# U.S. Excess Deaths Project

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## Import Packages

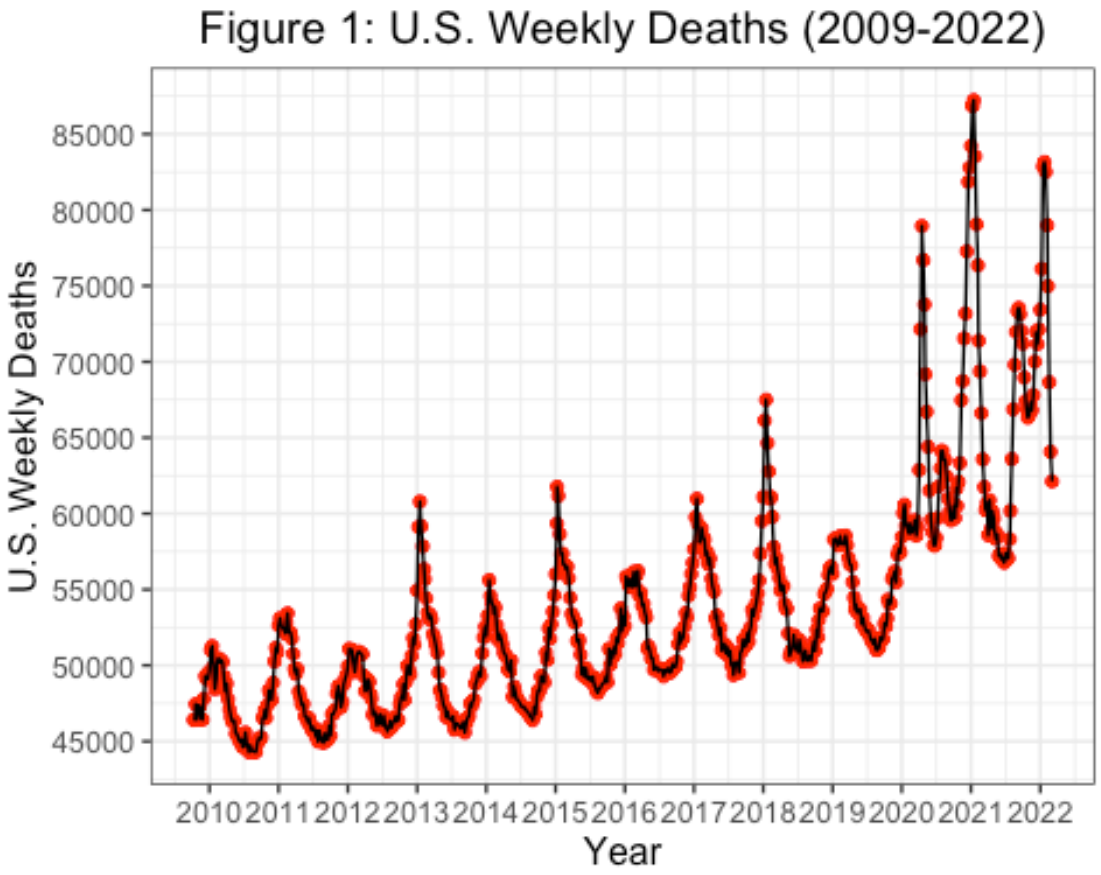
```
library(ggplot2)
library(forecast)

## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo

library(urca)
```

## Import Data and Split into Training and Testing Data Sets

```
data <- read.csv("US_Weekly_Deaths.csv", as.is=T)
training_data <- as.ts(data[1:535,]) # Before COVID deaths
training_data <- ts(training_data, start = 2009.7665982, frequency = 52.17857
)
testing_data <- as.ts(data[536:dim(data)[1],]) # Week 536 has first COVID dea
th
testing_data <- ts(testing_data, start = 2020.03832991, frequency = 52.17857)
```

## Figure 1

```
# Plot of US Weekly Deaths (2009-2022)
ggplot(data, aes(x = Date, y = All.Deaths)) +
  geom_point(col = "red") +
  geom_line() +
  labs(x = "Year",
       y = "U.S. Weekly Deaths",
       title = "Figure 1: U.S. Weekly Deaths (2009-2022)") +
  scale_x_continuous(breaks = seq(2009, 2022, by = 1)) +
  scale_y_continuous(breaks = seq(45000, 85000, by = 5000)) +
  theme_bw() +
  theme(text = element_text(size = 12),
        plot.title = element_text(hjust = 0.5))
```



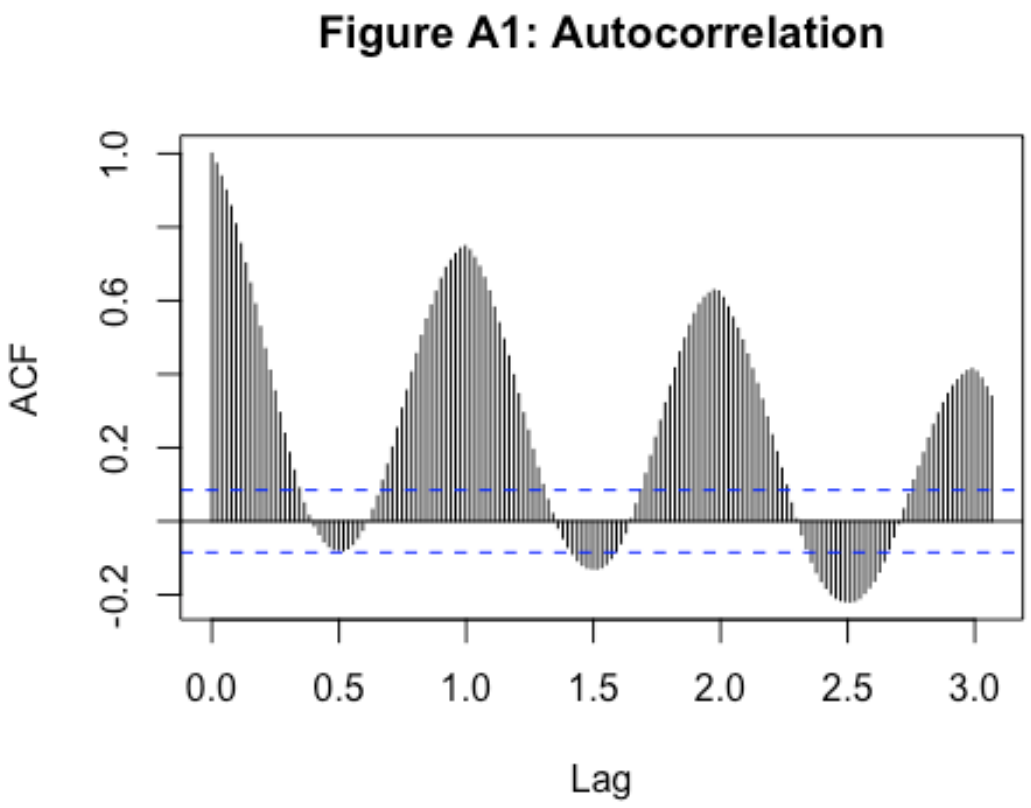

```
# Time Series for All Deaths
Deaths <- training_data[,"All.Deaths"]
Year <- training_data[,"Year"]
Week <- training_data[,"Week"]
```

## Summary Statistics

```
summary(Deaths) # Summary of Weekly Deaths Pre-COVID (Training Dataset)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   44281   47912   50749   51070   53468   67495

summary(testing_data[,"All.Deaths"]) # Summary of Weekly Deaths During COVID
(Testing Dataset)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   56764   59570   63576   66336   71969   87233
```

## Figure A1

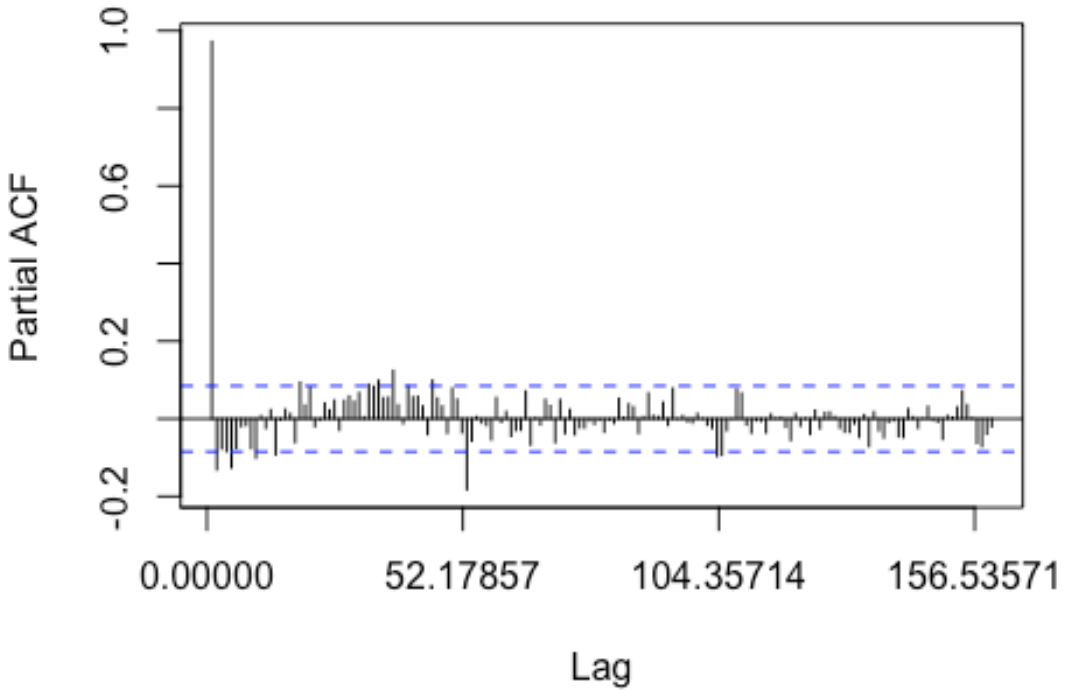
```
# Autocorrelation
acf(Deaths, lag = 160, main = 'Figure A1: Autocorrelation') # acf
```




## Figure A2

```
# Partial Autocorrelation
Pacf(Deaths, lag = 160, main = 'Figure A2: Partial Autocorrelation')
```

**Figure A2: Partial Autocorrelation**




## Test for Stationarity Using Original Data from Training Set

```
# Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for Stationarity
summary(ur.kpss(Deaths)) # reject null (NOT stationary)
```

```
##
## ########################
## # KPSS Unit Root Test #
## ########################
##
## Test is of type: mu with 6 lags.
##
## Value of test-statistic is: 3.3102
##
## Critical value for a significance level of:
##                 10pct  5pct 2.5pct  1pct
## critical values 0.347 0.463  0.574 0.739
```

## Take Seasonal Difference of Weekly Deaths for Training Data Set

```
SD_Deaths <- diff(Deaths, lag = 52, differences = 1)
```

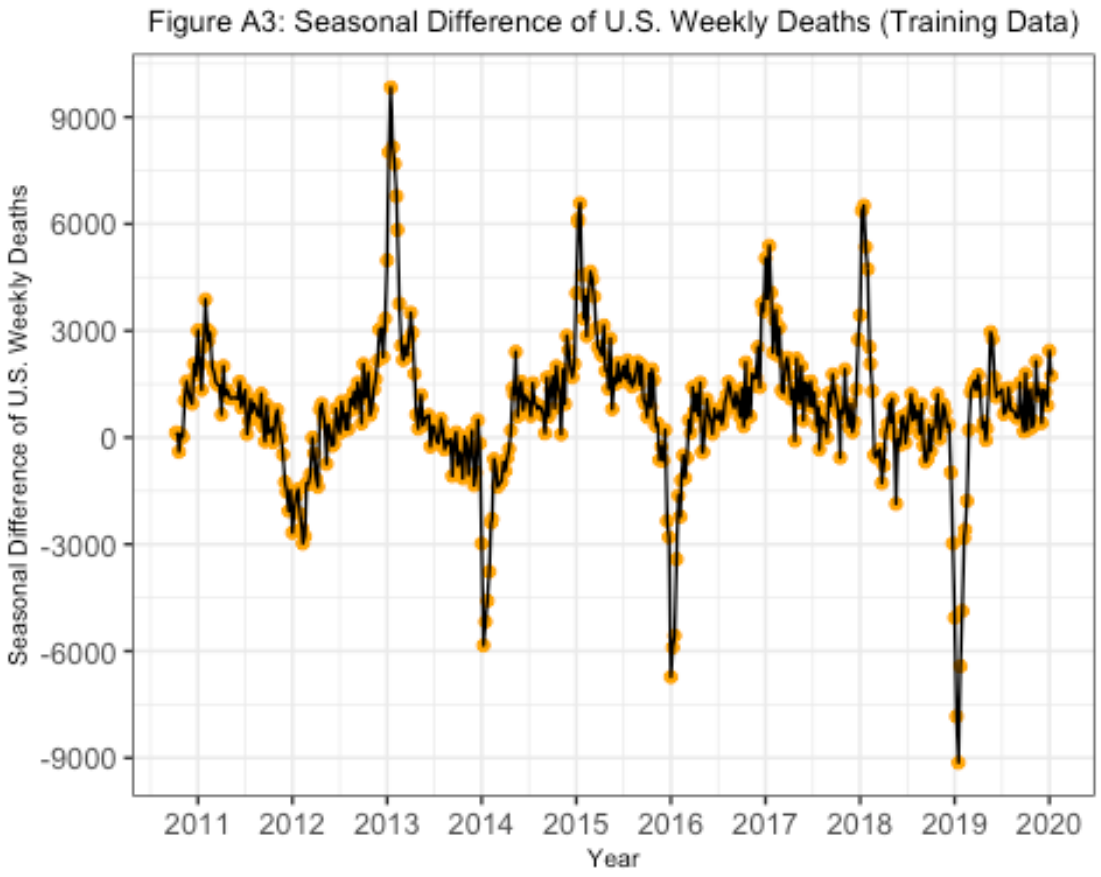
## Test for Stationarity Using Seasonally-Differenced Data from Training Set

```
summary(ur.kpss(SD_Deaths)) # stationary
```

```
##
## ########################
## # KPSS Unit Root Test #
## ########################
##
## Test is of type: mu with 5 lags.
##
## Value of test-statistic is: 0.1032
##
## Critical value for a significance level of:
##                 10pct  5pct 2.5pct  1pct
## critical values 0.347 0.463  0.574 0.739
```

## Figure A3

```
# Seasonal Difference of U.S. Weekly Deaths
SD_deaths_data <- data.frame(Year = training_data[53:length(Deaths),"Date"],
SD_Deaths)

ggplot(SD_deaths_data, aes(x = Year, y = SD_Deaths)) +
  geom_point(col = "orange") +
  geom_line() +
  labs(x = "Year",
       y = "Seasonal Difference of U.S. Weekly Deaths",
       title = "Figure A3: Seasonal Difference of U.S. Weekly Deaths (Trainin
g Data)") +
  scale_x_continuous(breaks = seq(2009, 2020, by = 1)) +
  scale_y_continuous(breaks = seq(-15000, 15000, by = 3000)) +
  theme_bw() +
  theme(text = element_text(size = 12),
        plot.title = element_text(hjust = 0.5),
        title = element_text(size = 8))
```




## Model Selection

```
# Seasonal Component (0, 1, 0)
M000 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(0,1,0), per
iod = 52))
M001 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(0,1,0), per
iod = 52))
M002 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(0,1,0), per
iod = 52))
M003 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(0,1,0), per
iod = 52))
M004 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(0,1,0), per
iod = 52))
M005 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(0,1,0), per
iod = 52))
M006 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(0,1,0), per
iod = 52))
M007 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(0,1,0), per
iod = 52))
M008 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(0,1,0), per
iod = 52))
M009 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(0,1,0), per
```

```
iod = 52))
M010 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(0,1,0), per
iod = 52))
M011 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(0,1,0), per
iod = 52))
M012 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(0,1,0), per
iod = 52))
M013 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(0,1,0), per
iod = 52))
M014 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(0,1,0), per
iod = 52))
M015 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(0,1,0), per
iod = 52))

# Seasonal Component (1, 1, 0)
M100 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(1,1,0), per
iod = 52))
M101 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(1,1,0), per
iod = 52))
M102 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(1,1,0), per
iod = 52))
M103 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(1,1,0), per
iod = 52))
M104 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(1,1,0), per
iod = 52))
M105 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(1,1,0), per
iod = 52))
M106 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(1,1,0), per
iod = 52))
M107 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(1,1,0), per
iod = 52))
M108 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(1,1,0), per
iod = 52))
M109 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(1,1,0), per
iod = 52))
M110 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(1,1,0), per
iod = 52))
M111 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(1,1,0), per
iod = 52))
M112 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(1,1,0), per
iod = 52))
M113 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(1,1,0), per
iod = 52))
M114 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(1,1,0), per
iod = 52))
M115 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(1,1,0), per
iod = 52))

# Seasonal Component (0, 1, 1)
M200 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(0,1,1), per
```

```
iod = 52))
M201 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(0,1,1), per
iod = 52))
M202 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(0,1,1), per
iod = 52))
M203 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(0,1,1), per
iod = 52))
M204 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(0,1,1), per
iod = 52))
M205 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(0,1,1), per
iod = 52))
M206 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(0,1,1), per
iod = 52))
M207 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(0,1,1), per
iod = 52))
M208 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(0,1,1), per
iod = 52))
M209 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(0,1,1), per
iod = 52))
M210 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(0,1,1), per
iod = 52))
M211 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(0,1,1), per
iod = 52))
M212 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(0,1,1), per
iod = 52))
M213 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(0,1,1), per
iod = 52))
M214 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(0,1,1), per
iod = 52))
M215 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(0,1,1), per
iod = 52))

# Seasonal Component (1, 1, 1)
M300 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(1,1,1), per
iod = 52))
M301 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(1,1,1), per
iod = 52))
M302 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(1,1,1), per
iod = 52))
M303 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(1,1,1), per
iod = 52))
M304 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(1,1,1), per
iod = 52))
M305 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(1,1,1), per
iod = 52))
M306 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(1,1,1), per
iod = 52))
M307 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(1,1,1), per
iod = 52))
M308 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(1,1,1), per
```

```
iod = 52))
M309 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(1,1,1), per
iod = 52))
M310 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(1,1,1), per
iod = 52))
M311 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(1,1,1), per
iod = 52))
M312 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(1,1,1), per
iod = 52))
M313 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(1,1,1), per
iod = 52))
M314 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(1,1,1), per
iod = 52))
M315 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(1,1,1), per
iod = 52))

# Seasonal Component (2, 1, 0)
M400 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(2,1,0), per
iod = 52))
M401 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(2,1,0), per
iod = 52))
M402 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(2,1,0), per
iod = 52))
M403 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(2,1,0), per
iod = 52))
M404 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(2,1,0), per
iod = 52))
M405 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(2,1,0), per
iod = 52))
M406 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(2,1,0), per
iod = 52))
M407 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(2,1,0), per
iod = 52))
M408 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(2,1,0), per
iod = 52))
M409 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(2,1,0), per
iod = 52))
M410 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(2,1,0), per
iod = 52))
M411 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(2,1,0), per
iod = 52))
M412 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(2,1,0), per
iod = 52))
M413 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(2,1,0), per
iod = 52))
M414 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(2,1,0), per
iod = 52))
M415 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(2,1,0), per
iod = 52))
```

```r
# Seasonal Component (0, 1, 2)
M500 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(0,1,2), per
iod = 52))
M501 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(0,1,2), per
iod = 52))
M502 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(0,1,2), per
iod = 52))
M503 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(0,1,2), per
iod = 52))
M504 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(0,1,2), per
iod = 52))
M505 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(0,1,2), per
iod = 52))
M506 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(0,1,2), per
iod = 52))
M507 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(0,1,2), per
iod = 52))
M508 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(0,1,2), per
iod = 52))
M509 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(0,1,2), per
iod = 52))
M510 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(0,1,2), per
iod = 52))
M511 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(0,1,2), per
iod = 52))
M512 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(0,1,2), per
iod = 52))
M513 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(0,1,2), per
iod = 52))
M514 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(0,1,2), per
iod = 52))
M515 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(0,1,2), per
iod = 52))

# Seasonal Component (2, 1, 1)
M600 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(2,1,1), per
iod = 52))
M601 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(2,1,1), per
iod = 52))
M602 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(2,1,1), per
iod = 52))
M603 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(2,1,1), per
iod = 52))
M604 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(2,1,1), per
iod = 52))
M605 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(2,1,1), per
iod = 52))
M606 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(2,1,1), per
iod = 52))
M607 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(2,1,1), per
```

```
iod = 52))
M608 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(2,1,1), per
iod = 52))
M609 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(2,1,1), per
iod = 52))
M610 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(2,1,1), per
iod = 52))
M611 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(2,1,1), per
iod = 52))
M612 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(2,1,1), per
iod = 52))
M613 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(2,1,1), per
iod = 52))
M614 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(2,1,1), per
iod = 52))
M615 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(2,1,1), per
iod = 52))

# Seasonal Component (1, 1, 2)
M700 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(1,1,2), per
iod = 52))
M701 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(1,1,2), per
iod = 52))
M702 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(1,1,2), per
iod = 52))
M703 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(1,1,2), per
iod = 52))
M704 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(1,1,2), per
iod = 52))
M705 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(1,1,2), per
iod = 52))
M706 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(1,1,2), per
iod = 52))
M707 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(1,1,2), per
iod = 52))
M708 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(1,1,2), per
iod = 52))
M709 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(1,1,2), per
iod = 52))
M710 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(1,1,2), per
iod = 52))
M711 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(1,1,2), per
iod = 52))
M712 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(1,1,2), per
iod = 52))
M713 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(1,1,2), per
iod = 52))
M714 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(1,1,2), per
iod = 52))
M715 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(1,1,2), per
```

```
iod = 52))

# Seasonal Component (2, 1, 2)
M800 <- arima(Deaths, order = c(0,0,0), seasonal = list(order = c(2,1,2), per
iod = 52))
M801 <- arima(Deaths, order = c(1,0,0), seasonal = list(order = c(2,1,2), per
iod = 52))
M802 <- arima(Deaths, order = c(0,0,1), seasonal = list(order = c(2,1,2), per
iod = 52))
M803 <- arima(Deaths, order = c(1,0,1), seasonal = list(order = c(2,1,2), per
iod = 52))
M804 <- arima(Deaths, order = c(2,0,0), seasonal = list(order = c(2,1,2), per
iod = 52))
M805 <- arima(Deaths, order = c(0,0,2), seasonal = list(order = c(2,1,2), per
iod = 52))
M806 <- arima(Deaths, order = c(2,0,1), seasonal = list(order = c(2,1,2), per
iod = 52))
M807 <- arima(Deaths, order = c(1,0,2), seasonal = list(order = c(2,1,2), per
iod = 52))
M808 <- arima(Deaths, order = c(2,0,2), seasonal = list(order = c(2,1,2), per
iod = 52))
M809 <- arima(Deaths, order = c(3,0,0), seasonal = list(order = c(2,1,2), per
iod = 52))
M810 <- arima(Deaths, order = c(0,0,3), seasonal = list(order = c(2,1,2), per
iod = 52))
M811 <- arima(Deaths, order = c(3,0,1), seasonal = list(order = c(2,1,2), per
iod = 52))
M812 <- arima(Deaths, order = c(1,0,3), seasonal = list(order = c(2,1,2), per
iod = 52))
M813 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(2,1,2), per
iod = 52))
M814 <- arima(Deaths, order = c(2,0,3), seasonal = list(order = c(2,1,2), per
iod = 52))
M815 <- arima(Deaths, order = c(3,0,3), seasonal = list(order = c(2,1,2), per
iod = 52))
```

## Compare Model AIC's

```
# Compare Models (choose one with lowest AIC)
AIC(M000, M001, M002, M003, M004, M005, M006, M007,
    M008, M009, M010, M011, M012, M013, M014, M015,
    M100, M101, M102, M103, M104, M105, M106, M107,
    M108, M109, M110, M111, M112, M113, M114, M115,
    M200, M201, M202, M203, M204, M205, M206, M207,
    M208, M209, M210, M211, M212, M213, M214, M215,
    M300, M301, M302, M303, M304, M305, M306, M307,
    M308, M309, M310, M311, M312, M313, M314, M315,
    M400, M401, M402, M403, M404, M405, M406, M407,
    M408, M409, M410, M411, M412, M413, M414, M415,
```

```
    M500, M501, M502, M503, M504, M505, M506, M507,
    M508, M509, M510, M511, M512, M513, M514, M515,
    M600, M601, M602, M603, M604, M605, M606, M607,
    M608, M609, M610, M611, M612, M613, M614, M615,
    M700, M701, M702, M703, M704, M705, M706, M707,
    M708, M709, M710, M711, M712, M713, M714, M715,
    M800, M801, M802, M803, M804, M805, M806, M807,
    M808, M809, M810, M811, M812, M813, M814, M815)
```

## Final Model: M513: ARIMA(3, 0, 2)(0, 1, 2) [52]

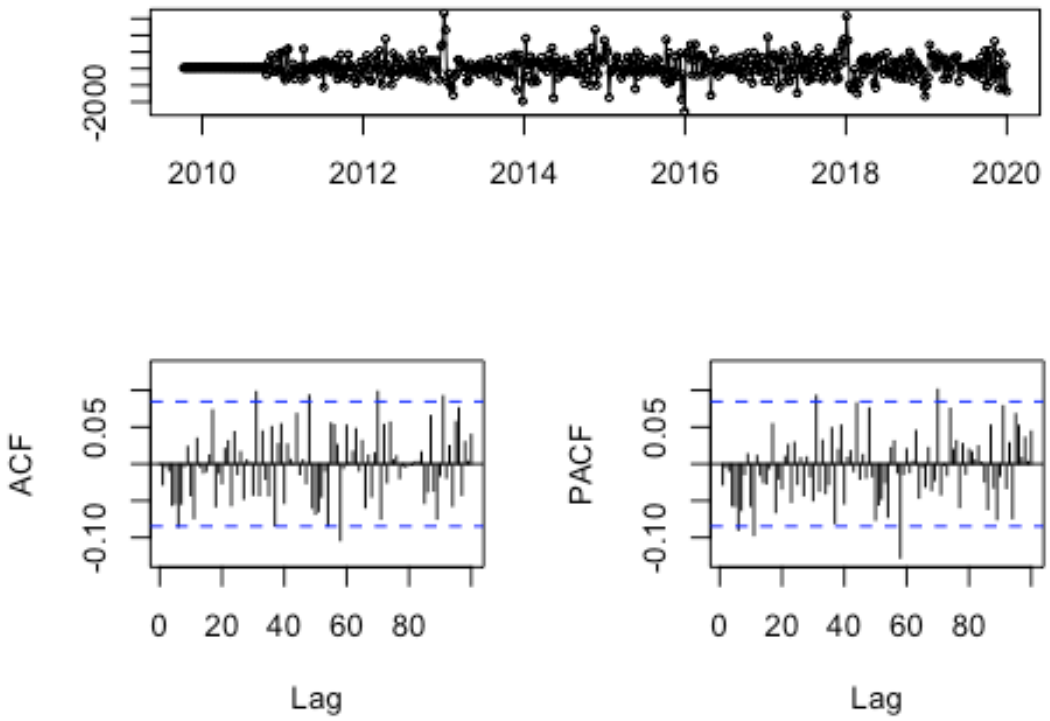
```
M513 <- arima(Deaths, order = c(3,0,2), seasonal = list(order = c(0,1,2), per
iod = 52))
summary(M513)
```

```
##
## Call:
## arima(x = Deaths, order = c(3, 0, 2), seasonal = list(order = c(0, 1, 2),
period = 52))
##
## Coefficients:
##           ar1     ar2     ar3     ma1     ma2     sma1    sma2
##       -0.8976  0.8908  0.8405  1.8074  0.8188  -0.7180  0.1034
## s.e.   0.0762  0.0263  0.0653  0.0980  0.0963   0.0499  0.0533
##
## sigma^2 estimated as 495982:  log likelihood = -3868.77,  aic = 7753.54
##
## Training set error measures:
##                     ME     RMSE      MAE       MPE      MAPE     MASE
## Training set 80.57158 669.3204 477.5416 0.1457515 0.9107069 0.776708
##                      ACF1
## Training set -0.02794821
```

## Figure A4

```
tsdisplay(residuals(M513), lag.max = 100, main='Figure A4: Model Residuals')
```

**Figure A4: Model Residuals**



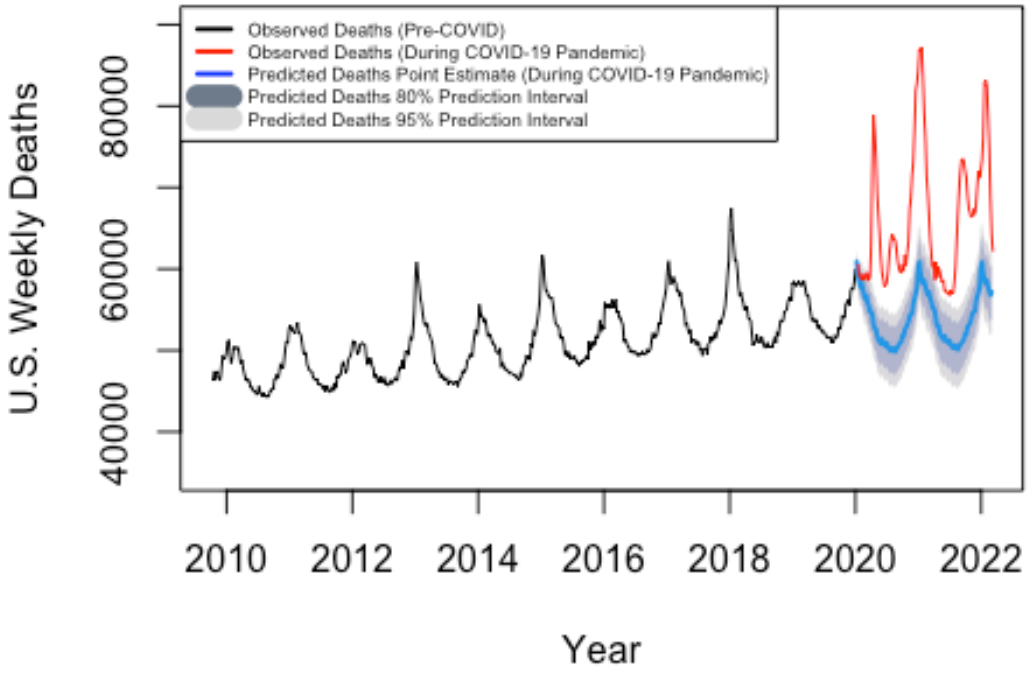

## Model Forecasting

```
forecast <- forecast(M513, h = 113) # 113 weeks in the testing data set
```

## Figure A5

```
plot(forecast, xlab = "Year",
     ylab = "U.S. Weekly Deaths",
     main = "Figure A5: Observed and Predicted U.S. Weekly Deaths",
     ylim = c(35000, 90000), cex.main = 0.85)
lines(testing_data[,"All.Deaths"], col = "red")
legend("topleft", legend = c("Observed Deaths (Pre-COVID)", "Observed Deaths
(During COVID-19 Pandemic)", "Predicted Deaths Point Estimate (During COVID-1
9 Pandemic)", "Predicted Deaths 80% Prediction Interval", "Predicted Deaths 9
5% Prediction Interval"),
       lty = 1, lwd = c(2, 2, 2, 10, 10), col = c("black", "red", "blue", "li
ghtsteelblue4", "gray85"), cex = 0.5)
```

**Figure A5: Observed and Predicted U.S. Weekly Deaths**




## Compute Excess Deaths

```
point_estimate <- forecast$mean
upper_bound <- forecast$upper[,2]
excess_deaths <- as.numeric(testing_data[,"All.Deaths"]) - as.numeric(upper_b
ound)
excess_deaths_data <- data.frame(Year = testing_data[,"Date"], COVID_deaths =
testing_data[,"COVID.19.Deaths"], excess_deaths)
```

## Total Excess Deaths

```
sum(excess_deaths) # total number of excess deaths

## [1] 883510.4
```

## Total COVID-19 Deaths

```
sum(testing_data[,"COVID.19.Deaths"]) # total number of COVID deaths

## [1] 981196
```

## Correlation Between Excess Deaths and COVID-19 Deaths

```
round(cor(excess_deaths, testing_data[,"COVID.19.Deaths"]), 3)

## [1] 0.951

cor.test(excess_deaths, testing_data[,"COVID.19.Deaths"])

##
##  Pearson's product-moment correlation
##
## data:  excess_deaths and testing_data[, "COVID.19.Deaths"]
## t = 32.442, df = 111, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.9297232 0.9660933
## sample estimates:
##       cor
## 0.9511033
```

## Figure 2

```
ggplot(excess_deaths_data, aes(x = Year, y = excess_deaths)) +
  geom_point(data = excess_deaths_data, aes(x = Year, y = excess_deaths), col
or = "black") +
  geom_point(data = excess_deaths_data, aes(x = Year, y = COVID_deaths), colo
r = "black") +
  geom_line(data = excess_deaths_data, aes(x = Year, y = excess_deaths, color
= 'Excess Deaths')) +
  geom_line(data = excess_deaths_data, aes(x = Year, y = COVID_deaths, color
= 'COVID-19 Deaths')) +
  labs(x = "Year",
       y = "U.S. Weekly Deaths",
       title = "Figure 2: U.S. Weekly Excess Deaths and COVID-19 Deaths (2020
-2022)") +
  scale_x_continuous(breaks = seq(2020, 2022.5, by = 0.5)) +
  scale_y_continuous(breaks = seq(0, 30000, by = 5000)) +
  theme_bw() +
  theme(text = element_text(size = 7),
        plot.title = element_text(hjust = 0.5)) +
  scale_color_manual(name = 'Legend',
                     breaks=c("Excess Deaths", "COVID-19 Deaths"),
                     values=c("Excess Deaths" = "blue", "COVID-19 Deaths" = "
red"))
```

Figure 2: U.S. Weekly Excess Deaths and COVID-19 Deaths (2020-2022)