts$totpop <- as.numeric(as.character(comb_ts$totpop))
comb_ts$treatpermil <- comb_ts$frequency.x/(comb_ts$totpop/1000000)
comb_ts$controlpermil <- comb_ts$frequency.y/(comb_ts$totpop/1000000)

treatment_tsM <- ts(comb_ts$treatpermil, frequency = 12, start = data_start)
control_tsM <- ts(comb_ts$controlpermil, frequency = 12, start = data_start)

plot.ts(treatment_tsM, main = "Breaches per Million over time", xlim=data_range, xlab = "Years", ylab =
```




```
plot.ts(control_tsM, main = "Breaches per Million over time", xlim=data_range, xlab = "Years", ylab = "
```




```
ts.plot(control_tsM, treatment_tsM, main = "Breaches over time", xlim=data_range, gpars = list(col = c(
```



Identifying and subsetting relevant dates

```
treatment_start<- format(as.Date(as.character(treatment_start), origin = "1970-01-01"), "%Y/%m")
treatment_end<- format(as.Date(as.character(treatment_end), origin = "1970-01-01"), "%Y/%m")

pretreat <- comb_ts[(which(comb_ts$yearmonth==treatment_start)-months_prior):which(comb_ts$yearmonth==tr
pretreat$type <- "pretest"

posttreat <- comb_ts[which(comb_ts$yearmonth==treatment_end):(which(comb_ts$yearmonth==treatment_end)+mo
posttreat$type <- "posttest"

mean(posttreat$treatpermil) - mean(pretreat$treatpermil)
```

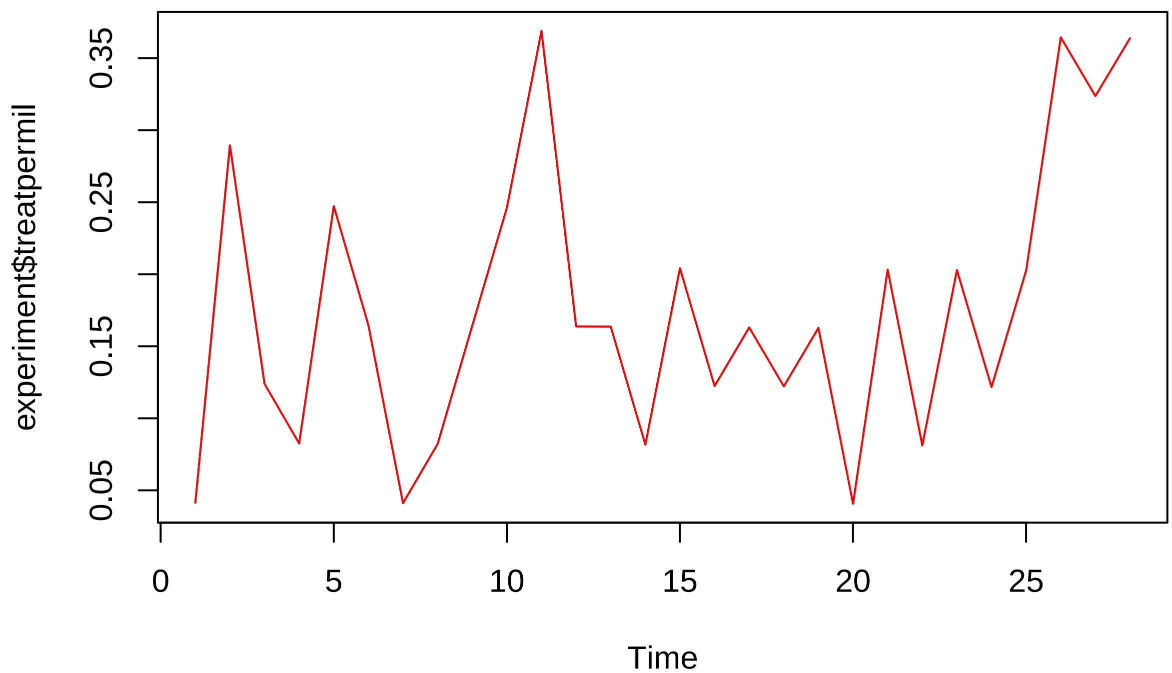
```
## [1] 0.09567449
```

```
mean(posttreat$controlpermil) - mean(pretreat$controlpermil)
```

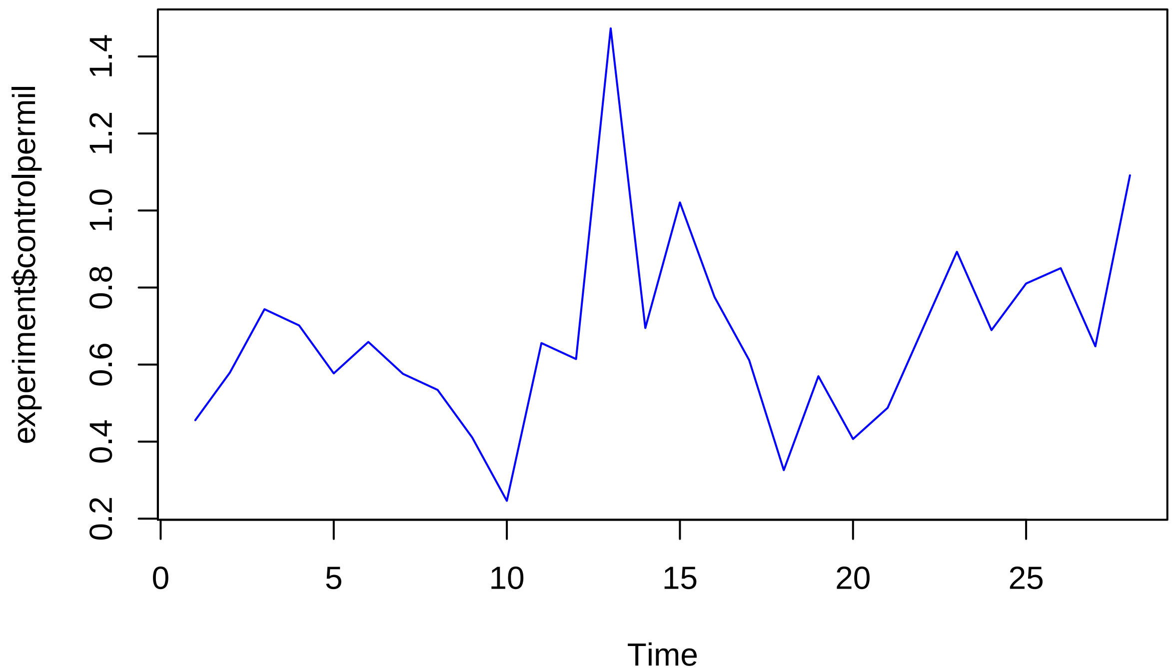
```
## [1] 0.1972033
```

```
treatment_range <- comb_ts[(which(comb_ts$yearmonth==treatment_start)+1):(which(comb_ts$yearmonth==treat
treatment_range$type <- "test"

experiment <- rbind(pretreat,treatment_range,posttreat)
experiment$treatpermil[is.na(experiment$treatpermil)]<-0
experiment$controlpermil[is.na(experiment$controlpermil)]<-0
```

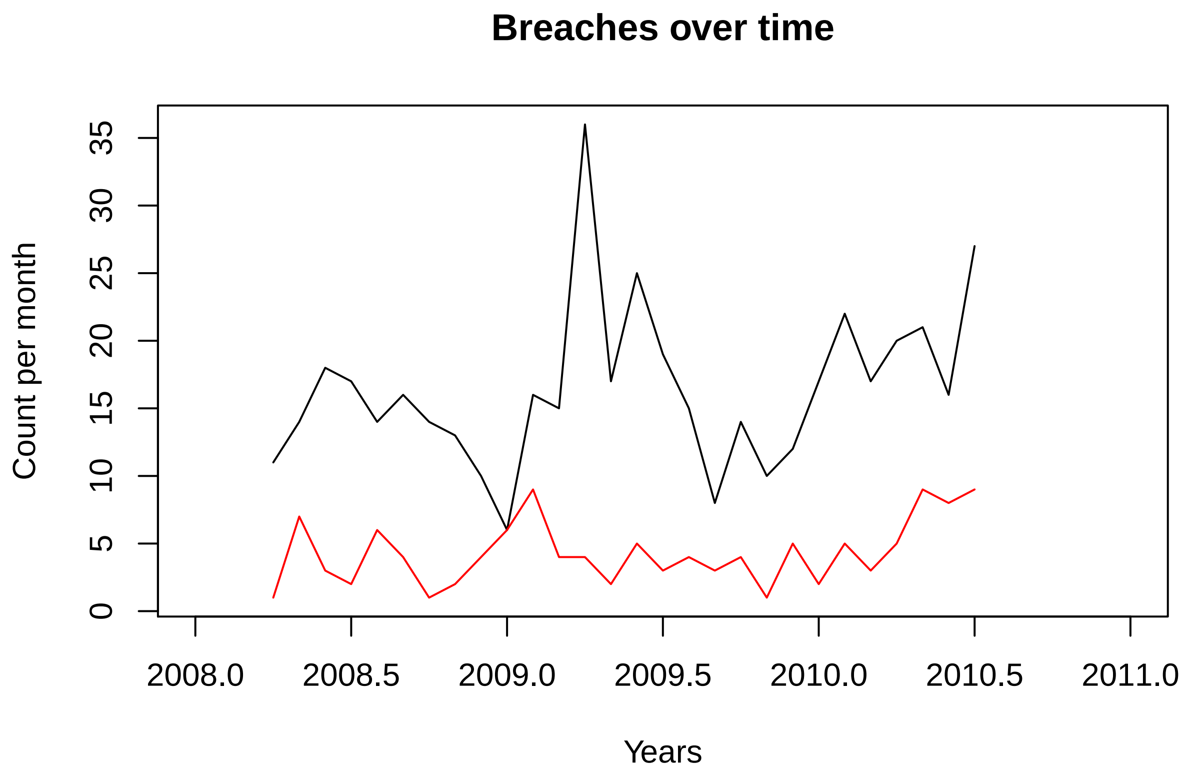
```r
ts.plot(experiment$treatpermil, col = "red")
```




```r
ts.plot(experiment$controlpermil, col = "blue")
```




```
# Look at Raw Frequency Counts
treatment_ts <- ts(experiment$frequency.x, frequency = 12, start = exp_start)
control_ts <- ts(experiment$frequency.y, frequency = 12, start = exp_start)
ts.plot(control_ts, treatment_ts, main = "Breaches over time", xlim=exp_range, gpars = list(col = c("bla
```




```r
# Look at Treatment and Control per Million
treatment_tsM <- ts(experiment$treatpermil, frequency = 12, start = exp_start)
mean(treatment_tsM)
```

```
## [1] 0.1764458
```

```r
sd(treatment_tsM)
```

```
## [1] 0.09775996
```

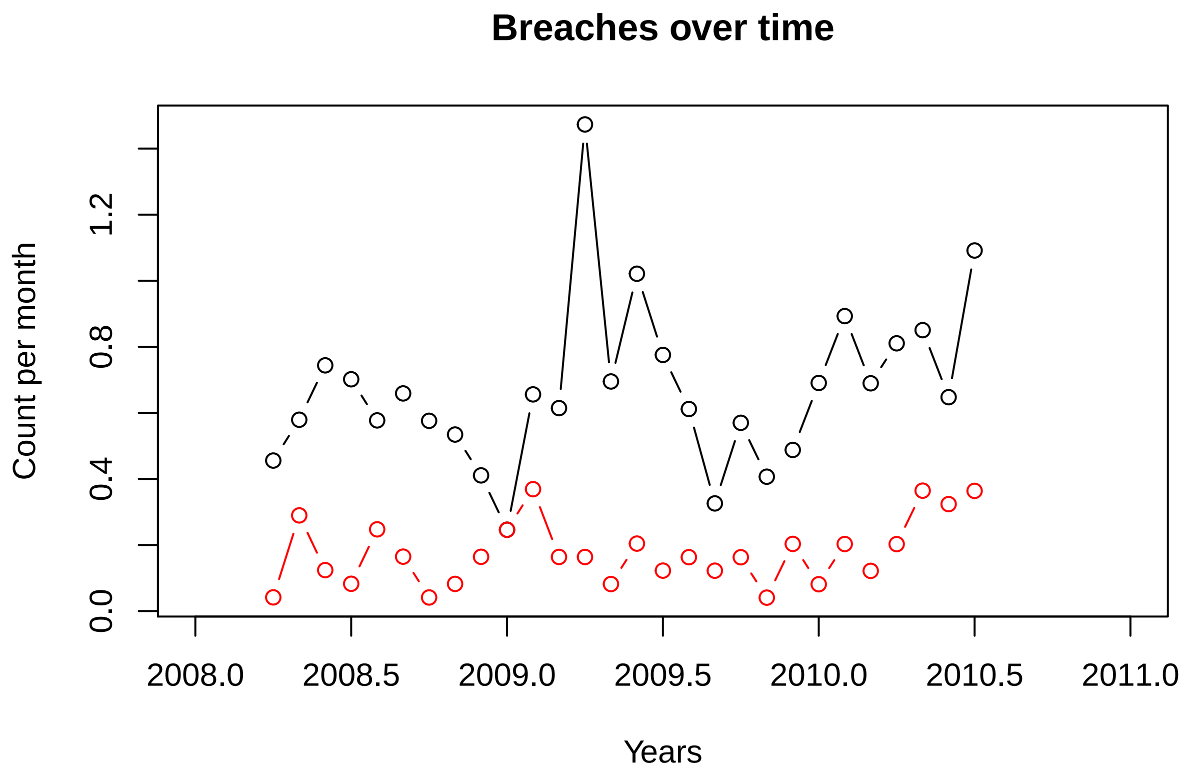
```r
control_tsM <- ts(experiment$controlpermil, frequency = 12, start = exp_start)
mean(control_tsM)
```

```
## [1] 0.671135
```

```r
sd(control_tsM)
```

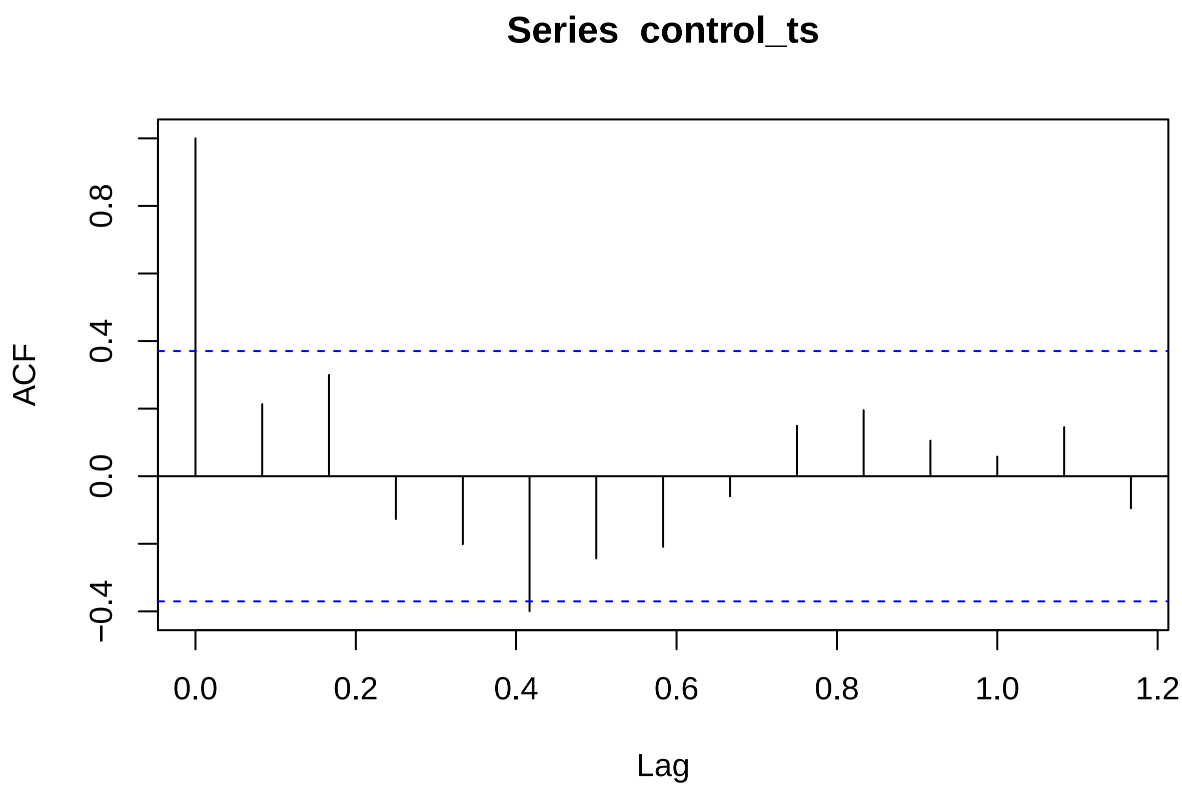
```
## [1] 0.2466004
```

```r
ts.plot(control_tsM, treatment_tsM, main = "Breaches over time", xlim=exp_range,
                    gpars = list(col = c("black", "red")), type = "b", xlab = "Years", ylab = "Count pe
```

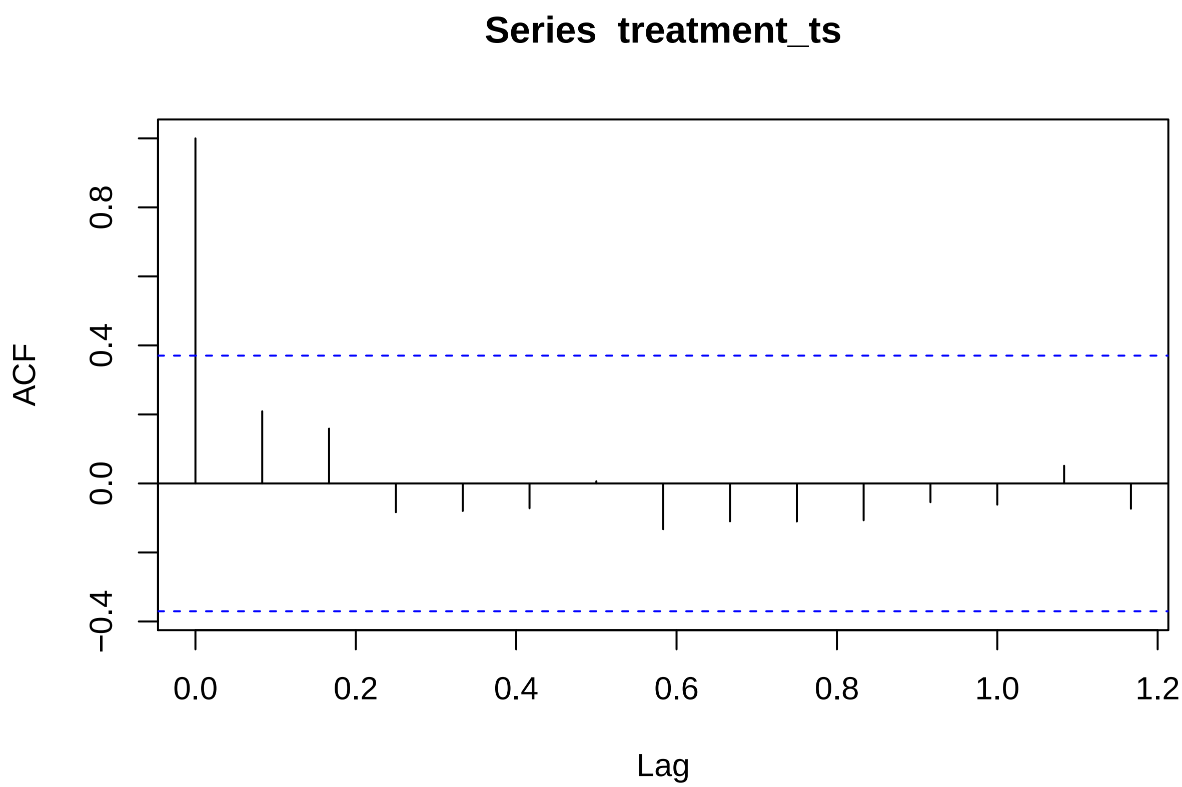


Run Statistical Tests on Time Series for Stationarity

```
# source of statistical tests http://r-statistics.co/Time-Series-Analysis-With-R.html

acfcontrol <- acf(control_ts) # autocorrelation (i.e. a Time Series with lags of itself)
```




```
acftreatment <- acf(treatment_ts)
```




```r
# shows that the control time series is a "stationary time series"

png(here::here("Output","acfcontrol.png"))
plot(acfcontrol)

png(here::here("Output","acftreatmentNH.png"))
plot(acftreatment)

pacfcontrolNH <- pacf(control_ts)  # partial autocorrelation (i.e. correlation of the time series with
pacftreatmentMA <- pacf(treatment_ts)  # partial autocorrelation (i.e. correlation of the time series w

png(here::here("Output","pacfcontrolNH.png"))
plot(pacfcontrolNH)

png(here::here("Output","pacftreatmentMA.png"))
plot(pacftreatmentMA)

ccfRes <- ccf(control_ts, treatment_ts, ylab = "cross-correlation")
ccfRes
```

```
##
## Autocorrelations of series 'X', by lag
##
## -0.9167 -0.8333 -0.7500 -0.6667 -0.5833 -0.5000 -0.4167 -0.3333 -0.2500 -0.1667
##   0.098   0.008  -0.261  -0.088  -0.270  -0.026  -0.097   0.083   0.027   0.207
## -0.0833  0.0000  0.0833  0.1667  0.2500  0.3333  0.4167  0.5000  0.5833  0.6667
##  -0.197   0.259   0.159   0.483   0.140   0.129  -0.039  -0.176  -0.142  -0.169
```

```
##  0.7500  0.8333  0.9167
##  -0.175  -0.110   0.158
```

```r
# adf test is an Augmented Dickey-Fuller Test
adf.test(control_ts) # p-value < 0.05 indicates the TS is stationary
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  control_ts
## Dickey-Fuller = -2.9713, Lag order = 3, p-value = 0.201
## alternative hypothesis: stationary
```

```r
adf.test(treatment_ts)
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  treatment_ts
## Dickey-Fuller = -1.6401, Lag order = 3, p-value = 0.7102
## alternative hypothesis: stationary
```

```r
kpss.test(control_ts) # Kwiatkowski-Phillips-Schmidt-Shin (KPSS) testz
```

```
## Warning in kpss.test(control_ts): p-value greater than printed p-value

##
##  KPSS Test for Level Stationarity
##
## data:  control_ts
## KPSS Level = 0.1848, Truncation lag parameter = 2, p-value = 0.1
```

```r
kpss.test(treatment_ts)
```

```
## Warning in kpss.test(treatment_ts): p-value greater than printed p-value

##
##  KPSS Test for Level Stationarity
##
## data:  treatment_ts
## KPSS Level = 0.26387, Truncation lag parameter = 2, p-value = 0.1
```

```r
# https://www.sas.com/content/dam/SAS/en_ca/User%20Group%20Presentations/Health-User-Groups/ITS_SAS.pdf
```

ITS analyses use regression-based techniques

```r
quasiexp <- experiment[experiment$type != "test",]

# Added dummy variables for ITS
control <- as.data.frame(t(rbind(quasiexp$yearmonth,quasiexp$controlpermil)))
control$treat <- as.vector(rep(0,nrow(control)))                    # Create example vector
time <- 1:nrow(control)
control$time <- as.vector(time)
control$z <- c(rep(0,6),1:(nrow(control)-6))

treatment <- as.data.frame(t(rbind(quasiexp$yearmonth,quasiexp$treatpermil)))
treatment$treat <- as.vector(rep(1,nrow(control)))                  # Create example vector
```

```r
time <- 1:nrow(control)
treatment$time <- as.vector(time)
treatment$z <- c(rep(0,6),1:(nrow(control)-6))
treatment
```

```
##         V1                 V2 treat time z
## 1  2008/02 0.0414154285972955     1    1 0
## 2  2008/03  0.289571124894053     1    2 0
## 3  2008/04  0.123957880930109     1    3 0
## 4  2008/05 0.0825427798592315     1    4 0
## 5  2008/06  0.247341582972115     1    5 0
## 6  2008/07  0.164703673386028     1    6 0
## 7  2008/08  0.041138734994595     1    7 1
## 8  2009/11 0.0812268041630687     1    8 2
## 9  2009/12  0.202916692065073     1    9 3
## 10 2010/01  0.121659967528144     1   10 4
## 11 2010/02   0.20261675486574     1   11 5
## 12 2010/03  0.364440783839238     1   12 6
## 13 2010/04  0.323708298683058     1   13 7
## 14 2010/05  0.363823302664242     1   14 8
```

```r
AppendITS <- rbind(treatment,control)
names(AppendITS) <- c("yearmonth","incident_permil","treat","time","z")
AppendITS$incident_permil <- as.numeric(as.character(AppendITS$incident_permil))
AppendITS$time <- as.numeric(as.character(AppendITS$time))
AppendITS$z <- as.numeric(as.character(AppendITS$z))
AppendITS
```

```
##    yearmonth incident_permil treat time z
## 1    2008/02      0.04141543     1    1 0
## 2    2008/03      0.28957112     1    2 0
## 3    2008/04      0.12395788     1    3 0
## 4    2008/05      0.08254278     1    4 0
## 5    2008/06      0.24734158     1    5 0
## 6    2008/07      0.16470367     1    6 0
## 7    2008/08      0.04113873     1    7 1
## 8    2009/11      0.08122680     1    8 2
## 9    2009/12      0.20291669     1    9 3
## 10   2010/01      0.12165997     1   10 4
## 11   2010/02      0.20261675     1   11 5
## 12   2010/03      0.36444078     1   12 6
## 13   2010/04      0.32370830     1   13 7
## 14   2010/05      0.36382330     1   14 8
## 15   2008/02      0.45556971     0    1 0
## 16   2008/03      0.57914225     0    2 0
## 17   2008/04      0.74374729     0    3 0
## 18   2008/05      0.70161363     0    4 0
## 19   2008/06      0.57713036     0    5 0
## 20   2008/07      0.65881469     0    6 0
## 21   2008/08      0.57594229     0    7 1
## 22   2009/11      0.69042784     0    8 2
## 23   2009/12      0.89283345     0    9 3
## 24   2010/01      0.68940648     0   10 4
## 25   2010/02      0.81046702     0   11 5
## 26   2010/03      0.85036183     0   12 6
```

```
## 27   2010/04      0.64741660     0    13 7
## 28   2010/05      1.09146991     0    14 8
```

```r
factor_cols <- c("treat","time","z")

sapply(AppendITS, class)
```

```
##       yearmonth incident_permil           treat            time               z
##     "character"       "numeric"       "numeric"       "numeric"       "numeric"
```

```r
regTest <- lm(incident_permil ~ time + treat + z, AppendITS)
summary(regTest)
```

```
##
## Call:
## lm(formula = incident_permil ~ time + treat + z, data = AppendITS)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.203257 -0.065282 -0.003389  0.055727  0.209999
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.620833   0.070114   8.855 5.00e-09 ***
## time         0.002377   0.015128   0.157    0.876
## treat       -0.522377   0.040895 -12.774 3.39e-12 ***
## z            0.028421   0.021616   1.315    0.201
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1082 on 24 degrees of freedom
## Multiple R-squared:  0.8836, Adjusted R-squared:  0.8691
## F-statistic: 60.74 on 3 and 24 DF,  p-value: 2.35e-11
```

```r
regTest2 <- lm(incident_permil ~ time + treat + time*treat + z + z*time + z*treat + z*treat*time, Appen
summary(regTest2)
```

```
##
## Call:
## lm(formula = incident_permil ~ time + treat + time * treat +
##     z + z * time + z * treat + z * treat * time, data = AppendITS)
##
## Residuals:
##       Min        1Q    Median        3Q       Max
## -0.234723 -0.057823 -0.005147  0.063169  0.176832
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)   0.531145   0.099351   5.346 3.12e-05 ***
## time          0.023967   0.024232   0.989   0.3344
## treat        -0.390557   0.140504  -2.780   0.0116 *
## z            -0.046090   0.093794  -0.491   0.6285
## time:treat   -0.022800   0.034269  -0.665   0.5134
## time:z        0.003979   0.005722   0.695   0.4948
## treat:z      -0.017423   0.132645  -0.131   0.8968
## time:treat:z  0.002799   0.008092   0.346   0.7330
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1096 on 20 degrees of freedom
## Multiple R-squared:  0.9005, Adjusted R-squared:  0.8657
## F-statistic: 25.85 on 7 and 20 DF,  p-value: 1.066e-08
```