CSSS 512 HW 2

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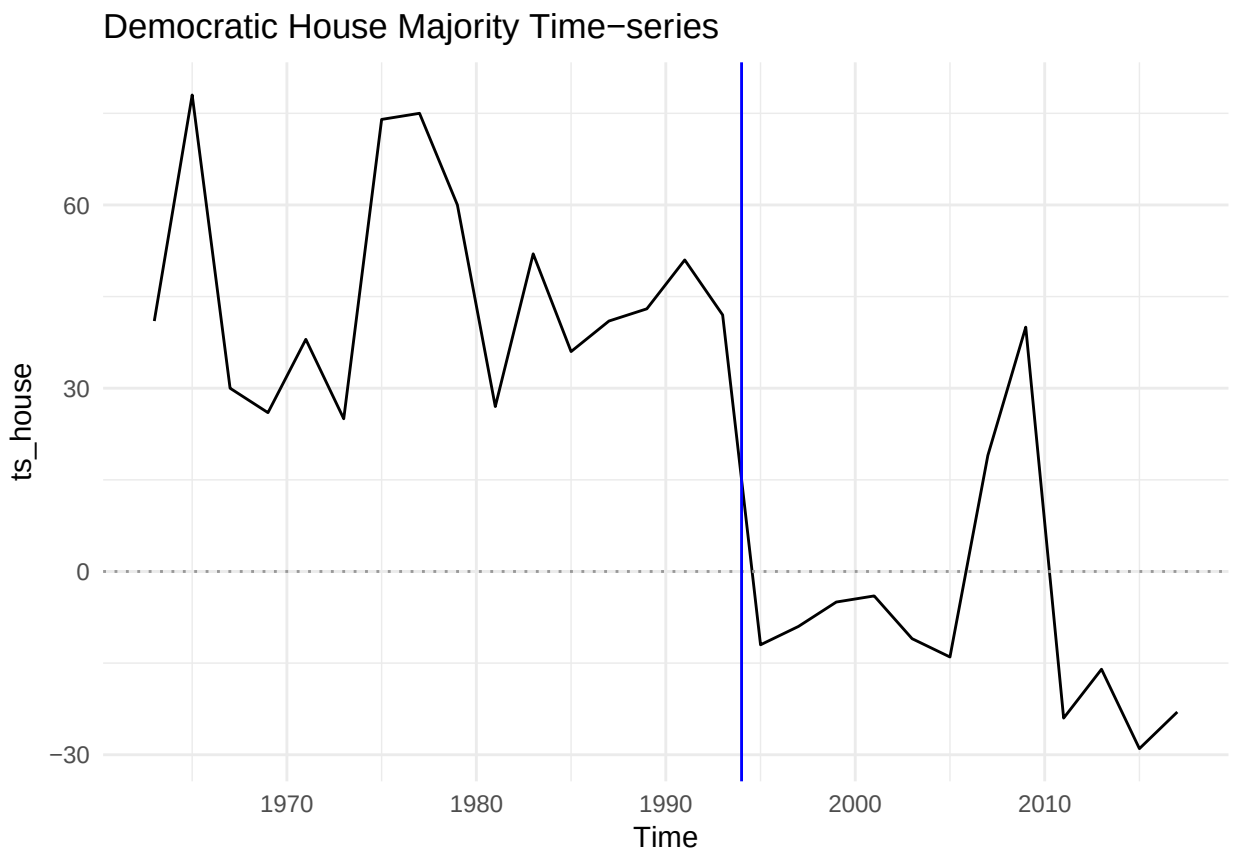
April 19, 2018

Contents

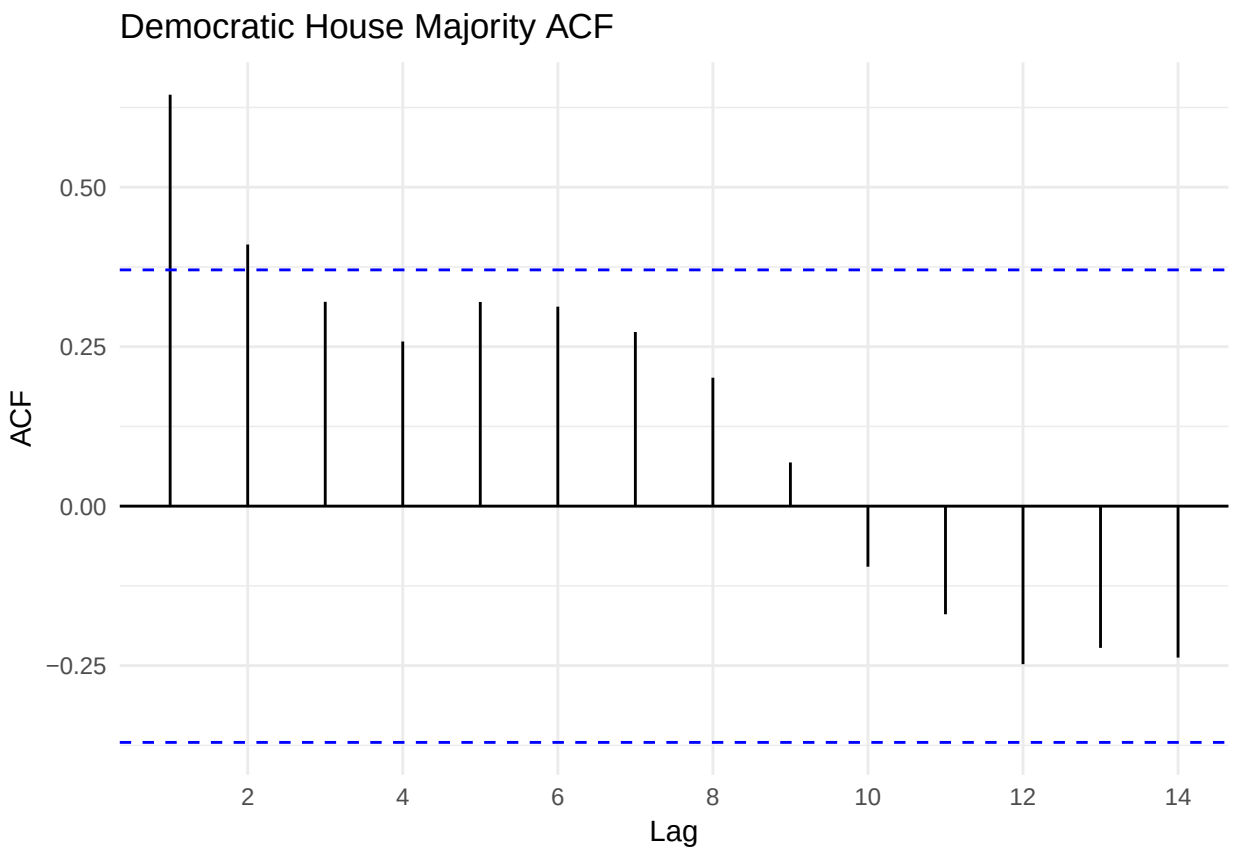
Problem 1 - U.S. House of Representatives

Part a

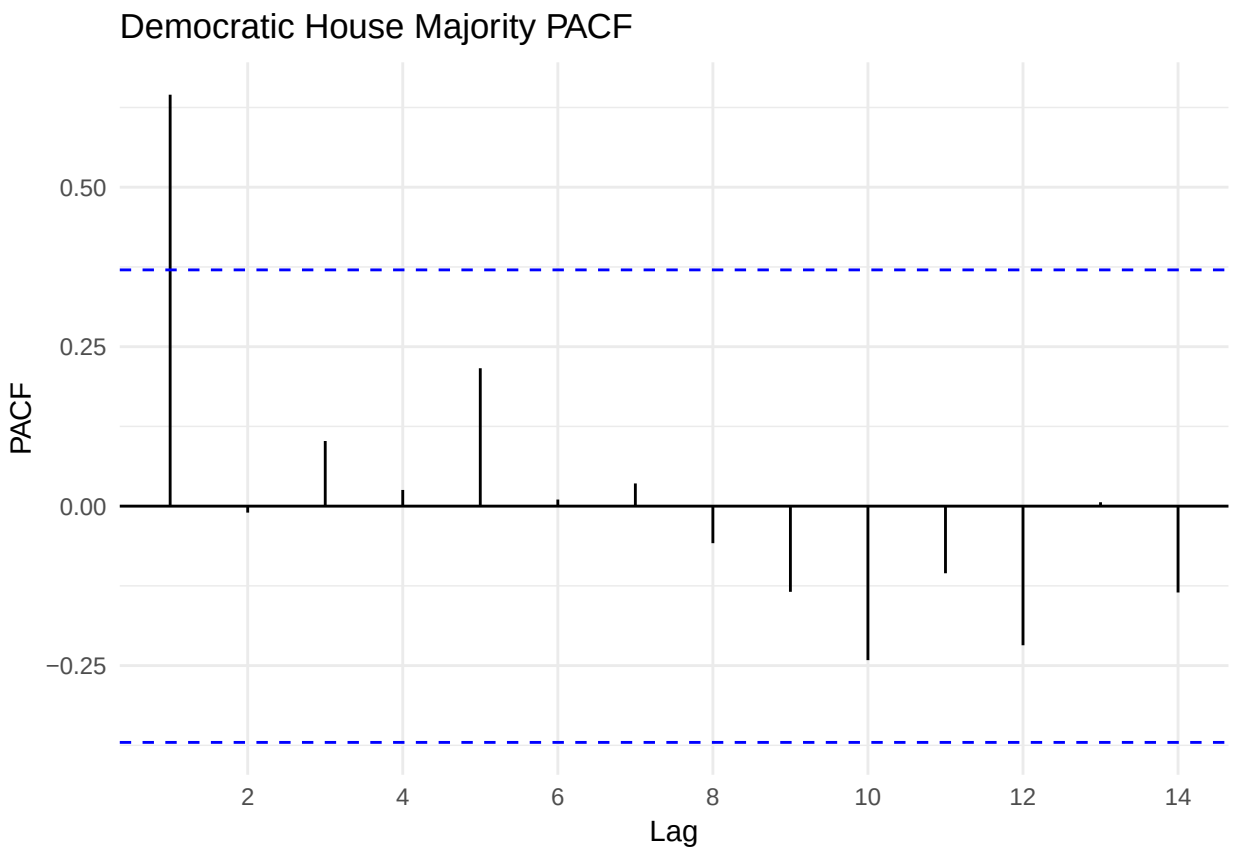
```
#plot ts, ACF, PACF
#run ADF and PP tests
#demean by pre/post 1994 periods
#plot ts, ACF, PACF
#what effect does 1994 structural break have on ts?

#pull ts, every other year frequency 1963-2017
ts_house <- ts(congress$DemHouseMaj,
               frequency = 1/2,
               start = 1963, end = 2017)

#plot as observed
autoplot(ts_house) +
  geom_hline(yintercept = 0, linetype = 3, color = "grey60") +
  geom_vline(xintercept = 1994, color = "Blue") +
  theme_minimal() +
  labs(title = "Democratic House Majority Time-series")
```



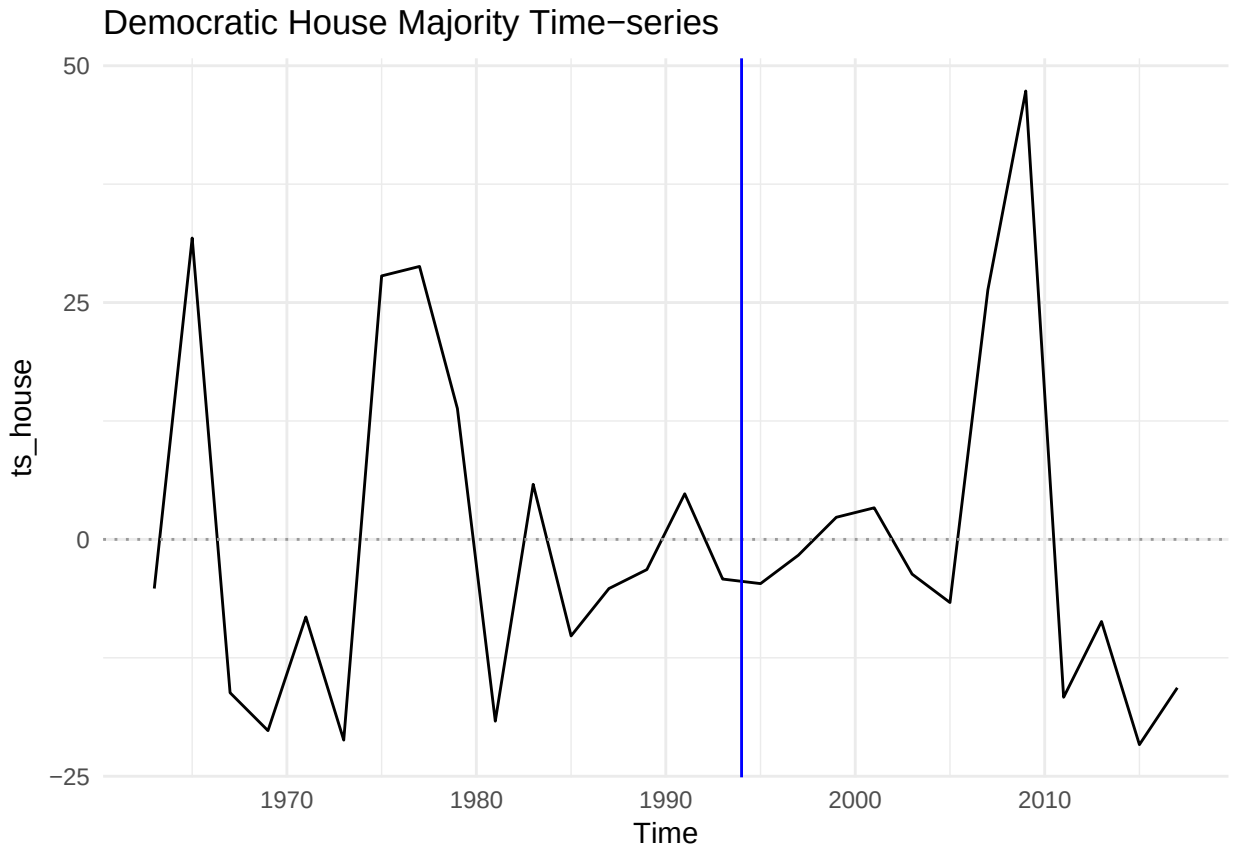

```
#observed ACF
ggAcf(ts_house) + #substantial autocorrelation but not quite geometric decline
  theme_minimal() +
  labs(title = "Democratic House Majority ACF")
```



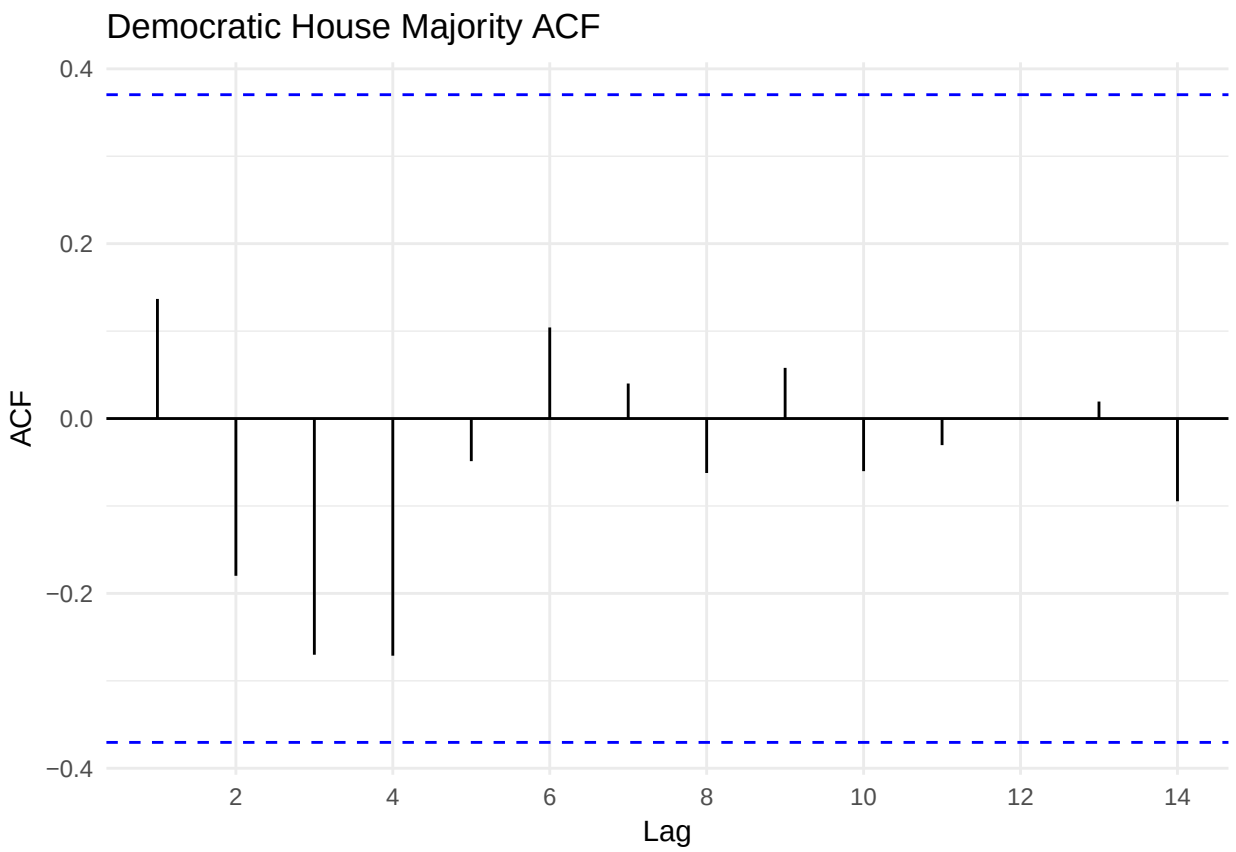

```
#observed PACF
ggPacf(ts_house) + #AR(1), phi = .65 ish
  theme_minimal() +
  labs(title = "Democratic House Majority PACF")
```



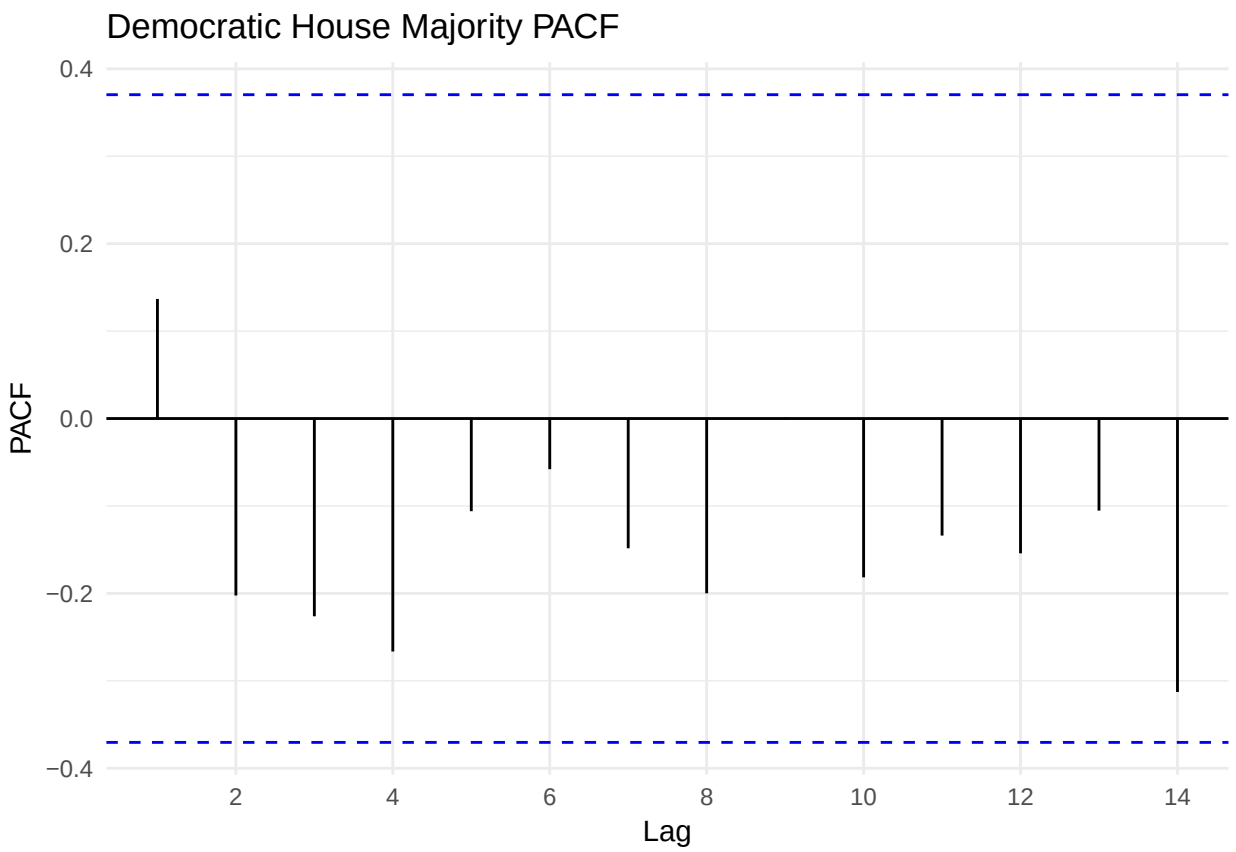

```
#pre-1994 mean for ts
preMean <- congress %>%
  filter(StartYear < 1994) %>%
  summarize(mean = mean(DemHouseMaj)) %>%
  pull(mean)

#post-1994 mean for ts
postMean <- congress %>%
  filter(StartYear >= 1994) %>%
  summarize(mean = mean(DemHouseMaj)) %>%
  pull(mean)

#demean based on pre/post 1994 (i.e. 1-16th obs vs 17-28th obs)
ts_house[1:16] <- ts_house[1:16] - preMean
ts_house[-1:-16] <- ts_house[-1:-16] - postMean

#demeaned ts - looks stationary now
autoplot(ts_house) +
  geom_hline(yintercept = 0, linetype = 3, color = "grey60") +
  geom_vline(xintercept = 1994, color = "Blue") +
  theme_minimal() +
  labs(title = "Democratic House Majority Time-series")
```




```
#demeaned ACF
ggAcf(ts_house) + #no autocorrelation
  theme_minimal() +
  labs(title = "Democratic House Majority ACF")
```




```
#demeaned PACF
ggPacf(ts_house) + #no need for lags
  theme_minimal() +
  labs(title = "Democratic House Majority PACF")
```



Part b

```
#pull ts, every other year frequency 1963-2017
ts_house <- ts(congress$DemHouseMaj,
               frequency = 1/2,
               start = 1963, end = 2017)

#create df of covariates
covar <- congress %>% select(PartisanMidterm, PartisanUnem, Coattails, Pre1994)

#function to provide sum stats that can be passed to xtable()
armaFit <- function(ts, order = c(0, 0, 0), seasonal.order = c(1, 0, 0),
                    seasonal.period = NA, xdf = NULL){
  if(is.na(seasonal.period)){
    mod <- Arima(ts, order = order, xreg = xdf)
  } else{
    mod <- Arima(ts, order = order,
                 seasonal = list(order = seasonal.order,
                                 period = seasonal.period), xreg = xdf)
  }
  lab.order <- paste0("(", order[1], ",", order[2], ",", order[3], ")")
  aic <- round(mod[['aic']], 3)
  rmse <- round(sqrt(mean((ts - mod$fitted)^2)), 3)
  se_reg <- round(sqrt(mod[['sigma2']]), 3)

  phi1 <- round(mod$coef["ar1"], 3)
  phi2 <- round(mod$coef["ar2"], 3)
```

```
  psi1 <- round(mod$coef["ma1"], 3)
  sar1 <- round(mod$coef["sar1"], 3)
  phi1 <- ifelse(is.na(phi1), "", phi1)
  phi2 <- ifelse(is.na(phi2), "", phi2)
  psi1 <- ifelse(is.na(psi1), "", psi1)
  sar1 <- ifelse(is.na(sar1), "", sar1)

  coef <- round(mod[['coef']], 3)
  coef <- round(coef[c((length(coef)-2), (length(coef)-1), length(coef))], 3)

  se <- round(sqrt(diag(mod[['var.coef']])), 3)
  se_phi1 <- round(se["ar1"], 3)
  se_phi2 <- round(se["ar2"], 3)
  se_psi1 <- round(se["ma1"], 3)
  se_sar1 <- round(se["sar1"], 3)
  se_phi1 <- ifelse(is.na(se_phi1), "", se_phi1)
  se_phi2 <- ifelse(is.na(se_phi2), "", se_phi2)
  se_psi1 <- ifelse(is.na(se_psi1), "", se_psi1)
  se_sar1 <- ifelse(is.na(se_sar1), "", se_sar1)
  se <- round(se[c((length(se)-2), (length(se)-1), length(se))], 3)


  names(lab.order) <- "ARMA Model"
  names(aic) <- "AIC"
  names(rmse) <- "RMSE"
  names(phi1) <- "$\\phi_1$"
  names(phi2) <- "$\\phi_2$"
  names(psi1) <- "$\\psi_1$"
  names(sar1) <- "Seasonal $\\phi_1$"
  names(se_reg) <- "Std. Err"

  oneline <- c(lab.order, aic, rmse, se_reg, phi1, phi2, psi1, sar1, coef)
  twoline <- c("", "", "", "",
               ifelse(se_phi1 == "", "", paste0("(", se_phi1, ")")),
               ifelse(se_phi2 == "", "", paste0("(", se_phi2, ")")),
               ifelse(se_psi1 == "", "", paste0("(", se_psi1, ")")),
               ifelse(se_sar1 == "", "", paste0("(", se_sar1, ")")),
               paste0("(", se, ")"))
  lines <- rbind(oneline, twoline)
  rownames(lines) <- NULL

  return(lines)
}

#AR(0) with covariates
ar0 <- armaFit(ts_house, order = c(0, 0, 0), xdf = covar)
```

```
print(xtable(ar0, digits = 3), booktabs = T, include.rownames = FALSE,
      sanitize.colnames.function=function(x){x})
```

ARMA Model	AIC	RMSE	Std. Err	ϕ_1	ϕ_2	ψ_1	Seasonal ϕ_1	PartisanUnem	Coattails	Pre1994
(0,0,0)	239.243	13.999	15.446					-2.053	18.396	47.994
								(1.733)	(5.331)	(5.703)

Part c

```
#AR(1)
ar1 <- armaFit(ts_house, order = c(1, 0, 0), xdf = covar)

#AR(2)
ar2 <- armaFit(ts_house, order = c(2, 0, 0), xdf = covar)

#MA(1)
ma1 <- armaFit(ts_house, order = c(0, 0, 1), xdf = covar)

#ARMA(1,1)
arma11 <- armaFit(ts_house, order = c(1, 0, 1), xdf = covar)

#bind the sum stat rows together
sums <- rbind(ar0, ar1, ar2, ma1, arma11)
```

```
print(xtable(sums, digits = 3), booktabs = T, include.rownames= FALSE,
      sanitize.colnames.function=function(x){x})
```

ARMA Model	AIC	RMSE	Std. Err	ϕ_1	ϕ_2	ψ_1	Seasonal ϕ_1	PartisanUnem	Coattails	Pre1994
(0,0,0)	239.243	13.999	15.446					-2.053	18.396	47.994
								(1.733)	(5.331)	(5.703)
(1,0,0)	240.221	13.732	15.492	0.234				-2.42	15.364	46.656
				(0.223)				(1.75)	(5.828)	(7.023)
(2,0,0)	239.662	13.034	15.05	0.448	-0.377			-2.858	10.279	44.729
				(0.238)	(0.215)			(1.744)	(5.862)	(6.038)
(0,0,1)	239.495	13.529	15.263			0.389		-2.761	13.121	45.386
						(0.3)		(1.841)	(6.315)	(7.58)
(1,0,1)	238.096	12.189	14.075	-0.382		1		-3.846	14.522	42.887
				(0.254)		(0.108)		(1.484)	(6.058)	(6.623)

Part d

```
#ar0
f_ar0 <- function(x, h){forecast(Arima(x, order=c(0,0,0)), h=h)}
e_ar0 <- tsCV(ts_house, f_ar0, h = 3,
              window = 20)
mae_ar0 <- round(apply(e_ar0, 2, function(x){mean(abs(ts_house - x), na.rm = T)}), 3)
avg_mae_ar0 <- round(mean(mae_ar0), 3)
names(avg_mae_ar0) <- "avgMAE"
e_ar0 <- c(ar0[1, 1], ar0[1, 2], ar0[1, 3], mae_ar0, avg_mae_ar0)

#ar1
f_ar1 <- function(x, h){forecast(Arima(x, order=c(1,0,0)), h=h)}
e_ar1 <- tsCV(ts_house, f_ar1, h = 3,
              window = 20)
mae_ar1 <- round(apply(e_ar1, 2, function(x){mean(abs(ts_house - x), na.rm = T)}), 3)
avg_mae_ar1 <- round(mean(mae_ar1), 3)
names(avg_mae_ar1) <- "avgMAE"
e_ar1 <- c(ar1[1, 1], ar1[1, 2], ar1[1, 3], mae_ar1, avg_mae_ar1)

#ar2
f_ar2 <- function(x, h){forecast(Arima(x, order=c(2,0,0)), h=h)}
```

```
e_ar2 <- tsCV(ts_house, f_ar2, h = 3,
              window = 20)
mae_ar2 <- round(apply(e_ar2, 2, function(x){mean(abs(ts_house - x), na.rm = T)}), 3)
avg_mae_ar2 <- round(mean(mae_ar2), 3)
names(avg_mae_ar2) <- "avgMAE"
e_ar2 <- c(ar2[1, 1], ar2[1, 2], ar2[1, 3], mae_ar2, avg_mae_ar2)

#ma1
f_ma1 <- function(x, h){forecast(Arima(x, order=c(0,0,1)), h=h)}
e_ma1 <- tsCV(ts_house, f_ma1, h = 3,
              window = 20)
mae_ma1 <- round(apply(e_ma1, 2, function(x){mean(abs(ts_house - x), na.rm = T)}), 3)
avg_mae_ma1 <- round(mean(mae_ma1), 3)
names(avg_mae_ma1) <- "avgMAE"
e_ma1 <- c(ma1[1, 1], ma1[1, 2], ma1[1, 3], mae_ma1, avg_mae_ma1)

#arma1,1
f_arma11 <- function(x, h){forecast(Arima(x, order=c(1,0,1)), h=h)}
e_arma11 <- tsCV(ts_house, f_arma11, h = 3,
              window = 20)
mae_arma11 <- round(apply(e_arma11, 2, function(x){mean(abs(ts_house - x), na.rm = T)}), 3)
avg_mae_arma11 <- round(mean(mae_arma11), 3)
names(avg_mae_arma11) <- "avgMAE"
e_arma11 <- c(arma11[1, 1], arma11[1, 2], arma11[1, 3], mae_arma11, avg_mae_arma11)

#compile model fit stats
forecastMAE <- rbind(e_ar0, e_ar1, e_ar2, e_ma1, e_arma11)
```

```
print(xtable(forecastMAE), booktabs = T, include.rownames=FALSE)
```

ARMA Model	AIC	RMSE	h=1	h=2	h=3	avgMAE
(0,0,0)	239.243	13.999	30.975	41.386	42.208	38.19
(1,0,0)	240.221	13.732	26.078	39.36	37.721	34.386
(2,0,0)	239.662	13.034	26.944	39.481	37.505	34.643
(0,0,1)	239.495	13.529	30.738	41.285	41.653	37.892
(1,0,1)	238.096	12.189	27.598	39.671	37.665	34.978

Part e

```
#selecting AR(1) as final model
ar1 <- Arima(ts_house, order = c(1, 0, 0), xreg = covar)

#counterfactual 1 - unemployment stays at 4.6% for all three elections
cf1 <- data.frame(
  "Pre1994" = rep(0, 3), #all forecasts are post1994
  "ParisanUnemp" = rep(4.6, 3),
  "PartisanMidterm" = c(-1, 0, 1),
  "Coattails" = c(0, 1, 0)
)
cf1
```

```
##   Pre1994 ParisanUnemp PartisanMidterm Coattails
## 1       0          4.6              -1         0
## 2       0          4.6               0         1
## 3       0          4.6               1         0
```

```r
#forecast forward three periods based on cf1 X's
pred_cf1 <- predict(ar1, newxreg = cf1)

##counterfactual 2 - unemployment falls to 3.6% for all three elections
cf2 <- data.frame(
  "Pre1994" = rep(0, 3), #all forecasts are post1994
  "ParisanUnemp" = rep(3.6, 3),
  "PartisanMidterm" = c(-1, 0, 1),
  "Coattails" = c(0, 1, 0)
)
cf2
```

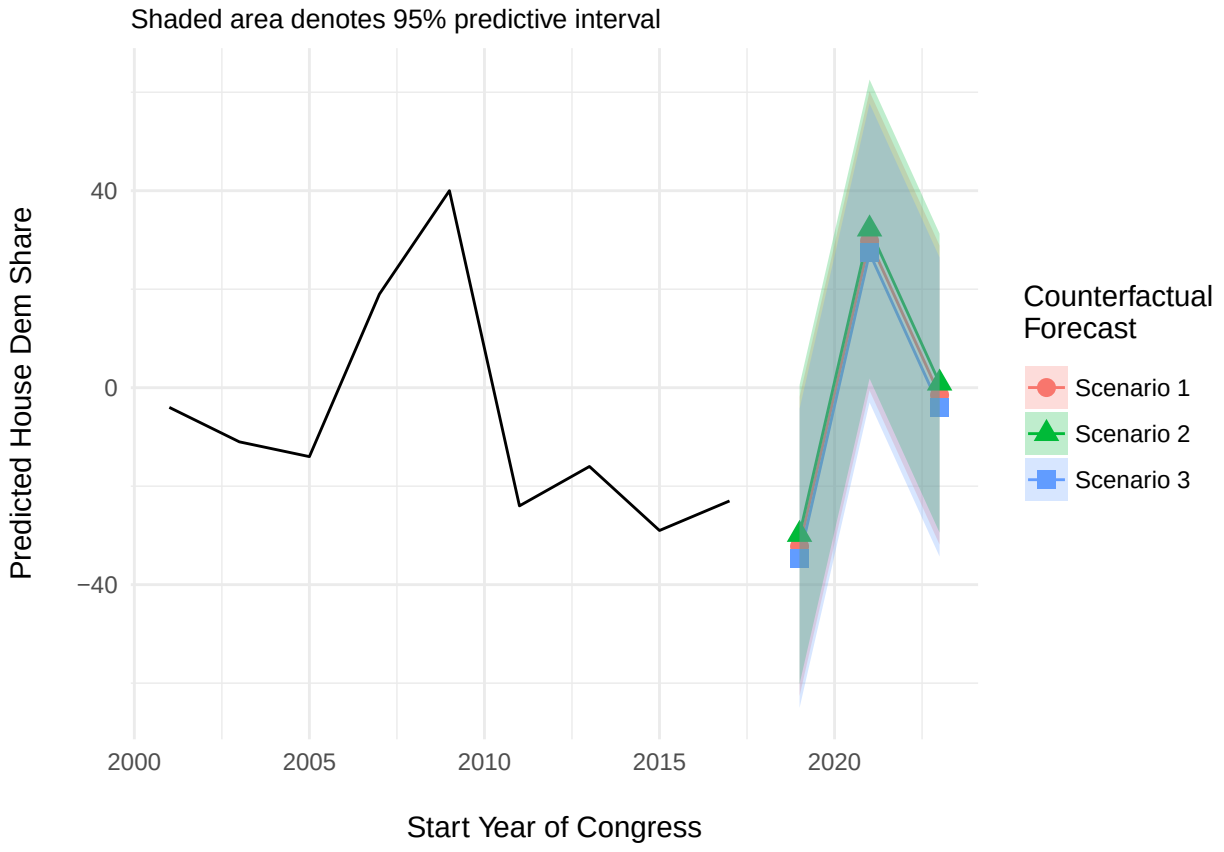
```
##   Pre1994 ParisanUnemp PartisanMidterm Coattails
## 1       0          3.6              -1         0
## 2       0          3.6               0         1
## 3       0          3.6               1         0
```

```r
#forecast forward three periods based on cf2 X's
pred_cf2 <- predict(ar1, newxreg = cf2)

##counterfactual 2 - unemployment rises to 5.6% for all three elections
cf3 <- data.frame(
  "Pre1994" = rep(0, 3), #all forecasts are post1994
  "ParisanUnemp" = rep(5.6, 3),
  "PartisanMidterm" = c(-1, 0, 1),
  "Coattails" = c(0, 1, 0)
)
cf3
```

```
##   Pre1994 ParisanUnemp PartisanMidterm Coattails
## 1       0          5.6              -1         0
## 2       0          5.6               0         1
## 3       0          5.6               1         0
```

```r
#forecast forward three periods based on cf2 X's
pred_cf3 <- predict(ar1, newxreg = cf3)

#construct tidy matrix for value, upper and lower
pred_vals <- data.frame(
  cf = c(rep("Scenario 1", 3), rep("Scenario 2", 3), rep("Scenario 3", 3)),
  time = rep(c(2019, 2021, 2023), 3),
  values = c(pred_cf1$pred, pred_cf2$pred, pred_cf3$pred),
  upper = c(pred_cf1$pred[1]+1.96*pred_cf1$se,
            pred_cf1$pred[2]+1.96*pred_cf1$se,
            pred_cf1$pred[3]+1.96*pred_cf1$se,
            pred_cf2$pred[1]+1.96*pred_cf2$se,
            pred_cf2$pred[2]+1.96*pred_cf2$se,
            pred_cf2$pred[3]+1.96*pred_cf2$se,
            pred_cf3$pred[1]+1.96*pred_cf3$se,
            pred_cf3$pred[2]+1.96*pred_cf3$se,
            pred_cf3$pred[3]+1.96*pred_cf3$se),
  lower = c(pred_cf1$pred[1]-1.96*pred_cf1$se,
            pred_cf1$pred[2]-1.96*pred_cf1$se,
            pred_cf1$pred[3]-1.96*pred_cf1$se,
            pred_cf2$pred[1]-1.96*pred_cf2$se,
            pred_cf2$pred[2]-1.96*pred_cf2$se,
            pred_cf2$pred[3]-1.96*pred_cf2$se,
```

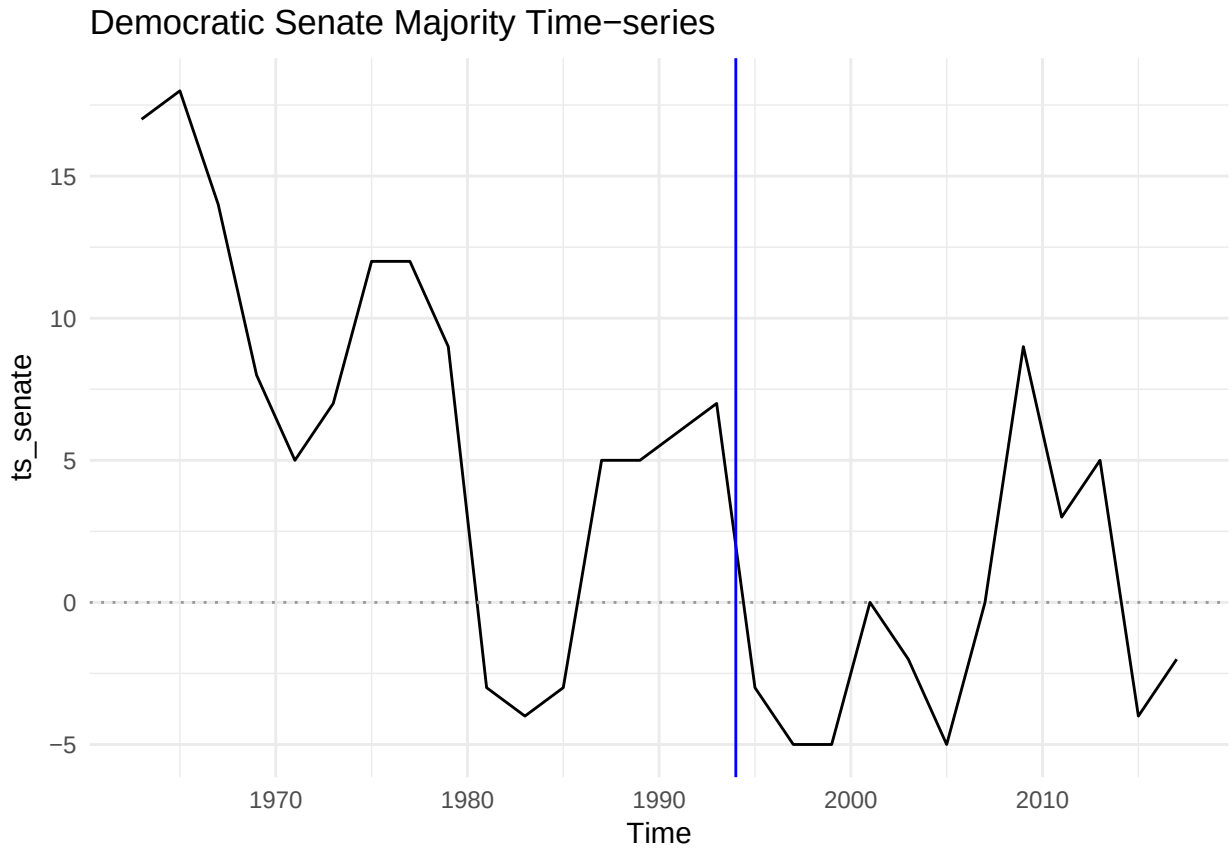
```
            pred_cf3$pred[1]-1.96*pred_cf3$se,
            pred_cf3$pred[2]-1.96*pred_cf3$se,
            pred_cf3$pred[3]-1.96*pred_cf3$se))

ggplot() +
  geom_line(data=pred_vals, aes(x = time, y = values,
                                group = cf, color = cf)) +
  geom_point(data = pred_vals, aes(x = time, y = values,
                                   group = cf, shape = cf, color = cf),
             size = 3) +
  geom_ribbon(data = pred_vals, aes(x = time, ymin = lower, ymax = upper,
                                    group = cf, fill = cf),
              color = NA, alpha = .25) +
  geom_line(data = congress %>% filter(StartYear >= 2000), aes(x = StartYear, y = DemHouseMaj),
            color = "black") +
  scale_x_continuous() +
  xlab("\nStart Year of Congress") +
  ylab("Predicted House Dem Share\n") +
  labs(subtitle = "Shaded area denotes 95% predictive interval",
       fill = "Counterfactual\nForecast",
       color = "Counterfactual\nForecast",
       shape = "Counterfactual\nForecast") +
  theme_minimal()
```



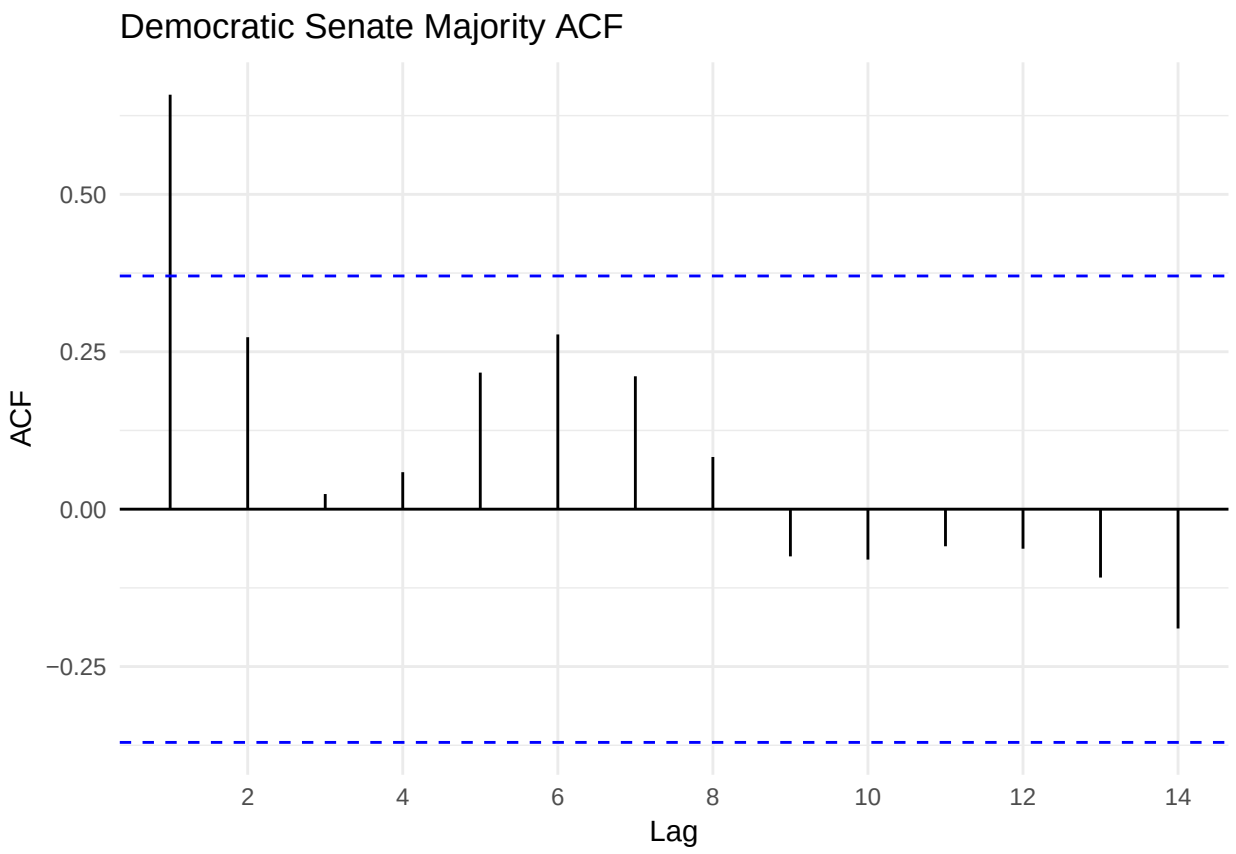
Problem 2 - U.S. Senate

Part a

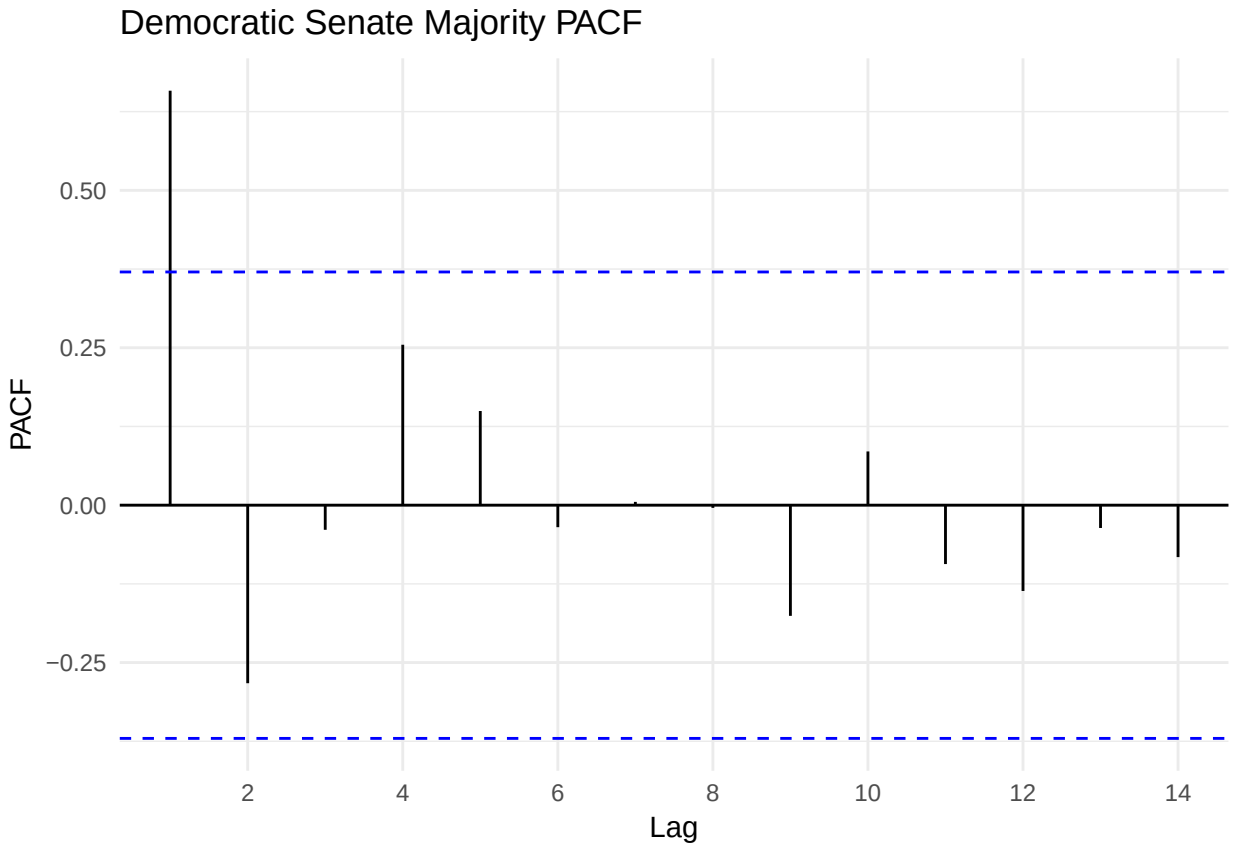
```
#plot ts, ACF, PACF
#run ADF and PP tests
#demean by pre/post 1994 periods
#plot ts, ACF, PACF
#what effect does 1994 structural break have on ts?

#pull ts, every other year frequency 1963-2017
ts_senate <- ts(congress$DemSenateMaj,
                frequency = 1/2,
                start = 1963, end = 2017)

#plot as observed
autoplot(ts_senate) +
  geom_hline(yintercept = 0, linetype = 3, color = "grey60") +
  geom_vline(xintercept = 1994, color = "Blue") +
  theme_minimal() +
  labs(title = "Democratic Senate Majority Time-series")
```



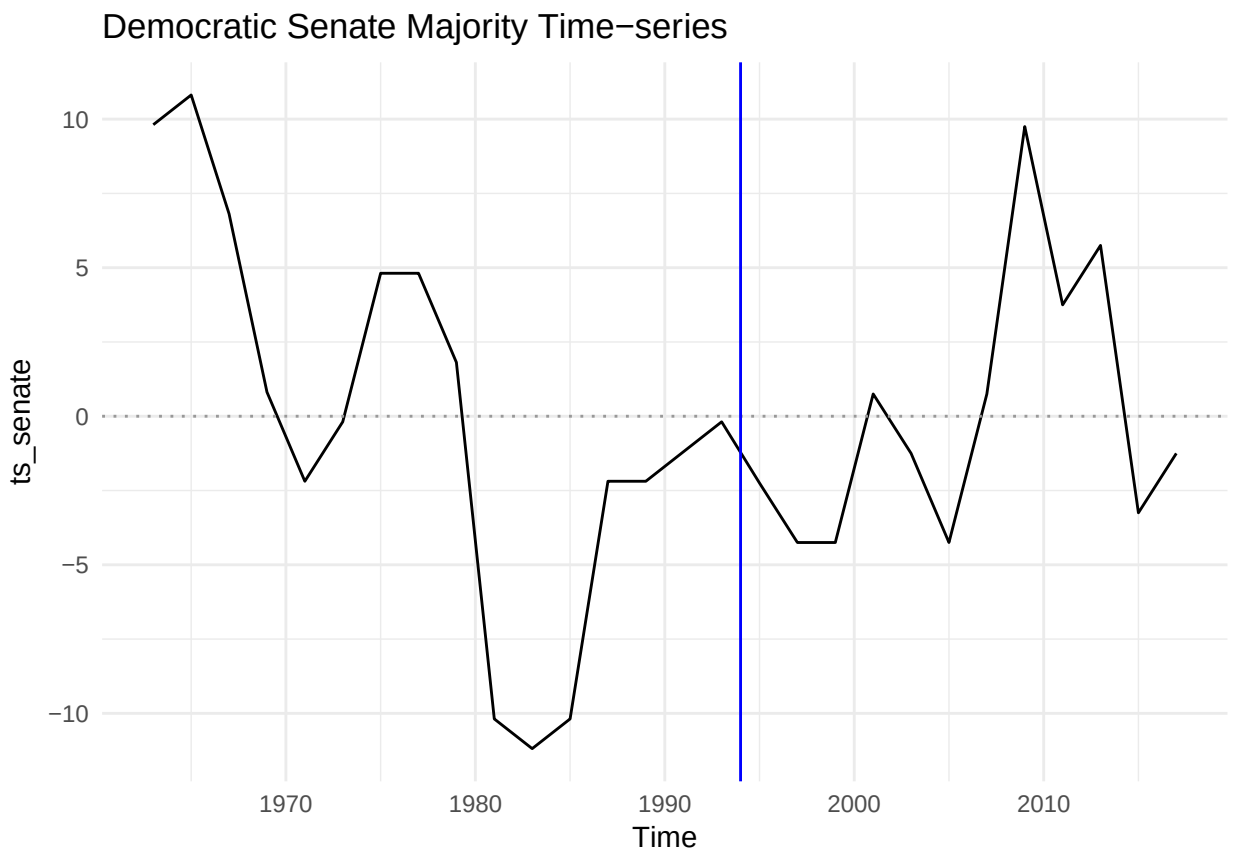

```
#observed ACF
ggAcf(ts_senate) + #could be AR(1)
  theme_minimal() +
  labs(title = "Democratic Senate Majority ACF")
```



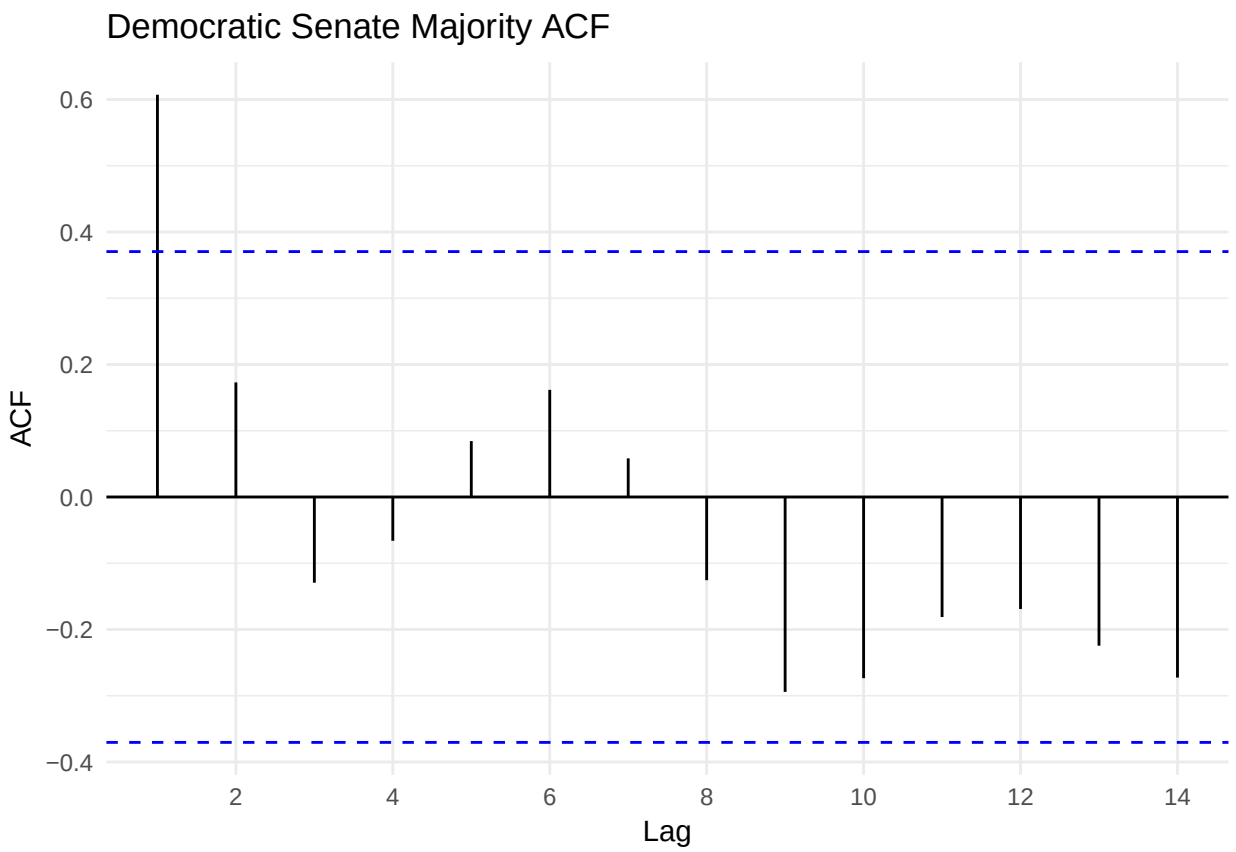

```
#observed PACF
ggPacf(ts_senate) + #AR(1), phi = .65 ish
  theme_minimal() +
  labs(title = "Democratic Senate Majority PACF")
```



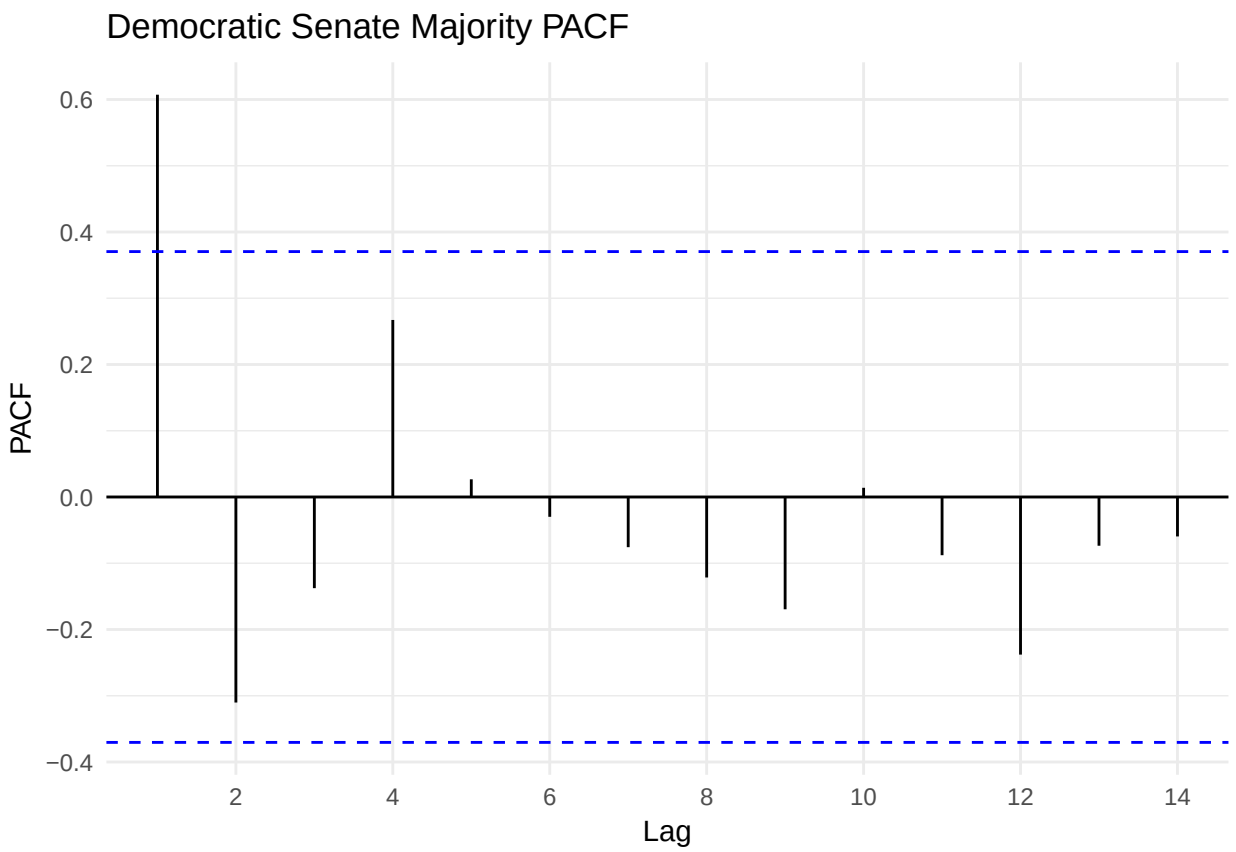

```
#pre-1994 mean for ts
preMean <- congress %>%
  filter(StartYear < 1994) %>%
  summarize(mean = mean(DemSenateMaj)) %>%
  pull(mean)

#post-1994 mean for ts
postMean <- congress %>%
  filter(StartYear >= 1994) %>%
  summarize(mean = mean(DemSenateMaj)) %>%
  pull(mean)

#demean based on pre/post 1994 (i.e. 1-16th obs vs 17-28th obs)
ts_senate[1:16] <- ts_senate[1:16] - preMean
ts_senate[-1:-16] <- ts_senate[-1:-16] - postMean

#demeaned ts - looks stationary now
autoplot(ts_senate) +
  geom_hline(yintercept = 0, linetype = 3, color = "grey60") +
  geom_vline(xintercept = 1994, color = "Blue") +
  theme_minimal() +
  labs(title = "Democratic Senate Majority Time-series")
```




```
#demeaned ACF
ggAcf(ts_senate) + #still shows autocorrelation
  theme_minimal() +
  labs(title = "Democratic Senate Majority ACF")
```




```
#demeaned PACF
ggPacf(ts_senate) + #need an AR(1) with phi = .6 for this ts
  theme_minimal() +
  labs(title = "Democratic Senate Majority PACF")
```



Part b

```
#pull ts, every other year frequency 1963-2017
ts_senate <- ts(congress$DemSenateMaj,
                frequency = 1/2,
                start = 1963, end = 2017)

#create df of covariates
covar <- congress %>% select(PartisanMidterm, PartisanUnem, Coattails, Pre1994)

#AR(0) with covariates
ar0 <- armaFit(ts_senate, order = c(0, 0, 0), xdf = covar)

#AR(1)
ar1 <- armaFit(ts_senate, order = c(1, 0, 0), xdf = covar)
tab.ar1 <- xtable(ar1)

#AR(2)
ar2 <- armaFit(ts_senate, order = c(2, 0, 0), xdf = covar)
tab.ar2 <- xtable(ar2)

#MA(1)
ma1 <- armaFit(ts_senate, order = c(0, 0, 1), xdf = covar)
tab.ma1 <- xtable(ma1)

#ARMA(1,1)
arma11 <- armaFit(ts_senate, order = c(1, 0, 1), xdf = covar)
```

```
tab.arma11 <- xtable(arma11)

#bind the sum stat rows together
sums <- rbind(ar0, ar1, ar2, ma1, arma11)
```

```
print(xtable(sums), booktabs = T, include.rownames = FALSE,
      sanitize.colnames.function=function(x){x})
```

ARMA Model	AIC	RMSE	Std. Err	ϕ_1	ϕ_2	ψ_1	Seasonal ϕ_1	PartisanUnem	Coattails	Pre1994
(0,0,0)	183.044	5.132	5.662					0.358	3.403	8.503
								(0.635)	(1.954)	(2.091)
(1,0,0)	172.3	4.039	4.557	0.696				-0.268	1.892	8.151
				(0.145)				(0.459)	(1.392)	(3.507)
(2,0,0)	168.047	3.563	4.115	1.087	-0.565			-0.884	0.103	6.611
				(0.16)	(0.174)			(0.367)	(1.091)	(2.581)
(0,0,1)	170.826	3.749	4.229			1		-1.224	1.784	7.377
						(0.122)		(0.339)	(1.467)	(2.204)
(1,0,1)	168.501	3.413	3.941	0.44		1		-1.35	0.807	9.131
				(0.187)		(0.148)		(0.24)	(1.134)	(2.171)

Part c

```
ar1_sar1 <- armaFit(ts_senate,
                    order = c(1, 0, 0),
                    seasonal.order = c(1, 0, 0),
                    seasonal.period = 3,
                    xdf = covar)
ar1_sar1[1,1] <- "(1, 0, 0)(1, 0, 0)"
sums <- rbind(ar0, ar1, ar2, ma1, arma11, ar1_sar1)
```

```
print(xtable(sums), booktabs = T, include.rownames = FALSE,
      sanitize.colnames.function=function(x){x})
```

ARMA Model	AIC	RMSE	Std. Err	ϕ_1	ϕ_2	ψ_1	Seasonal ϕ_1	PartisanUnem	Coattails	Pre1994
(0,0,0)	183.044	5.132	5.662					0.358	3.403	8.503
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(1,0,0)	172.3	4.039	4.557	0.696				-0.268	1.892	8.151
				(0.145)				(0.459)	(1.392)	(3.507)
(2,0,0)	168.047	3.563	4.115	1.087	-0.565			-0.884	0.103	6.611
				(0.16)	(0.174)			(0.367)	(1.091)	(2.581)
(0,0,1)	170.826	3.749	4.229			1		-1.224	1.784	7.377
						(0.122)		(0.339)	(1.467)	(2.204)
(1,0,1)	168.501	3.413	3.941	0.44		1		-1.35	0.807	9.131
				(0.187)		(0.148)		(0.24)	(1.134)	(2.171)
(1, 0, 0)(1, 0, 0)	169.047	3.622	4.182	0.818			-0.51	-0.301	0.728	6.887
				(0.12)			(0.185)	(0.388)	(1.029)	(3.045)