covid

November 20, 2021

[2]:
```
library("MTS")
library(tsDyn) # for vecm
library(urca)
library(lmtest) #granger test
library('readxl')
library('ggplot2')
library('dplyr')
library(lubridate)
library(corrplot)
library(tseries)
library(vars)
library(xts)
library(forecast)
```

1 Read Data

[3]:
```
covid=read_excel('covid.xlsx')
unemployment=read_excel('unemployment.xlsx')
economic=read_excel('Economic.xlsx')
health=read_excel('Health.xlsx')
response=read_excel('response.xlsx')
stringency=read_excel('Stringency.xlsx')
colnames(covid)=c('Date','Sing','UK','US')
colnames(unemployment)=c('Date','Sing','UK','US')
colnames(economic)=c('Date','Sing','UK','US')
colnames(health)=c('Date','Sing','UK','US')
colnames(response)=c('Date','Sing','UK','US')
colnames(stringency)=c('Date','Sing','UK','US')
covid$Date=as.Date(covid$Date)
economic$Date=as.Date(economic$Date)
health$Date=as.Date(health$Date)
response$Date=as.Date(response$Date)
stringency$Date=as.Date(stringency$Date)
head(covid)
head(unemployment)
```

A tibble: 6 × 4

Date <date>	Sing <dbl>	UK <dbl>	US <dbl>
2020-01-01	0	0	0
2020-01-02	0	0	0
2020-01-03	0	0	0
2020-01-04	0	0	0
2020-01-05	0	0	0
2020-01-06	0	0	0

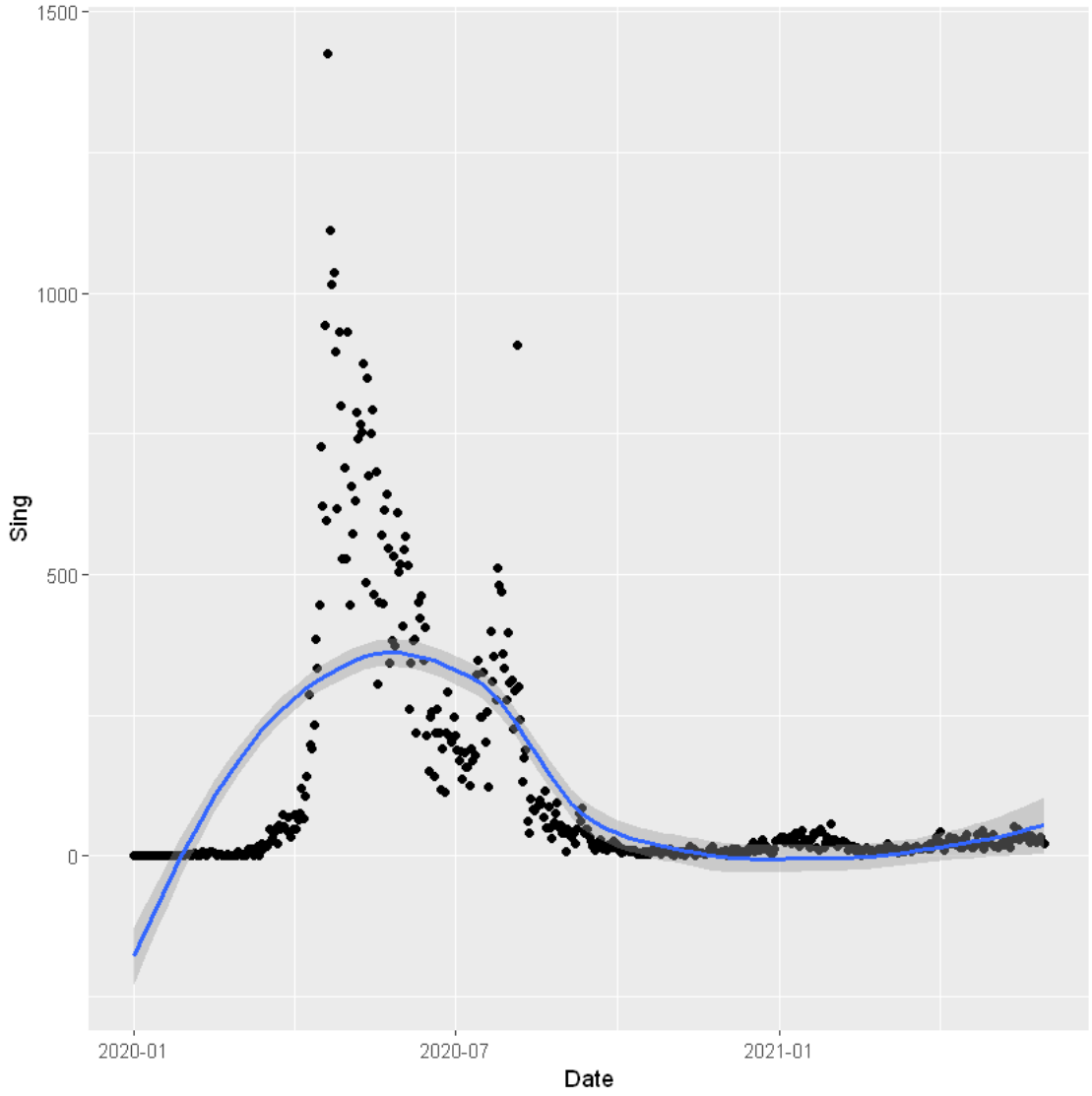
A tibble: 6 × 4

Date <chr>	Sing <dbl>	UK <dbl>	US <dbl>
01/2020	2.4	3.9	3.5
02/2020	2.4	4.0	3.5
03/2020	2.4	4.0	4.4
04/2020	2.6	4.0	14.8
05/2020	2.8	4.1	13.3
06/2020	2.8	4.1	11.1

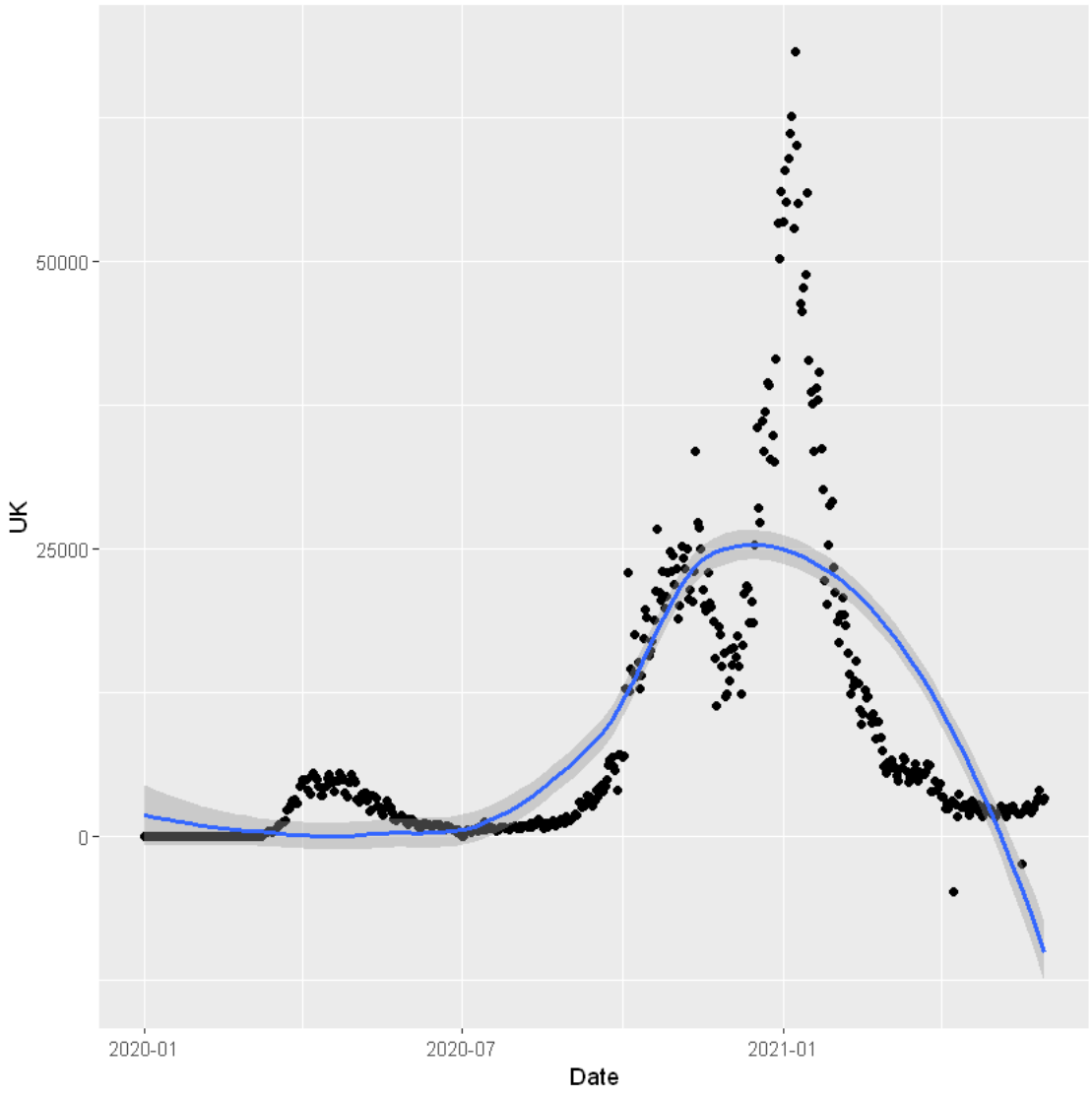
2 Show Data

[4]:
```
ggplot(data=covid,mapping = aes(x=Date,y=Sing))+geom_point()+geom_smooth()
ggplot(data=covid,mapping = aes(x=Date,y=UK))+geom_point()+geom_smooth()
ggplot(data=covid,mapping = aes(x=Date,y=US))+geom_point()+geom_smooth()
cumsum_covid=covid
cumsum_covid$Sing=cumsum(covid$Sing)
cumsum_covid$UK=cumsum(covid$UK)
cumsum_covid$US=cumsum(covid$US)
ggplot(data=cumsum_covid,mapping =␣
 ↪aes(x=Date,y=Sing))+geom_point()+geom_smooth()
ggplot(data=cumsum_covid,mapping = aes(x=Date,y=UK))+geom_point()+geom_smooth()
ggplot(data=cumsum_covid,mapping = aes(x=Date,y=US))+geom_point()+geom_smooth()
```

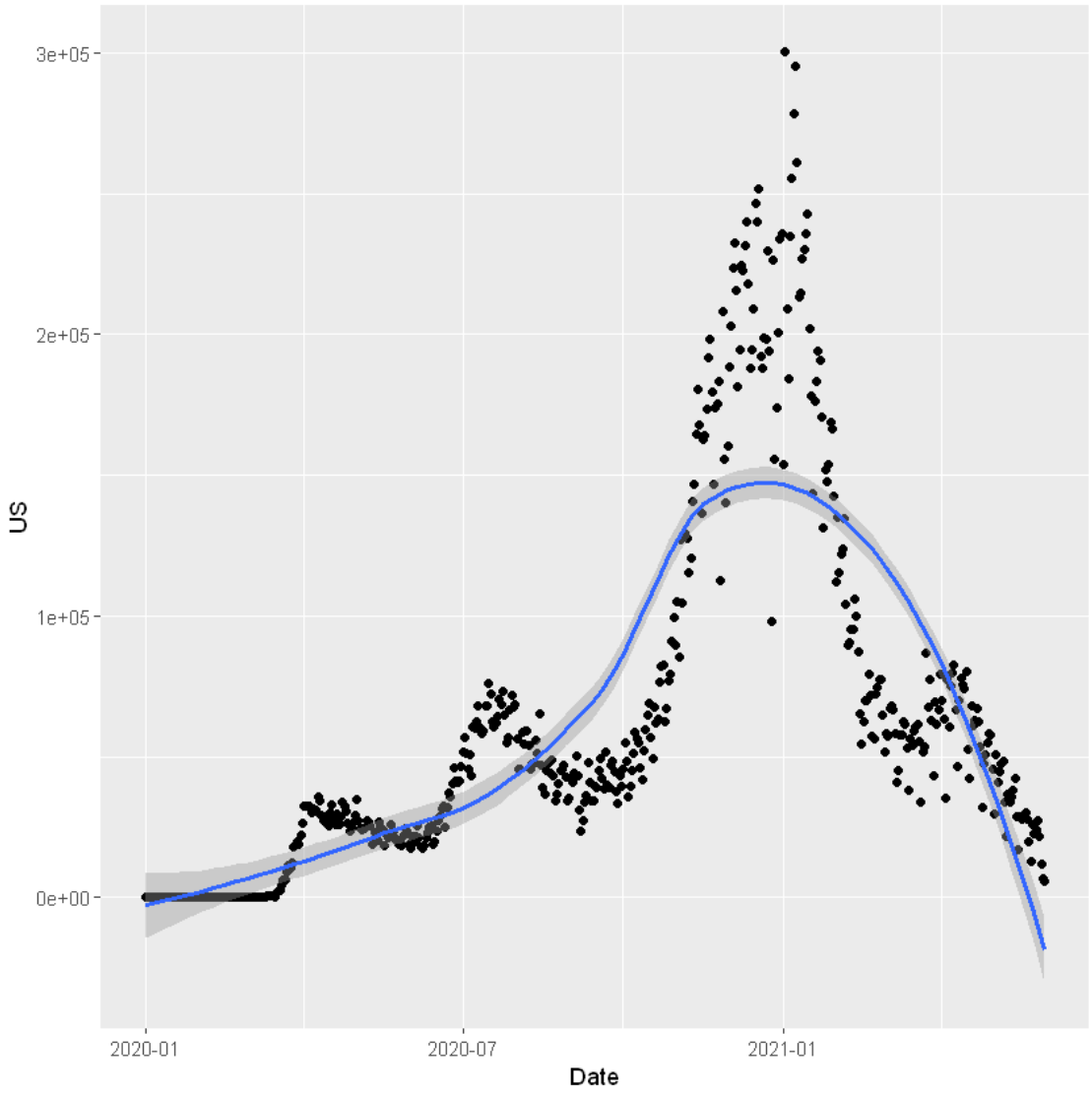
```
`geom_smooth()` using method = 'loess' and formula 'y ~ x'

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



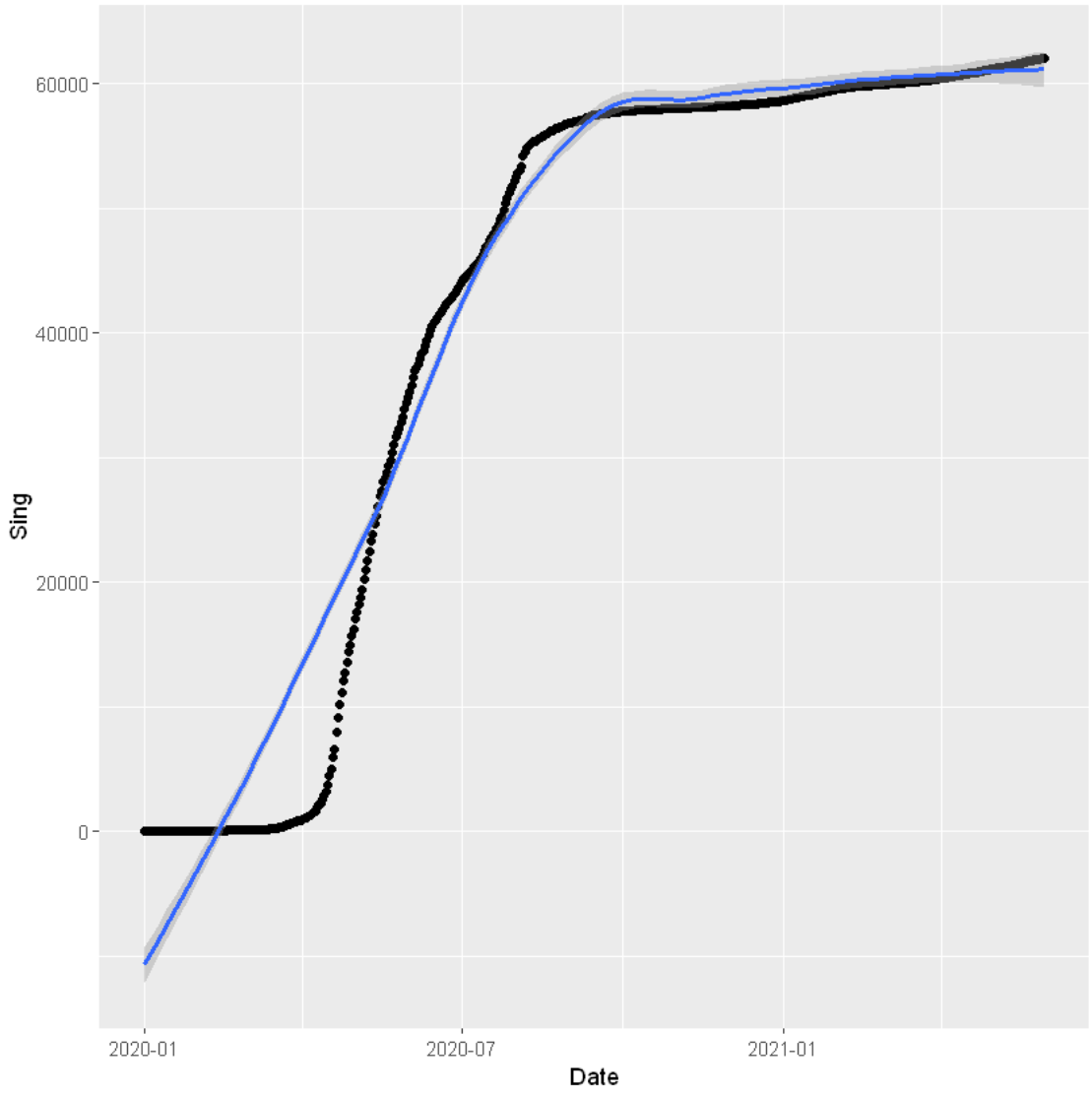

```
`geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



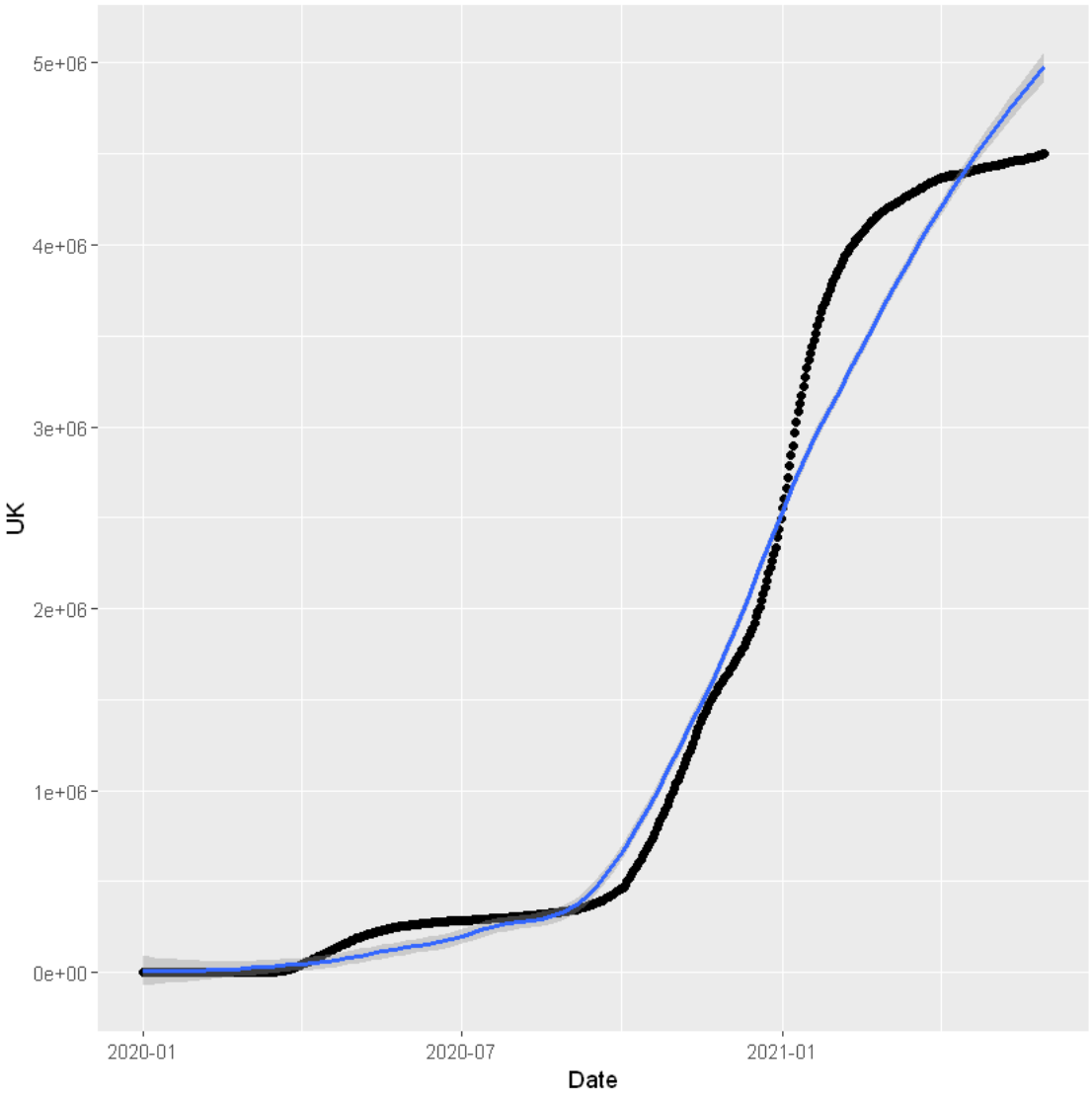

```
`geom_smooth()` using method = 'loess' and formula 'y ~ x'
```

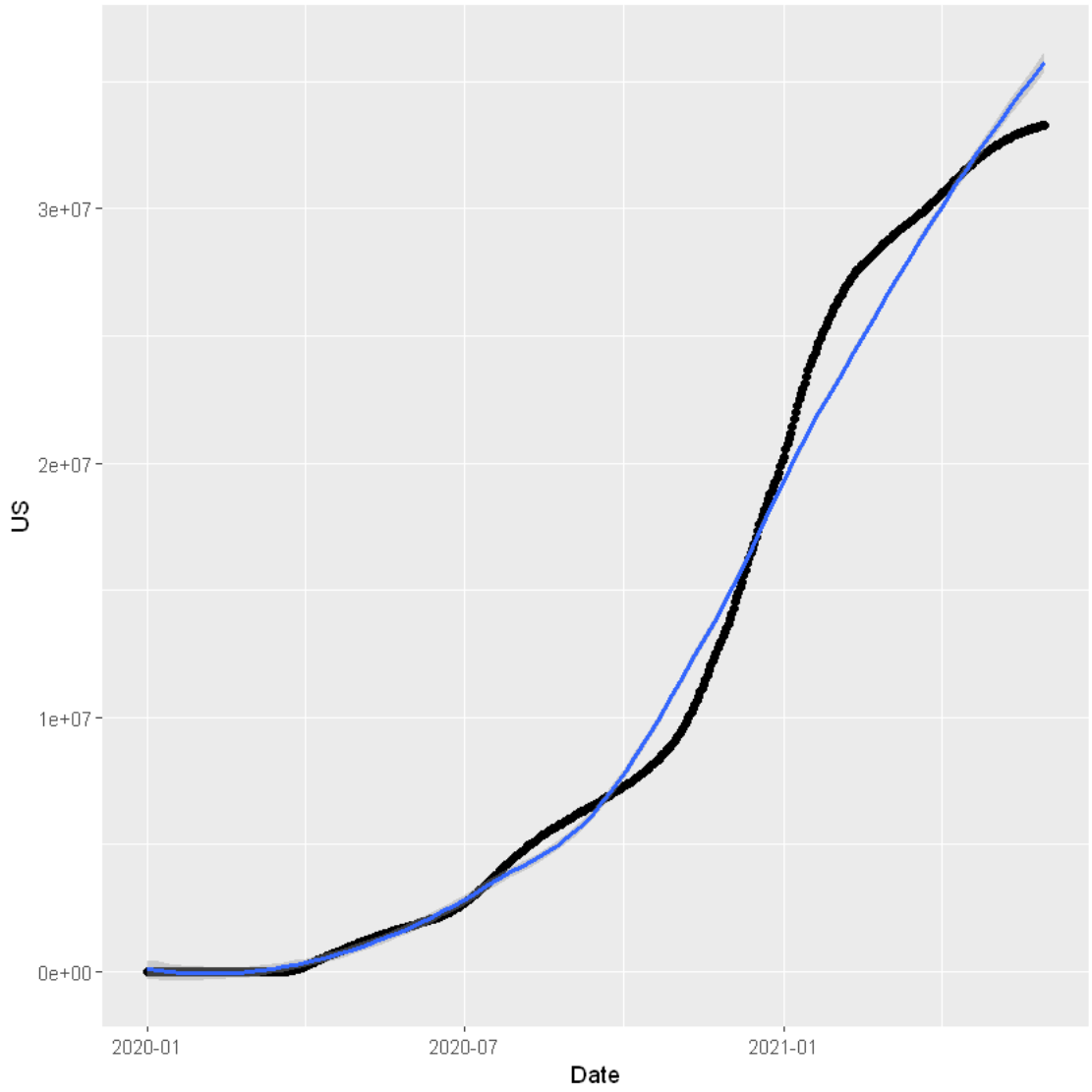



```
`geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



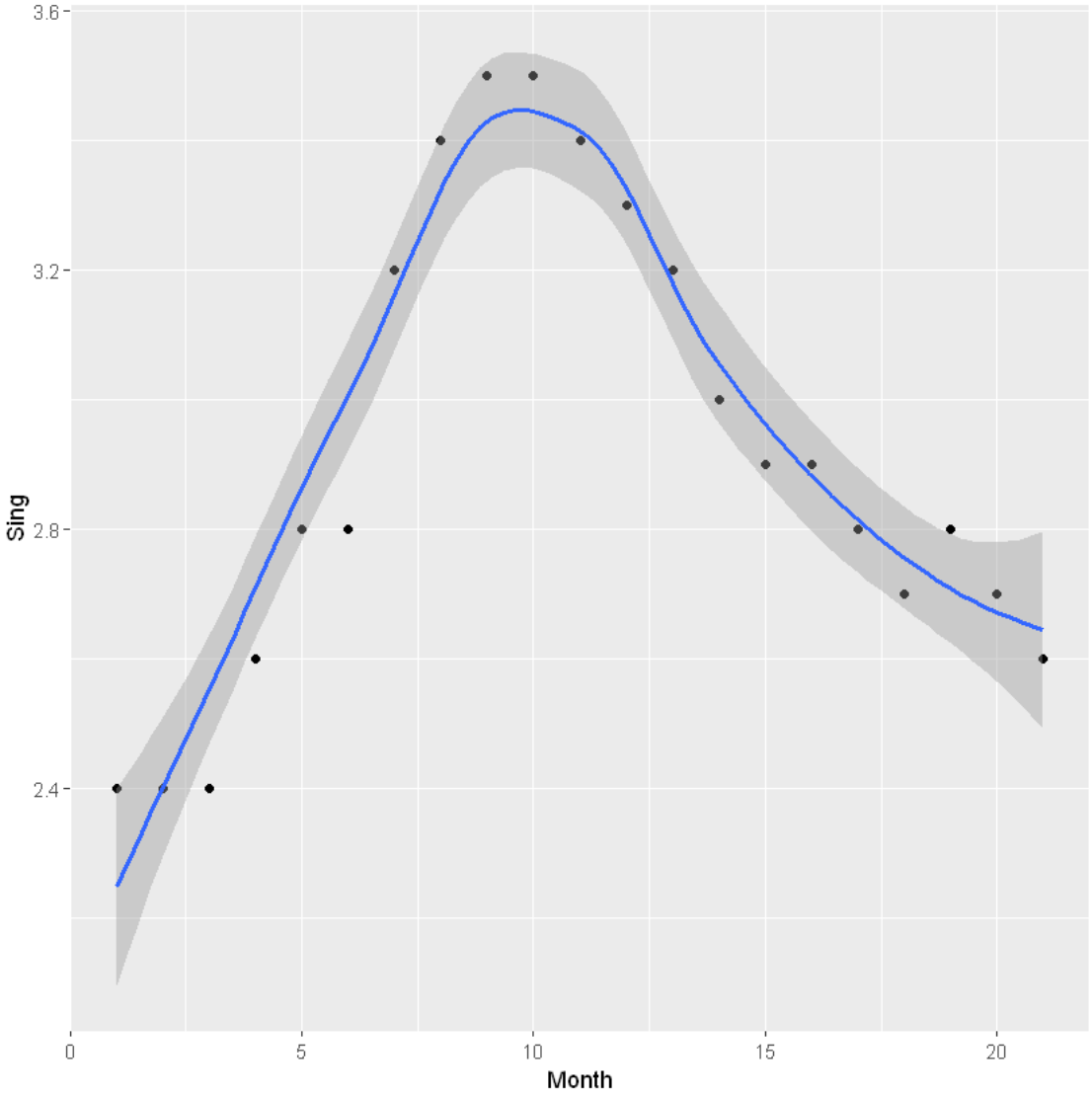

```
`geom_smooth()` using method = 'loess' and formula 'y ~ x'
```


5e+06
4e+06
3e+06
2e+06
1e+06
0e+00
UK
2020-01
2020-07
2021-01
Date

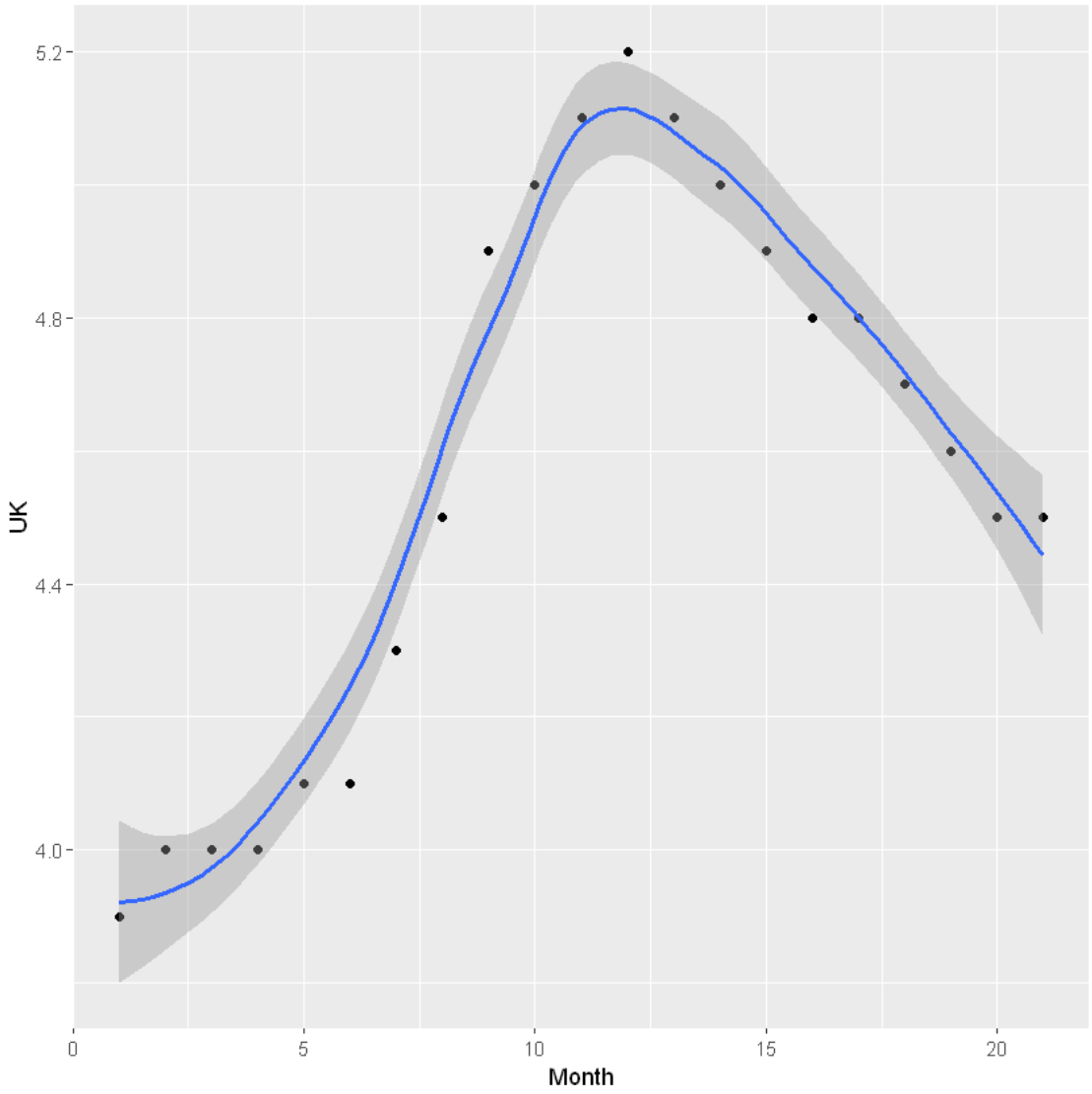


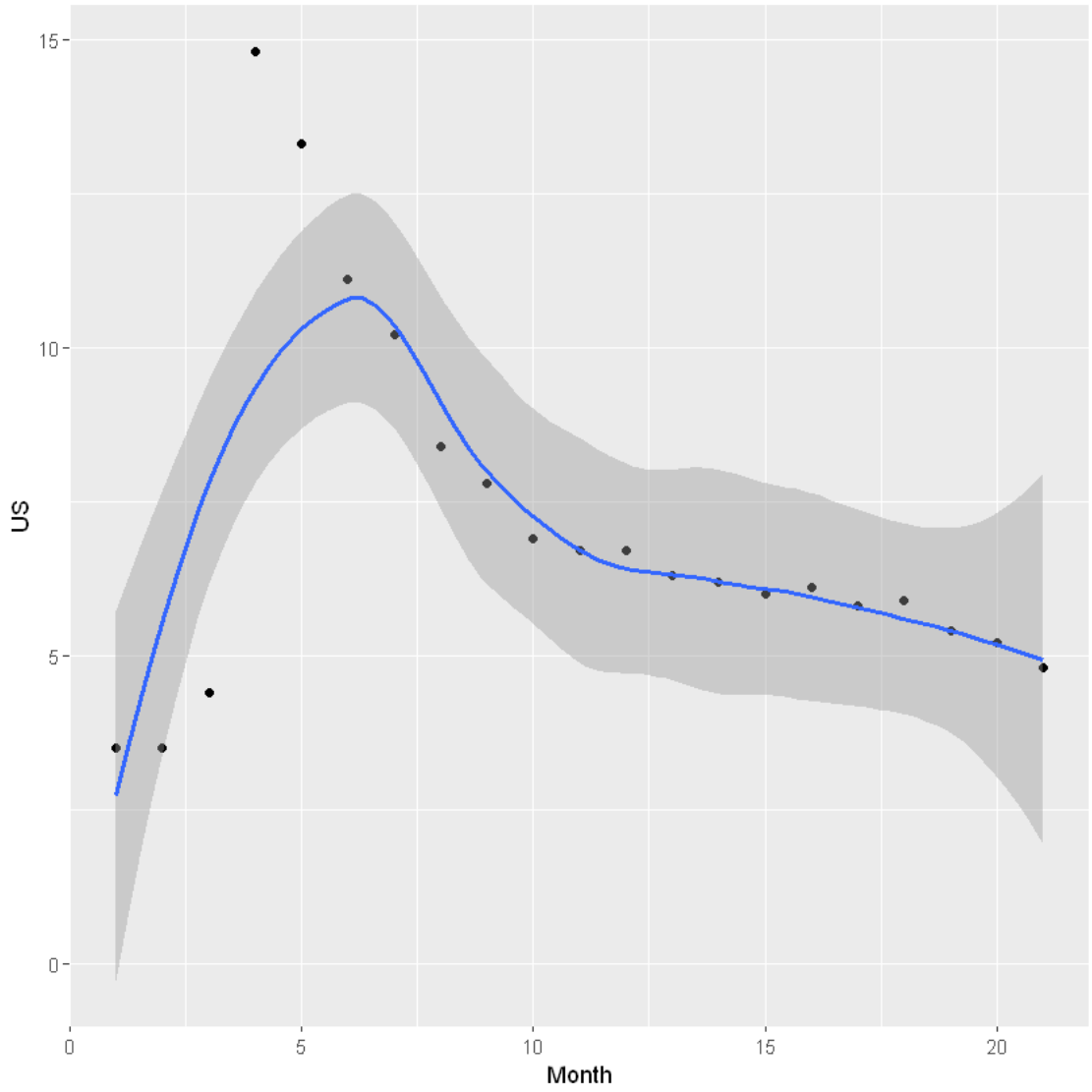
[5]:
```
unemployment$Month=c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21)
ggplot(data=unemployment,mapping =␣
 ↪aes(x=Month,y=Sing))+geom_point()+geom_smooth()
ggplot(data=unemployment,mapping = aes(x=Month,y=UK))+geom_point()+geom_smooth()
ggplot(data=unemployment,mapping = aes(x=Month,y=US))+geom_point()+geom_smooth()
```

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

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

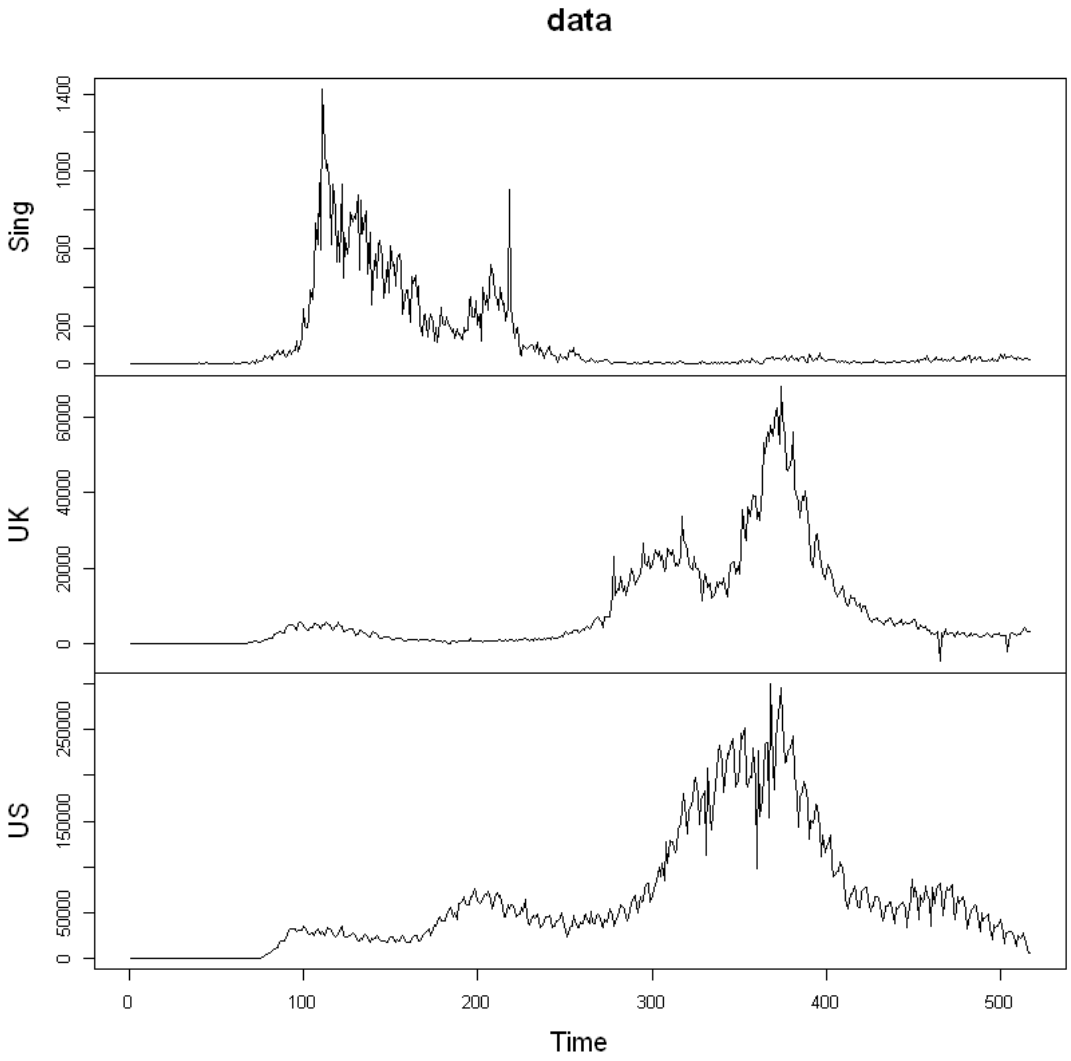


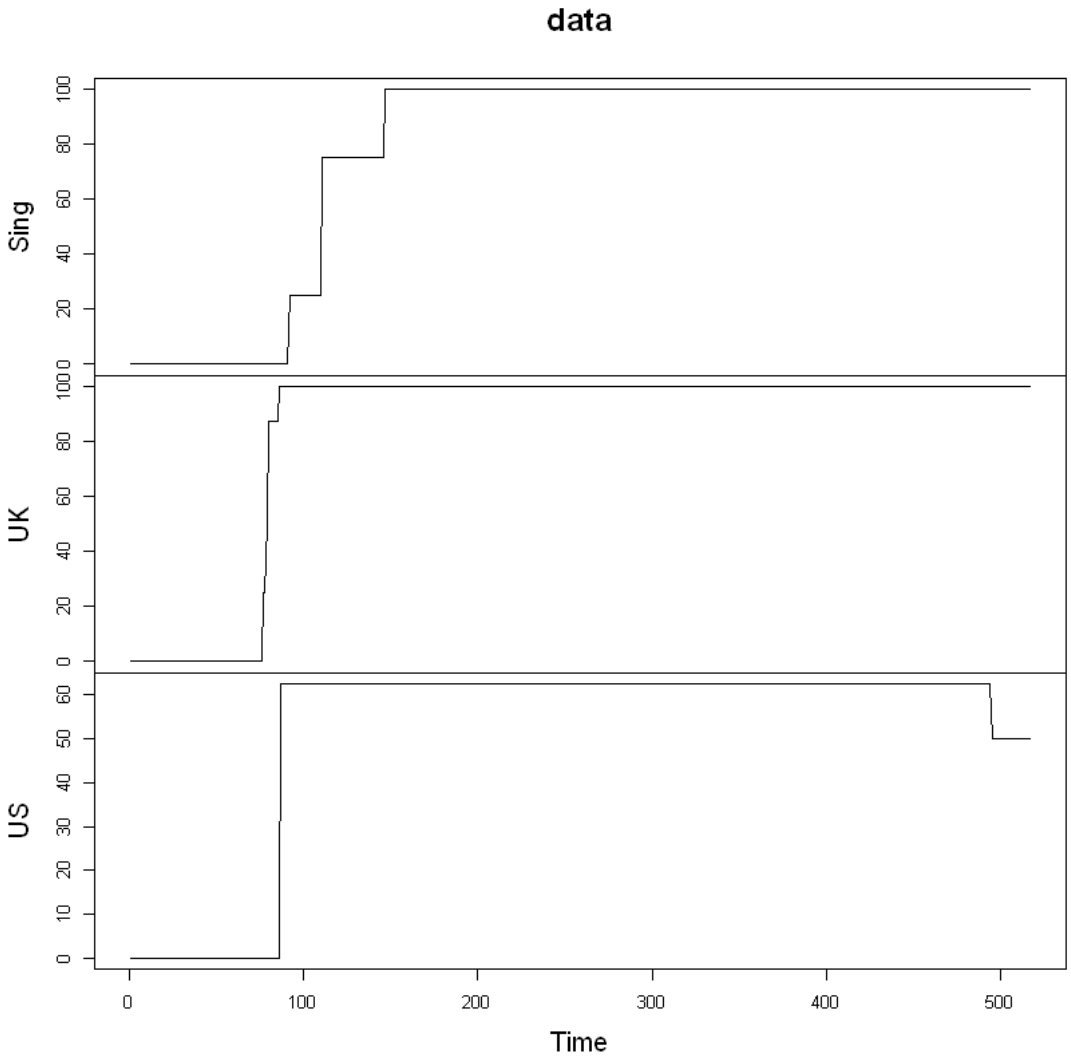

```
`geom_smooth()` using method = 'loess' and formula 'y ~ x'
```

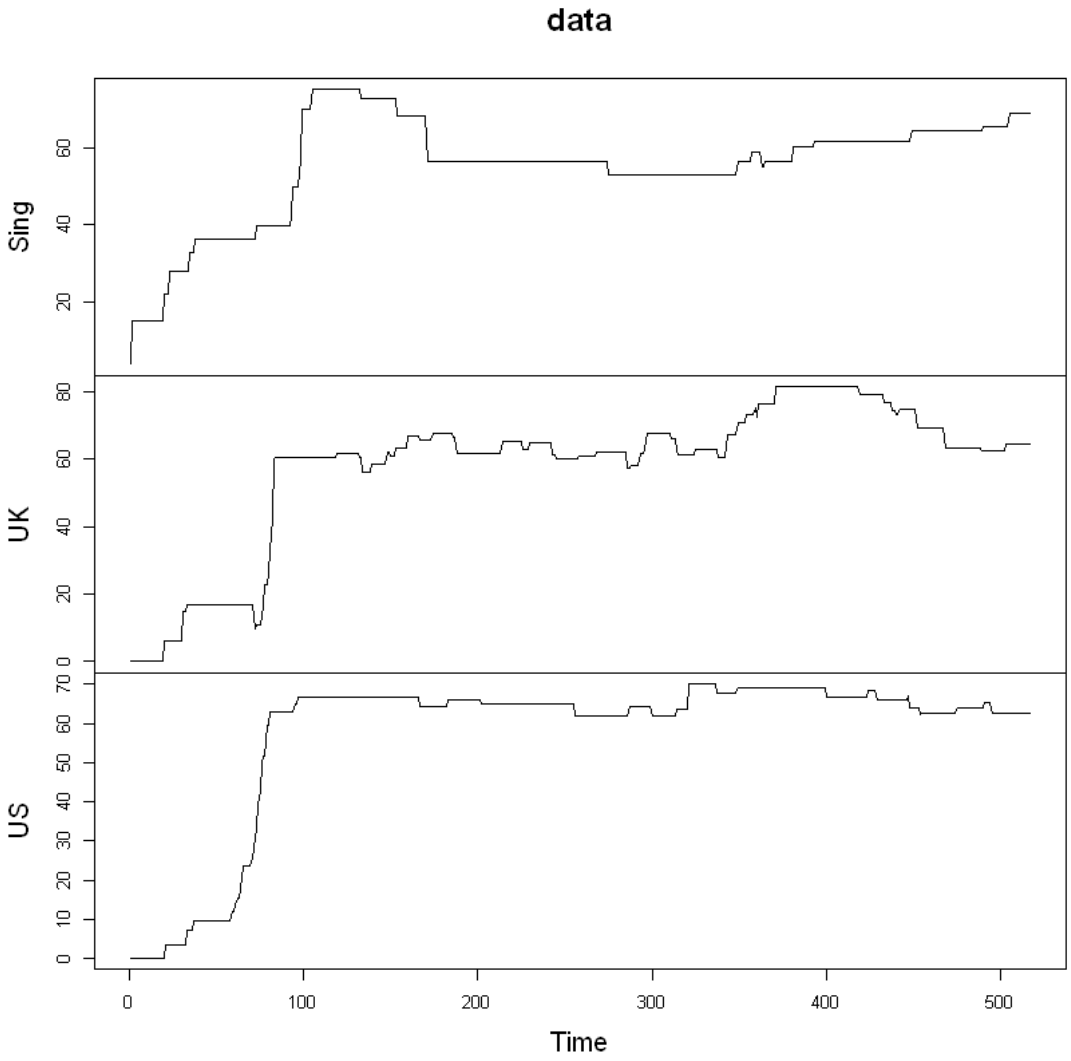

5.2
4.8
4.4
4.0
UK
0
5
10
15
20
Month

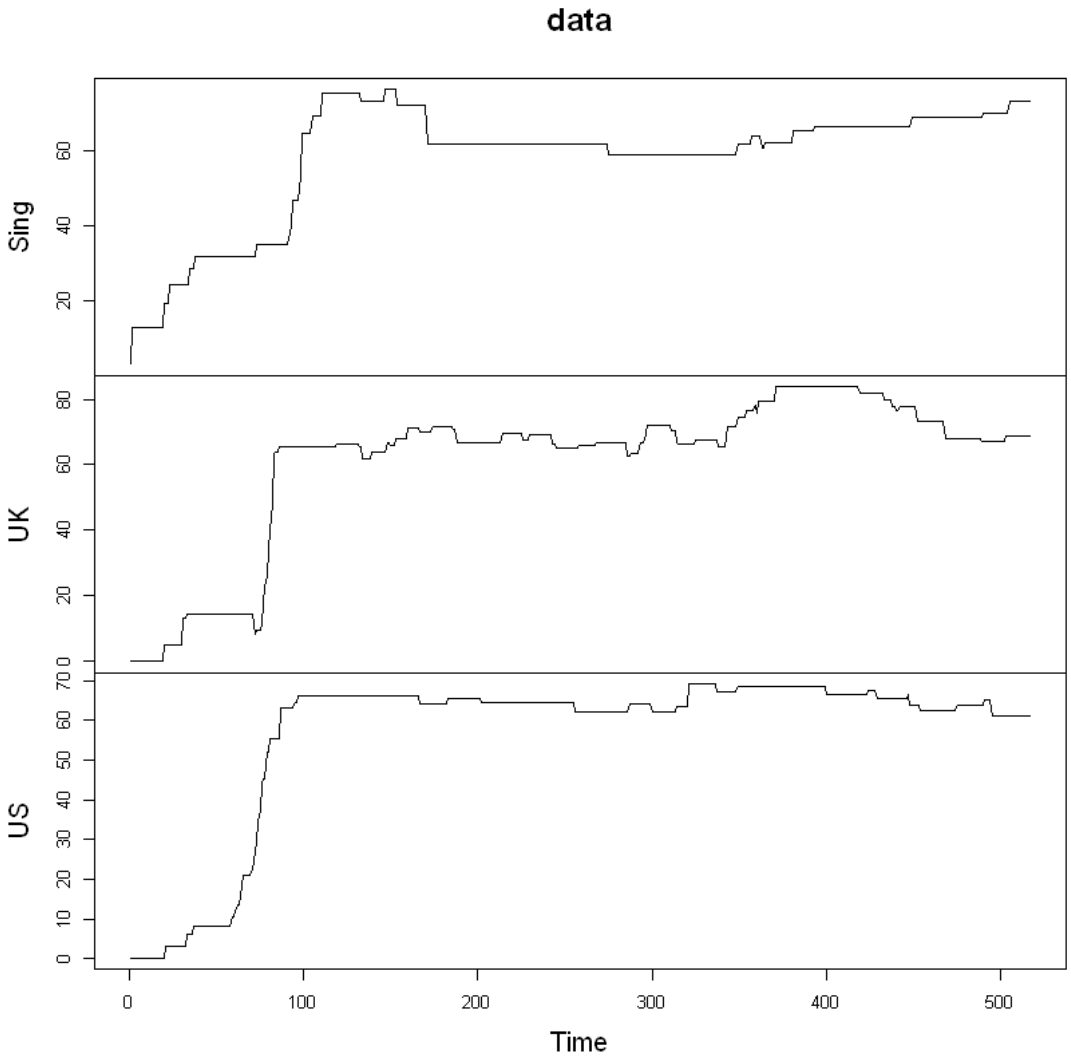


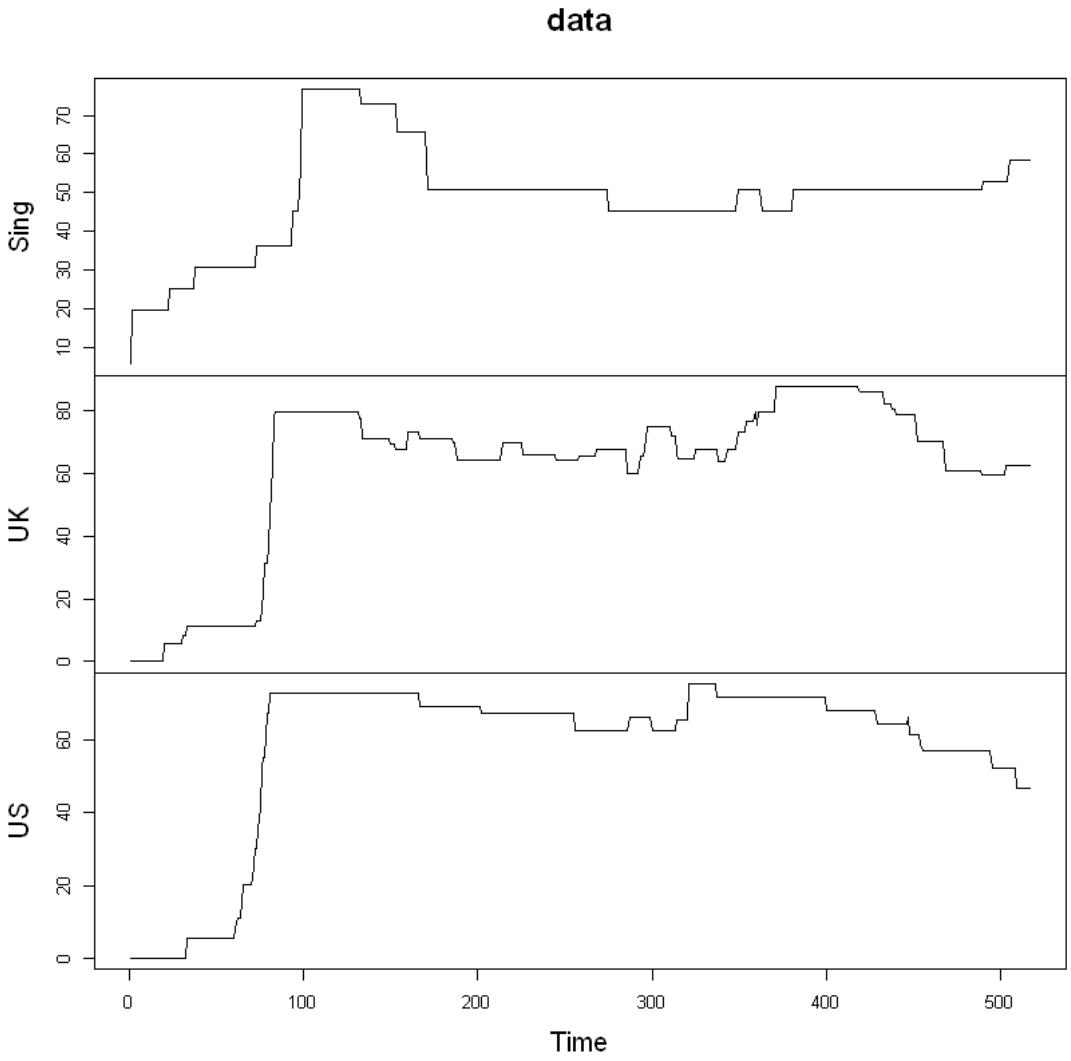
[6]:
```
MTSplot(as.ts(covid[,c(2,3,4)]))
MTSplot(as.ts(economic[,c(2,3,4)]))
MTSplot(as.ts(health[,c(2,3,4)]))
MTSplot(as.ts(response[,c(2,3,4)]))
MTSplot(as.ts(stringency[,c(2,3,4)]))
MTSplot(as.ts(unemployment[,c(2,3,4)]))
```

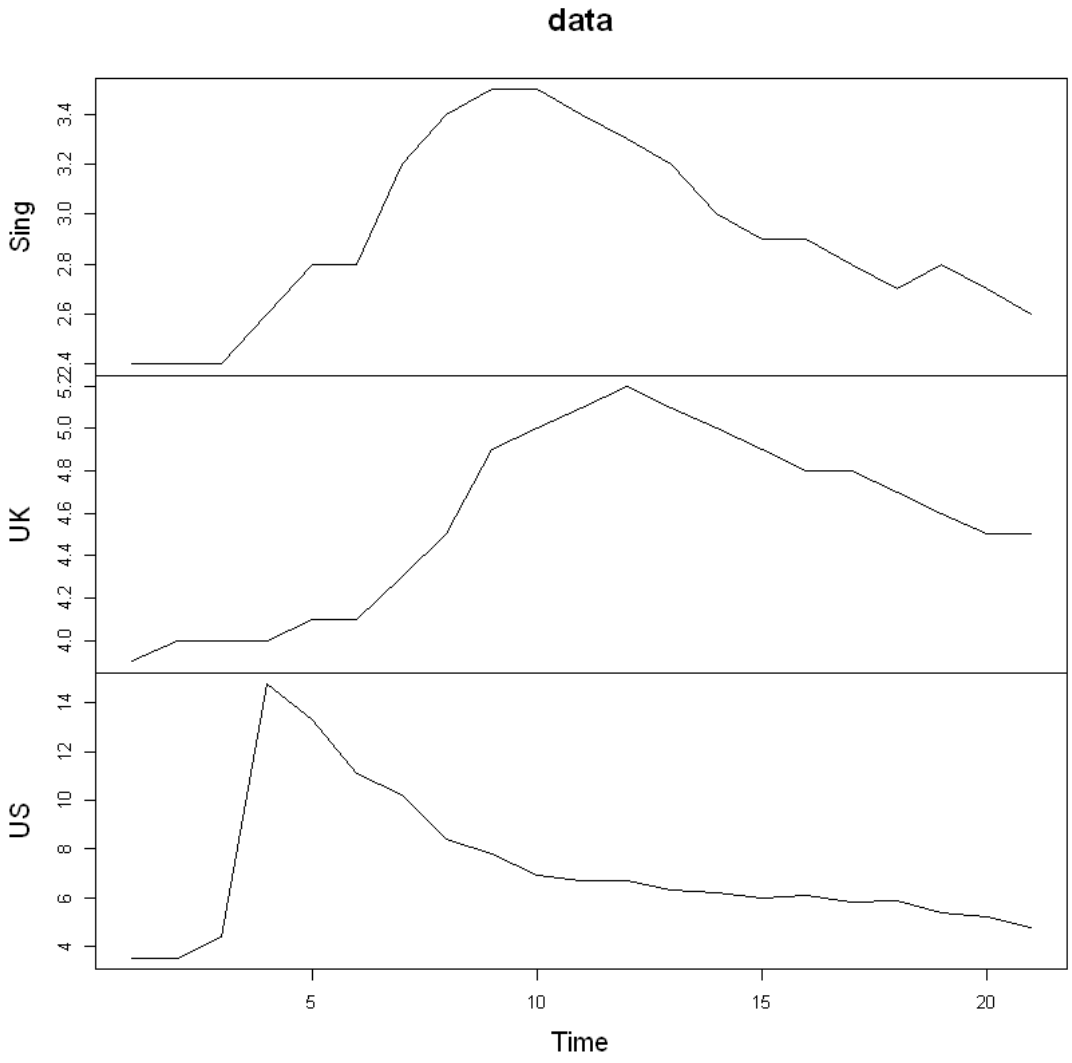

data
Sing
0
200
600
1000
1400
UK
0
20000
40000
60000
US
0
50000
150000
250000
0
100
200
300
400
500
Time


data
Sing
UK
US
Time
0
100
200
300
400
500


data
Sing
UK
US
Time
0
100
200
300
400
500
20
40
60
80
10
30
50
70


data
Sing
UK
US
Time
0
100
200
300
400
500

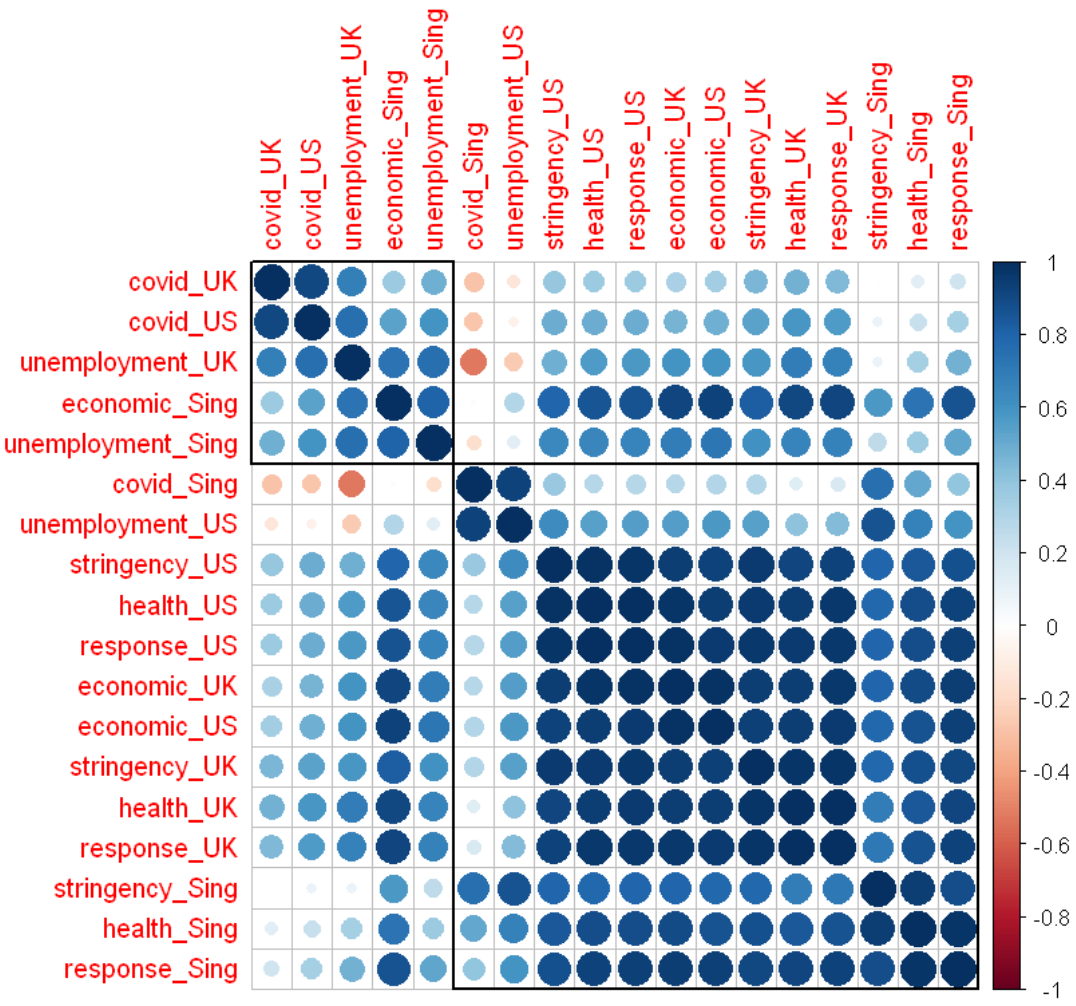

data
Sing
UK
US
Time
0
100
200
300
400
500

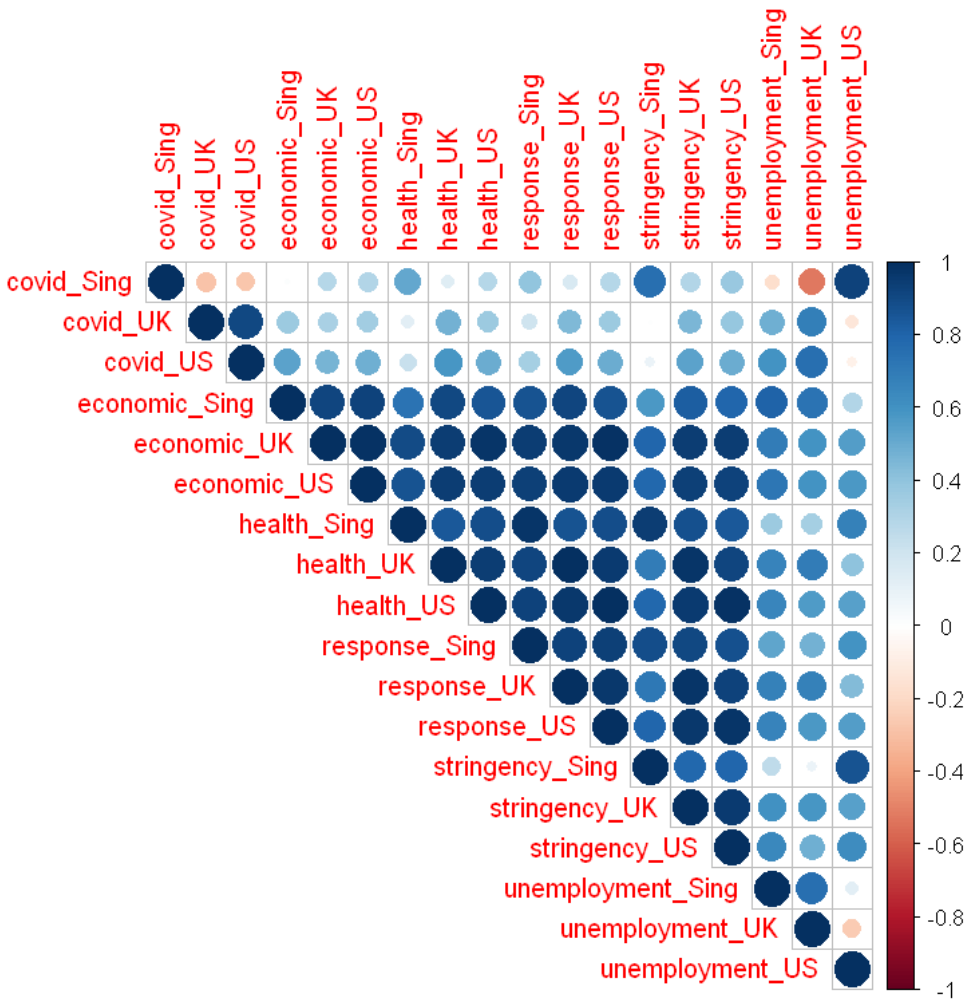


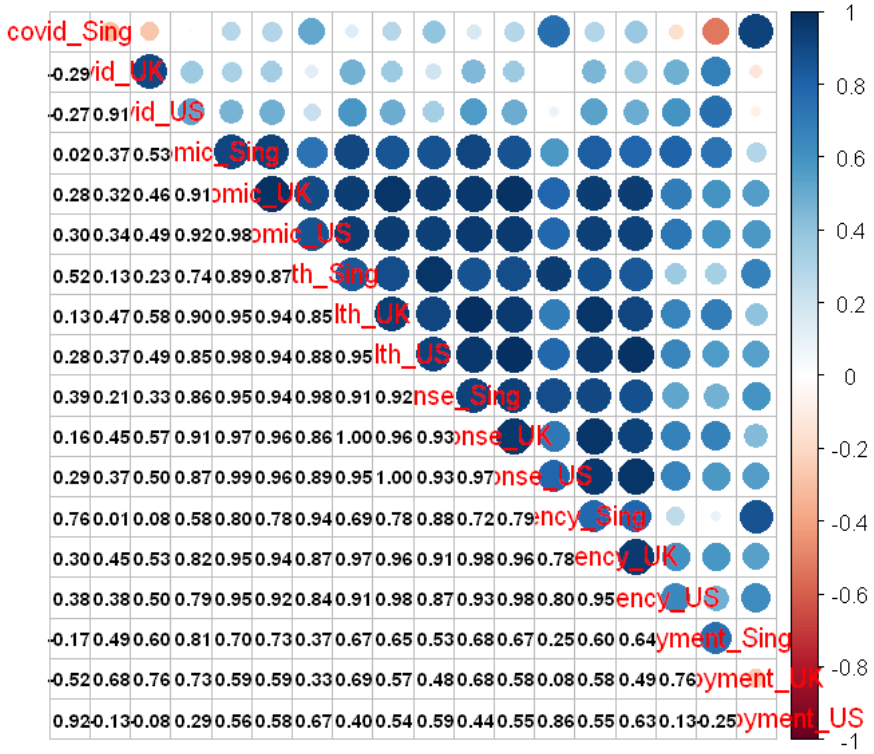
3 Correlation

[7]:
```
colnames(covid)=c('Date','covid_Sing','covid_UK','covid_US')
colnames(economic)=c('Date','economic_Sing','economic_UK','economic_US')
colnames(health)=c('Date','health_Sing','health_UK','health_US')
colnames(response)=c('Date','response_Sing','response_UK','response_US')
colnames(stringency)=c('Date','stringency_Sing','stringency_UK','stringency_US')
total=merge(covid,economic,by="Date")
total=merge(total,health,by="Date")
total=merge(total,response,by="Date")
total=merge(total,stringency,by="Date")
```

```
totalbymonth1 <-␣
 ↪aggregate(cbind(covid_Sing,covid_UK,covid_US,economic_Sing,economic_UK,economic_US,health_S
             data=total[total["Date"]<="2020-12-31 UTC",],FUN=sum)
totalbymonth2 <-␣
 ↪aggregate(cbind(covid_Sing,covid_UK,covid_US,economic_Sing,economic_UK,economic_US,health_S
             data=total[total["Date"]>="2021-01-01 UTC",],FUN=sum)

colnames(totalbymonth1)[1]="Month"
colnames(totalbymonth2)[1]="Month"

totalbymonth2$Month=c(13,14,15,16,17)
totalbymonth=rbind(totalbymonth1,totalbymonth2)

colnames(unemployment)=c("Date","unemployment_Sing","unemployment_UK","unemployment_US","Month

totalbymonth=merge(totalbymonth,unemployment,by="Month")
totalbymonth=totalbymonth[,-17]
M = cor(totalbymonth[,-1])
corrplot(M, order = "hclust", addrect = 2)
corrplot(M, type = "upper")
corrplot.mixed(M, lower.col = "black", number.cex = .7)
```


covid_UK
covid_US
unemployment_UK
economic_Sing
unemployment_Sing
covid_Sing
unemployment_US
stringency_US
health_US
response_US
economic_UK
economic_US
stringency_UK
health_UK
response_UK
stringency_Sing
health_Sing
response_Sing
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


covid_Sing
covid_UK
covid_US
economic_Sing
economic_UK
economic_US
health_Sing
health_UK
health_US
response_Sing
response_UK
response_US
stringency_Sing
stringency_UK
stringency_US
unemployment_Sing
unemployment_UK
unemployment_US
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1



4 Linear Model

[8]:
```
model_Sing_lm=lm(unemployment_Sing~economic_Sing+health_Sing+response_Sing+stringency_Sing+cov
 ↪= totalbymonth)
summary(model_Sing_lm)
```

```
Call:
lm(formula = unemployment_Sing ~ economic_Sing + health_Sing +
    response_Sing + stringency_Sing + covid_Sing, data = totalbymonth)

Residuals:
     Min       1Q   Median       3Q      Max
```

```
-0.25021 -0.11540  0.02254  0.09730  0.20212

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      2.567e+00  3.292e-01   7.799 8.31e-06 ***
economic_Sing    1.029e-01  6.492e-02   1.585    0.141
health_Sing      7.165e-01  4.548e-01   1.575    0.143
response_Sing   -8.207e-01  5.196e-01  -1.580    0.143
stringency_Sing  1.612e-03  1.003e-03   1.606    0.137
covid_Sing      -3.128e-05  2.960e-05  -1.057    0.313
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1756 on 11 degrees of freedom
Multiple R-squared:  0.856,        Adjusted R-squared:  0.7905
F-statistic: 13.07 on 5 and 11 DF,  p-value: 0.0002551
```

[9]:
```
model_US_lm=lm(unemployment_US~economic_US+health_US+response_US+stringency_US+covid_US,data
 ↪= totalbymonth)
summary(model_US_lm)
```

```
Call:
lm(formula = unemployment_US ~ economic_US + health_US + response_US +
    stringency_US + covid_US, data = totalbymonth)

Residuals:
    Min      1Q  Median      3Q     Max
-2.0154 -1.2542 -0.0179  0.8272  3.1884

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    4.123e+00  1.439e+00   2.865  0.01539 *
economic_US   -1.128e-01  9.539e-01  -0.118  0.90798
health_US     -8.264e-01  6.674e+00  -0.124  0.90369
response_US    9.297e-01  7.629e+00   0.122  0.90521
stringency_US  1.271e-02  3.325e-03   3.822  0.00283 **
covid_US      -8.554e-07  2.603e-07  -3.287  0.00724 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.753 on 11 degrees of freedom
Multiple R-squared:  0.7907,        Adjusted R-squared:  0.6956
F-statistic: 8.313 on 5 and 11 DF,  p-value: 0.001806
```

[10]:
```
model_UK_lm=lm(unemployment_UK~economic_UK+health_UK+response_UK+stringency_UK+covid_UK,data
 ↪= totalbymonth)
summary(model_UK_lm)
```

```
Call:
lm(formula = unemployment_UK ~ economic_UK + health_UK + response_UK +
    stringency_UK + covid_UK, data = totalbymonth)

Residuals:
     Min       1Q   Median       3Q      Max
-0.39788 -0.05597  0.01124  0.10677  0.34587

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    3.851e+00  1.989e-01  19.362 7.56e-10 ***
economic_UK   -6.679e-02  1.067e-01  -0.626   0.5440
health_UK     -4.671e-01  7.461e-01  -0.626   0.5440
response_UK    5.355e-01  8.527e-01   0.628   0.5429
stringency_UK -1.215e-03  4.113e-04  -2.954   0.0131 *
covid_UK       6.352e-07  2.158e-07   2.944   0.0134 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2505 on 11 degrees of freedom
Multiple R-squared:  0.808,        Adjusted R-squared:  0.7207
F-statistic: 9.258 on 5 and 11 DF,  p-value: 0.001155
```

5 data representation

[11]:
```
total.
 ↪Sing=total[,c("Date","covid_Sing","economic_Sing","health_Sing","response_Sing","stringency
total.
 ↪US=total[,c("Date","covid_US","economic_US","health_US","response_US","stringency_US")]
total.
 ↪UK=total[,c("Date","covid_UK","economic_UK","health_UK","response_UK","stringency_UK")]
totalbymonth.
 ↪Sing=totalbymonth[,c("Month","covid_Sing","economic_Sing","health_Sing","response_Sing","st
totalbymonth.
 ↪US=totalbymonth[,c("Month","covid_US","economic_US","health_US","response_US","stringency_U
totalbymonth.
 ↪UK=totalbymonth[,c("Month","covid_UK","economic_UK","health_UK","response_UK","stringency_U
```

6 Granger Test

[12]:
```
for (i in 2:7){
  for(j in 2:7){
    if (j!=i){
      GX=colnames(totalbymonth.Sing)[i]
      GY=colnames(totalbymonth.Sing)[j]
      EGtest <- grangertest(totalbymonth.Sing[,j] ~ totalbymonth.Sing[,i],order
 ↪= 1, data = totalbymonth.Sing)
      if (EGtest$`Pr(>F)`[2]<0.1){
        print(paste(GX," is a cause for",GY))
      }
    }
  }
}
```

```
[1] "covid_Sing  is a cause for economic_Sing"
[1] "covid_Sing  is a cause for unemployment_Sing"
[1] "economic_Sing  is a cause for covid_Sing"
[1] "economic_Sing  is a cause for health_Sing"
[1] "economic_Sing  is a cause for stringency_Sing"
[1] "health_Sing  is a cause for economic_Sing"
[1] "response_Sing  is a cause for economic_Sing"
[1] "response_Sing  is a cause for health_Sing"
[1] "stringency_Sing  is a cause for economic_Sing"
[1] "unemployment_Sing  is a cause for covid_Sing"
```

[13]:
```
for (i in 2:7){
  for(j in 2:7){
    if (j!=i){
      GX=colnames(totalbymonth.US)[i]
      GY=colnames(totalbymonth.US)[j]
      EGtest <- grangertest(totalbymonth.US[,j] ~ totalbymonth.US[,i],order =
 ↪1, data = totalbymonth.US)
      if (EGtest$`Pr(>F)`[2]<0.1){
        print(paste(GX," is a cause for",GY))
      }
    }
  }
}
```

```
[1] "economic_US  is a cause for health_US"
[1] "economic_US  is a cause for response_US"
[1] "economic_US  is a cause for stringency_US"
[1] "health_US  is a cause for economic_US"
[1] "health_US  is a cause for response_US"
[1] "response_US  is a cause for economic_US"
[1] "response_US  is a cause for health_US"
```

```
[1] "stringency_US  is a cause for economic_US"
```

[14]:
```
for (i in 2:7){
  for(j in 2:7){
    if (j!=i){
      GX=colnames(totalbymonth.UK)[i]
      GY=colnames(totalbymonth.UK)[j]
      EGtest <- grangertest(totalbymonth.UK[,j] ~ totalbymonth.UK[,i],order =␣
↪1, data = totalbymonth.UK)
      if (EGtest$`Pr(>F)`[2]<0.1){
        print(paste(GX," is a cause for",GY))
      }
    }
  }
}
```

[15]:
```
for (i in 2:6){
  for(j in 2:6){
    if (j!=i){
      GX=colnames(total.Sing)[i]
      GY=colnames(total.Sing)[j]
      EGtest <- grangertest(total.Sing[,j] ~ total.Sing[,i],order = 1, data =␣
↪total.Sing)
      if (EGtest$`Pr(>F)`[2]<0.1){
        print(paste(GX," is a cause for",GY))
      }
    }
  }
}
```

```
[1] "covid_Sing  is a cause for economic_Sing"
[1] "economic_Sing  is a cause for health_Sing"
[1] "economic_Sing  is a cause for response_Sing"
[1] "economic_Sing  is a cause for stringency_Sing"
[1] "health_Sing  is a cause for covid_Sing"
[1] "health_Sing  is a cause for economic_Sing"
[1] "health_Sing  is a cause for response_Sing"
[1] "response_Sing  is a cause for covid_Sing"
[1] "response_Sing  is a cause for economic_Sing"
[1] "response_Sing  is a cause for health_Sing"
[1] "stringency_Sing  is a cause for covid_Sing"
[1] "stringency_Sing  is a cause for economic_Sing"
```

[16]:
```
for (i in 2:6){
  for(j in 2:6){
    if (j!=i){
      GX=colnames(total.US)[i]
      GY=colnames(total.US)[j]
```

```
      EGtest <- grangertest(total.US[,j] ~ total.US[,i],order = 1, data = total.
 ↪US)
      if (EGtest$`Pr(>F)`[2]<0.1){
        print(paste(GX," is a cause for",GY))
      }
    }
  }
}
```

```
[1] "economic_US  is a cause for health_US"
[1] "economic_US  is a cause for response_US"
[1] "economic_US  is a cause for stringency_US"
[1] "health_US  is a cause for economic_US"
[1] "health_US  is a cause for response_US"
[1] "response_US  is a cause for economic_US"
[1] "response_US  is a cause for health_US"
[1] "response_US  is a cause for stringency_US"
[1] "stringency_US  is a cause for covid_US"
[1] "stringency_US  is a cause for economic_US"
[1] "stringency_US  is a cause for response_US"
```

[17]:
```
for (i in 2:6){
  for(j in 2:6){
    if (j!=i){
      GX=colnames(total.UK)[i]
      GY=colnames(total.UK)[j]
      EGtest <- grangertest(total.UK[,j] ~ total.UK[,i],order = 1, data = total.
 ↪UK)
      if (EGtest$`Pr(>F)`[2]<0.1){
        print(paste(GX," is a cause for",GY))
      }
    }
  }
}
```

```
[1] "covid_UK  is a cause for health_UK"
[1] "covid_UK  is a cause for stringency_UK"
[1] "economic_UK  is a cause for health_UK"
[1] "economic_UK  is a cause for response_UK"
[1] "economic_UK  is a cause for stringency_UK"
[1] "health_UK  is a cause for response_UK"
[1] "health_UK  is a cause for stringency_UK"
[1] "response_UK  is a cause for health_UK"
[1] "response_UK  is a cause for stringency_UK"
[1] "stringency_UK  is a cause for health_UK"
[1] "stringency_UK  is a cause for response_UK"
```

7 Unit Root Test

[30]:
```
p2 <- round(adf.test(totalbymonth.Sing[,2])$p.value,3)
p3 <- round(adf.test(totalbymonth.Sing[,3])$p.value,3)
p4 <- round(adf.test(totalbymonth.Sing[,4])$p.value,3)
p5 <- round(adf.test(totalbymonth.Sing[,5])$p.value,3)
p6 <- round(adf.test(totalbymonth.Sing[,6])$p.value,3)
p7 <- round(adf.test(totalbymonth.Sing[,7])$p.value,3)
Sing_df <- data.frame(matrix(c(p2,p3,p4,p5,p6,p7),nrow=1))
colnames(Sing_df) <-␣
 ↪c("covid_Sing","economic_Sing","health_Sing","response_Sing","stringency_Sing","Unemployment
rownames(Sing_df) <- c("Unit Root Test p value")
p2 <- round(adf.test(totalbymonth.US[,2])$p.value,3)
p3 <- round(adf.test(totalbymonth.US[,3])$p.value,3)
p4 <- round(adf.test(totalbymonth.US[,4])$p.value,3)
p5 <- round(adf.test(totalbymonth.US[,5])$p.value,3)
p6 <- round(adf.test(totalbymonth.US[,6])$p.value,3)
p7 <- round(adf.test(totalbymonth.US[,7])$p.value,3)
US_df <- data.frame(matrix(c(p2,p3,p4,p5,p6,p7),nrow=1))
colnames(US_df) <-␣
 ↪c("covid_US","economic_US","health_US","response_US","stringency_US","Unemployment_US")
rownames(US_df) <- c("Unit Root Test p value")
p2 <- round(adf.test(totalbymonth.UK[,2])$p.value,3)
p3 <- round(adf.test(totalbymonth.UK[,3])$p.value,3)
p4 <- round(adf.test(totalbymonth.UK[,4])$p.value,3)
p5 <- round(adf.test(totalbymonth.UK[,5])$p.value,3)
p6 <- round(adf.test(totalbymonth.UK[,6])$p.value,3)
p7 <- round(adf.test(totalbymonth.UK[,7])$p.value,3)
UK_df <- data.frame(matrix(c(p2,p3,p4,p5,p6,p7),nrow=1))
colnames(UK_df) <-␣
 ↪c("covid_UK","economic_UK","health_UK","response_UK","stringency_UK","Unemployment_UK")
rownames(UK_df) <- c("Unit Root Test p value")
Sing_df
US_df
UK_df
```

```
Warning message in adf.test(totalbymonth.Sing[, 3]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.Sing[, 4]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.Sing[, 5]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.Sing[, 6]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.US[, 3]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.US[, 4]):
"p-value smaller than printed p-value"
```

```
Warning message in adf.test(totalbymonth.US[, 5]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.US[, 7]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.UK[, 3]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.UK[, 5]):
"p-value smaller than printed p-value"
Warning message in adf.test(totalbymonth.UK[, 6]):
"p-value smaller than printed p-value"
```

A data.frame: 1 × 6

	covid_Sing <dbl>	economic_Sing <dbl>	health_Sing <dbl>	response_Sing <dbl>	stri <d
Unit Root Test p value	0.014	0.01	0.01	0.01	0.0

A data.frame: 1 × 6

	covid_US <dbl>	economic_US <dbl>	health_US <dbl>	response_US <dbl>	stringenc <dbl>
Unit Root Test p value	0.938	0.01	0.01	0.01	0.358

A data.frame: 1 × 6

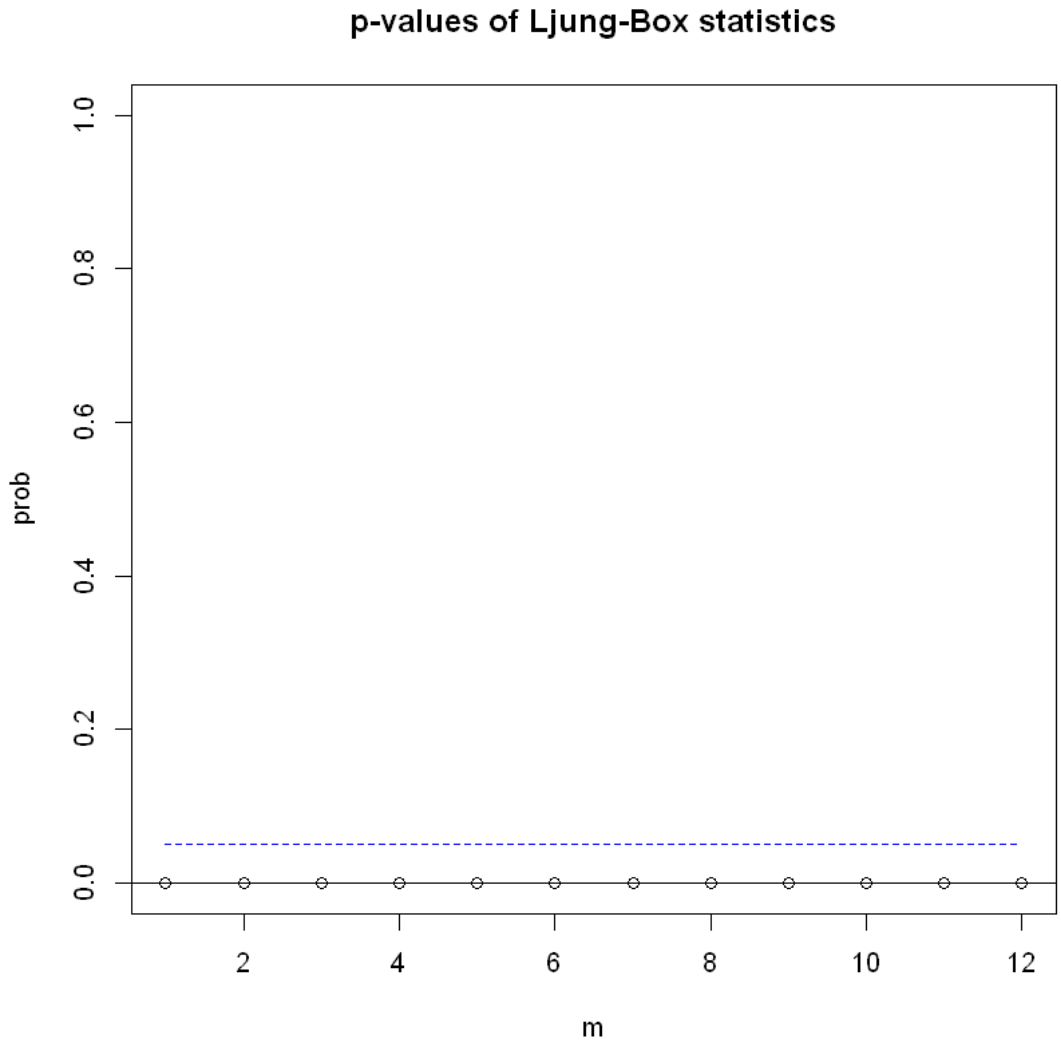
	covid_UK <dbl>	economic_UK <dbl>	health_UK <dbl>	response_UK <dbl>	stringe <dbl>
Unit Root Test p value	0.702	0.01	0.023	0.01	0.01

8 Ljung-Box statistics

[19]:
```
mq(total.Sing[,-1],lag=12)
mq(total.US[,-1],lag=12)
mq(total.UK[,-1],lag=12)

mq(totalbymonth.Sing[,-1],lag=12)
mq(totalbymonth.US[,-1],lag=12)
mq(totalbymonth.UK[,-1],lag=12)
```

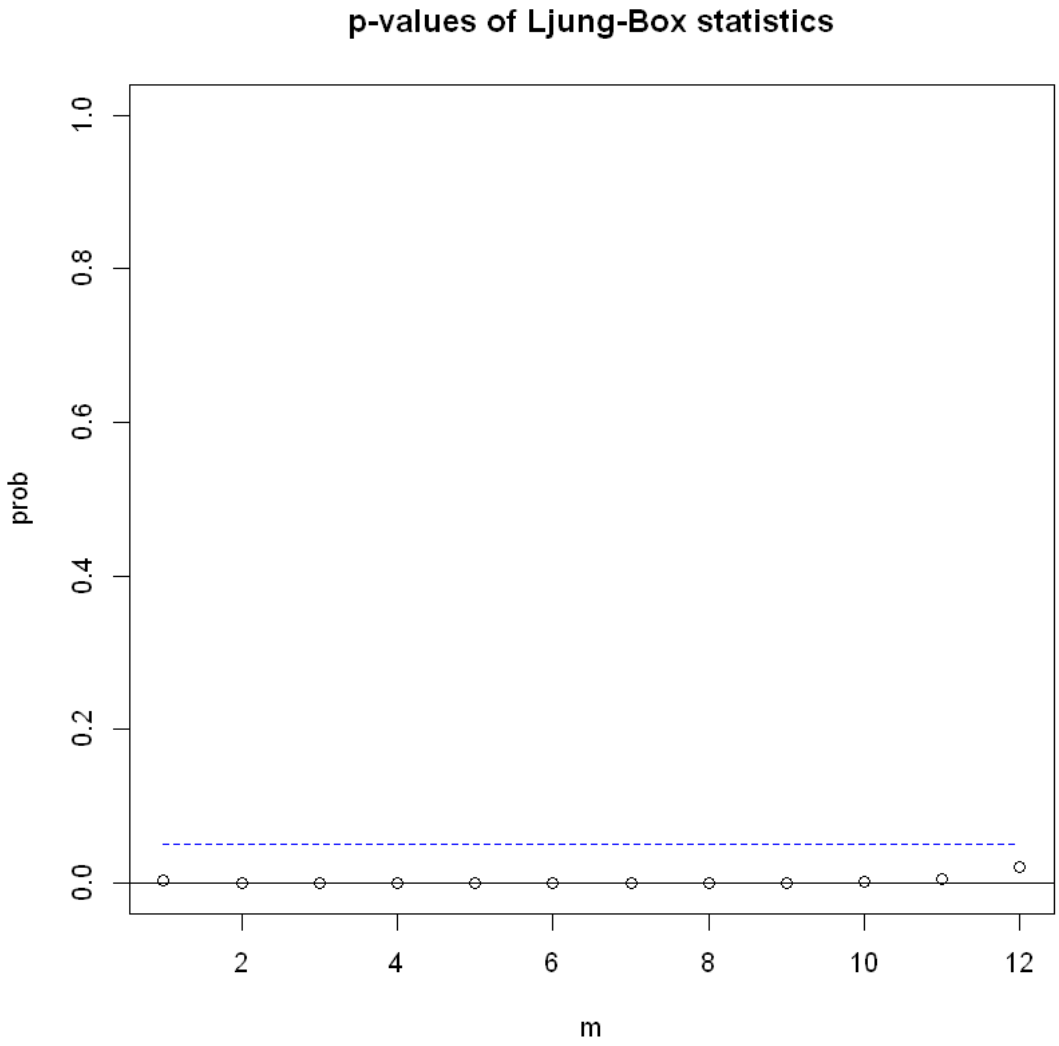
```
Ljung-Box Statistics:
        m       Q(m)     df    p-value
 [1,]     1      2198      25        0
 [2,]     2      4307      50        0
 [3,]     3      6266      75        0
 [4,]     4      8128     100        0
 [5,]     5      9884     125        0
 [6,]     6     11547     150        0
 [7,]     7     13147     175        0
 [8,]     8     14681     200        0
 [9,]     9     16162     225        0
[10,]    10     17595     250        0
[11,]    11     18986     275        0
[12,]    12     20342     300        0
Ljung-Box Statistics:
        m       Q(m)     df    p-value
```

```
 [1,]     1      2353      25         0
 [2,]     2      4536      50         0
 [3,]     3      6576      75         0
 [4,]     4      8480     100         0
 [5,]     5     10281     125         0
 [6,]     6     11998     150         0
 [7,]     7     13634     175         0
 [8,]     8     15164     200         0
 [9,]     9     16605     225         0
[10,]    10     17986     250         0
[11,]    11     19310     275         0
[12,]    12     20595     300         0
Ljung-Box Statistics:
        m       Q(m)     df    p-value
 [1,]     1      2372      25         0
 [2,]     2      4563      50         0
 [3,]     3      6609      75         0
 [4,]     4      8555     100         0
 [5,]     5     10423     125         0
 [6,]     6     12226     150         0
 [7,]     7     13966     175         0
 [8,]     8     15636     200         0
 [9,]     9     17242     225         0
[10,]    10     18782     250         0
[11,]    11     20260     275         0
[12,]    12     21686     300         0
Ljung-Box Statistics:
        m       Q(m)     df    p-value
 [1,]   1.0     62.2    36.0     0.00
 [2,]   2.0    125.2    72.0     0.00
 [3,]   3.0    183.5   108.0     0.00
 [4,]   4.0    233.2   144.0     0.00
 [5,]   5.0    278.6   180.0     0.00
 [6,]   6.0    322.9   216.0     0.00
 [7,]   7.0    358.0   252.0     0.00
 [8,]   8.0    392.2   288.0     0.00
 [9,]   9.0    418.8   324.0     0.00
[10,]  10.0    447.0   360.0     0.00
[11,]  11.0    470.4   396.0     0.01
[12,]  12.0    493.7   432.0     0.02
```



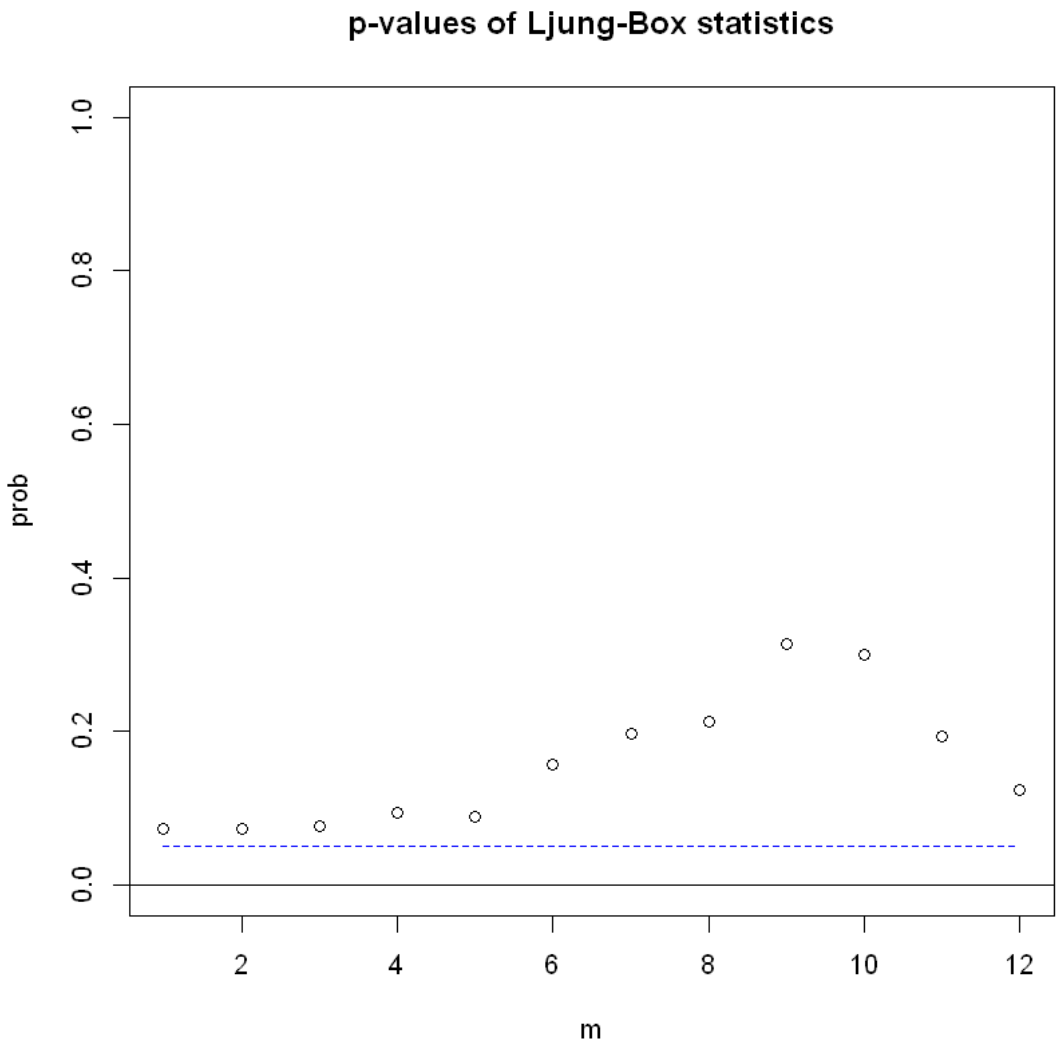

```
Ljung-Box Statistics:
        m       Q(m)     df    p-value
 [1,]   1.0      48.9    36.0     0.07
 [2,]   2.0      90.1    72.0     0.07
 [3,]   3.0     129.5   108.0     0.08
 [4,]   4.0     166.7   144.0     0.09
 [5,]   5.0     206.0   180.0     0.09
 [6,]   6.0     236.9   216.0     0.16
 [7,]   7.0     270.8   252.0     0.20
 [8,]   8.0     306.8   288.0     0.21
 [9,]   9.0     335.8   324.0     0.31
[10,]  10.0     373.6   360.0     0.30
[11,]  11.0     420.1   396.0     0.19
```

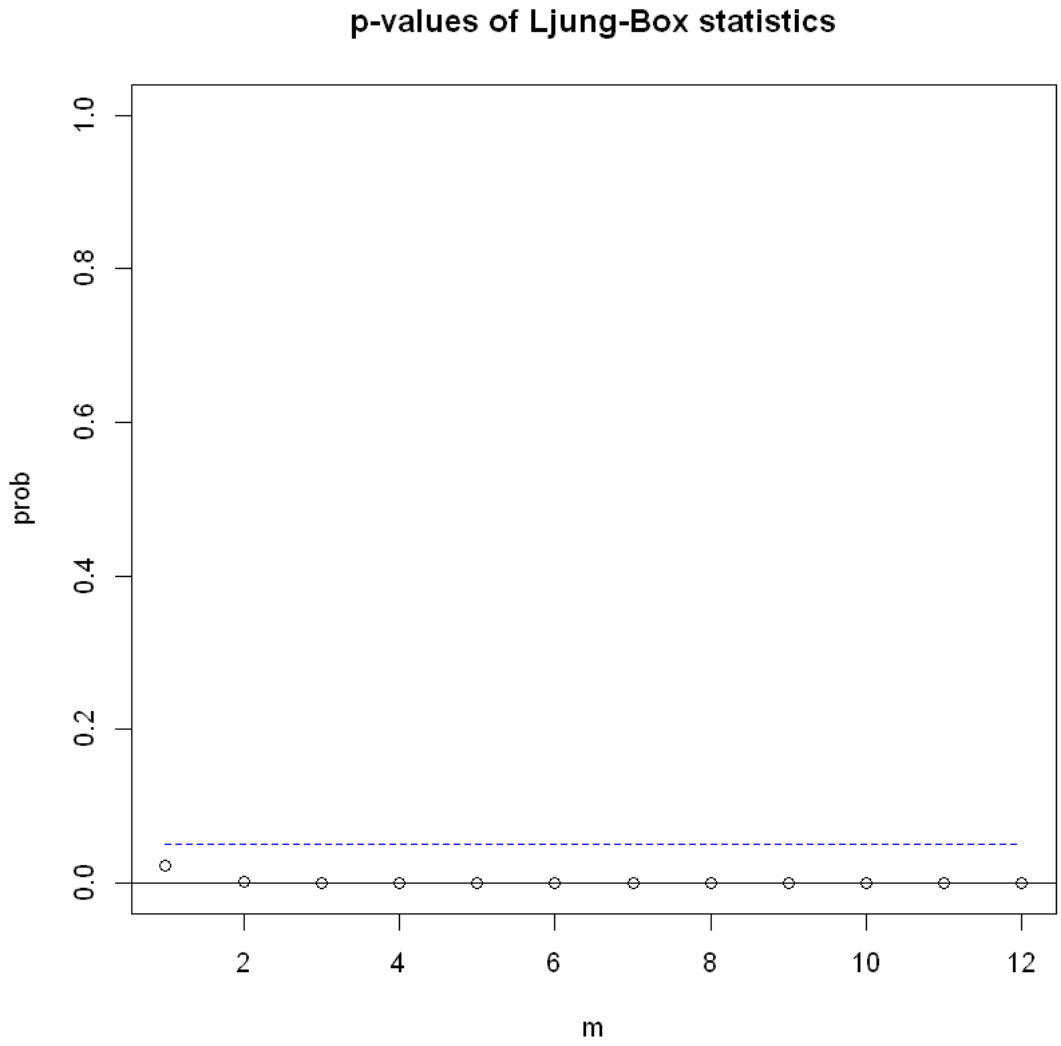
```
[12,]  12.0     466.1   432.0     0.12
```




```
Ljung-Box Statistics:
        m       Q(m)     df    p-value
 [1,]   1.0      54.7    36.0     0.02
 [2,]   2.0     111.8    72.0     0.00
 [3,]   3.0     160.6   108.0     0.00
 [4,]   4.0     206.5   144.0     0.00
 [5,]   5.0     246.8   180.0     0.00
 [6,]   6.0     290.6   216.0     0.00
 [7,]   7.0     327.2   252.0     0.00
 [8,]   8.0     372.4   288.0     0.00
 [9,]   9.0     412.7   324.0     0.00
[10,]  10.0     464.5   360.0     0.00
```

```
[11,]  11.0     511.4   396.0     0.00
[12,]  12.0     560.2   432.0     0.00
```

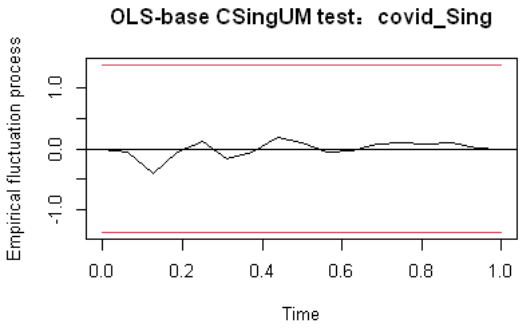


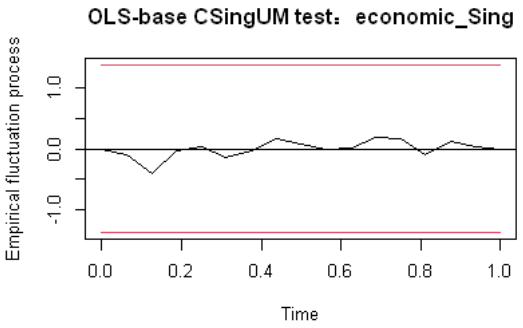


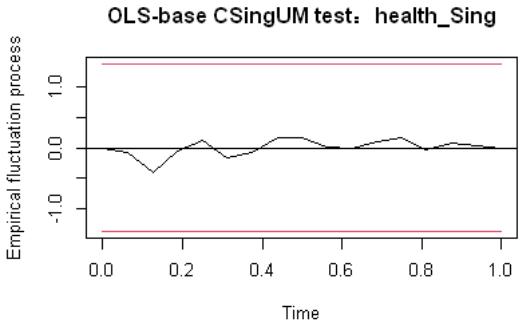
9 OLS-base CUSUM test

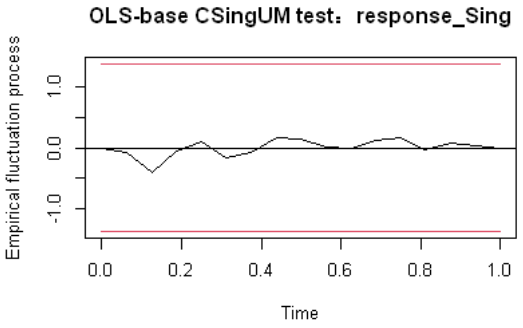
[20]:
```
Sing_var=vars::VAR(totalbymonth.Sing,p=1)
diagnostic_Sing <- stability(Sing_var, type = c("OLS-CUSUM"), h = 0.15, dynamic␣
↪= FALSE, rescale = T)
par(mfrow=c(3,2))
plot(diagnostic_Sing$stability$covid_Sing,main='OLS-base CSingUM␣
↪test covid_Sing')
plot(diagnostic_Sing$stability$economic_Sing,main='OLS-base CSingUM␣
↪test economic_Sing')
plot(diagnostic_Sing$stability$health_Sing,main='OLS-base CSingUM␣
↪test health_Sing')
```

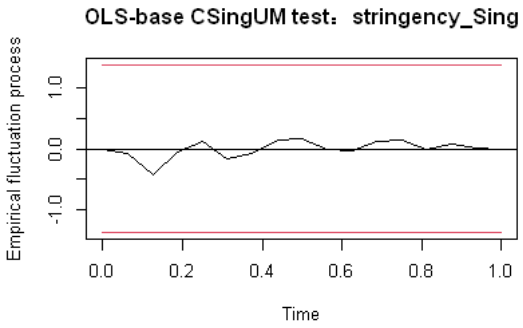
```
plot(diagnostic_Sing$stability$response_Sing,main='OLS-base CSingUM␣
 ↪test response_Sing')
plot(diagnostic_Sing$stability$stringency_Sing,main='OLS-base CSingUM␣
 ↪test stringency_Sing')
plot(diagnostic_Sing$stability$unemployment_Sing,main='OLS-base CSingUM␣
 ↪test unemployment_Sing')


US_var=vars::VAR(totalbymonth.US,p=1)
diagnostic_US <- stability(US_var, type = c("OLS-CUSUM"), h = 0.15, dynamic =␣
 ↪FALSE, rescale = T)


par(mfrow=c(3,2))
plot(diagnostic_US$stability$covid_US,main='OLS-base CUSUM test covid_US')
plot(diagnostic_US$stability$economic_US,main='OLS-base CUSUM test economic_US')
plot(diagnostic_US$stability$health_US,main='OLS-base CUSUM test health_US')
plot(diagnostic_US$stability$response_US,main='OLS-base CUSUM test response_US')
plot(diagnostic_US$stability$stringency_US,main='OLS-base CUSUM␣
 ↪test stringency_US')
plot(diagnostic_US$stability$unemployment_US,main='OLS-base CUSUM␣
 ↪test unemployment_US')



UK_var=vars::VAR(totalbymonth.UK,p=1)
diagnostic_UK <- stability(UK_var, type = c("OLS-CUSUM"), h = 0.15, dynamic =␣
 ↪FALSE, rescale = T)


par(mfrow=c(3,2))
plot(diagnostic_UK$stability$covid_UK,main='OLS-base CUSUM test covid_UK')
plot(diagnostic_UK$stability$economic_UK,main='OLS-base CUSUM test economic_UK')
plot(diagnostic_UK$stability$health_UK,main='OLS-base CUSUM test health_UK')
plot(diagnostic_UK$stability$response_UK,main='OLS-base CUSUM test response_UK')
plot(diagnostic_UK$stability$stringency_UK,main='OLS-base CUSUM␣
 ↪test stringency_UK')
plot(diagnostic_UK$stability$unemployment_UK,main='OLS-base CUSUM␣
 ↪test unemployment_UK')
```


OLS-base CSingUM test：covid_Sing
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time

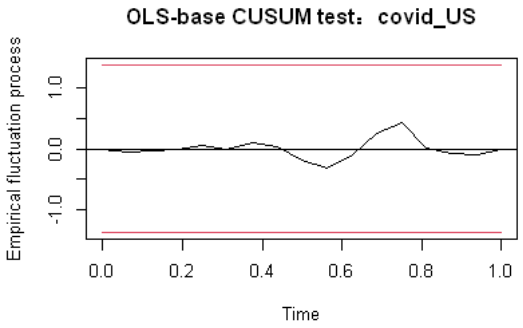

OLS-base CSingUM test：economic_Sing
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time

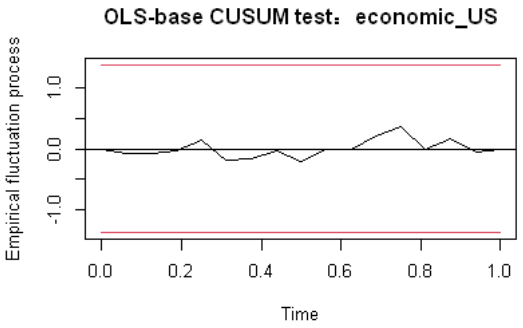

OLS-base CSingUM test：health_Sing
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time

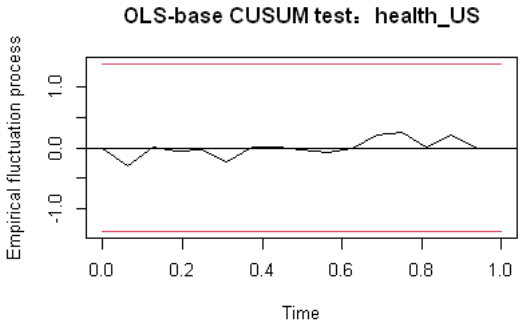

OLS-base CSingUM test：response_Sing
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time

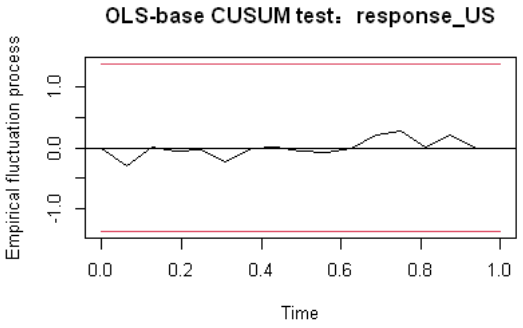

OLS-base CSingUM test：stringency_Sing
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time

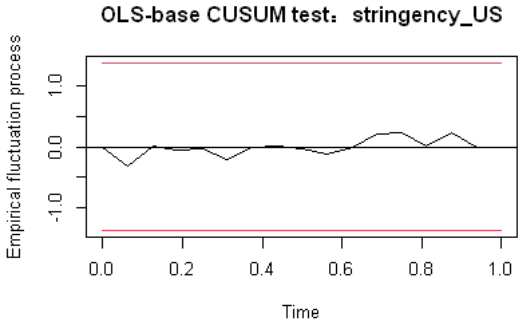

OLS-base CSingUM test：unemployment_Sing
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time


OLS-base CUSUM test：covid_US
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time

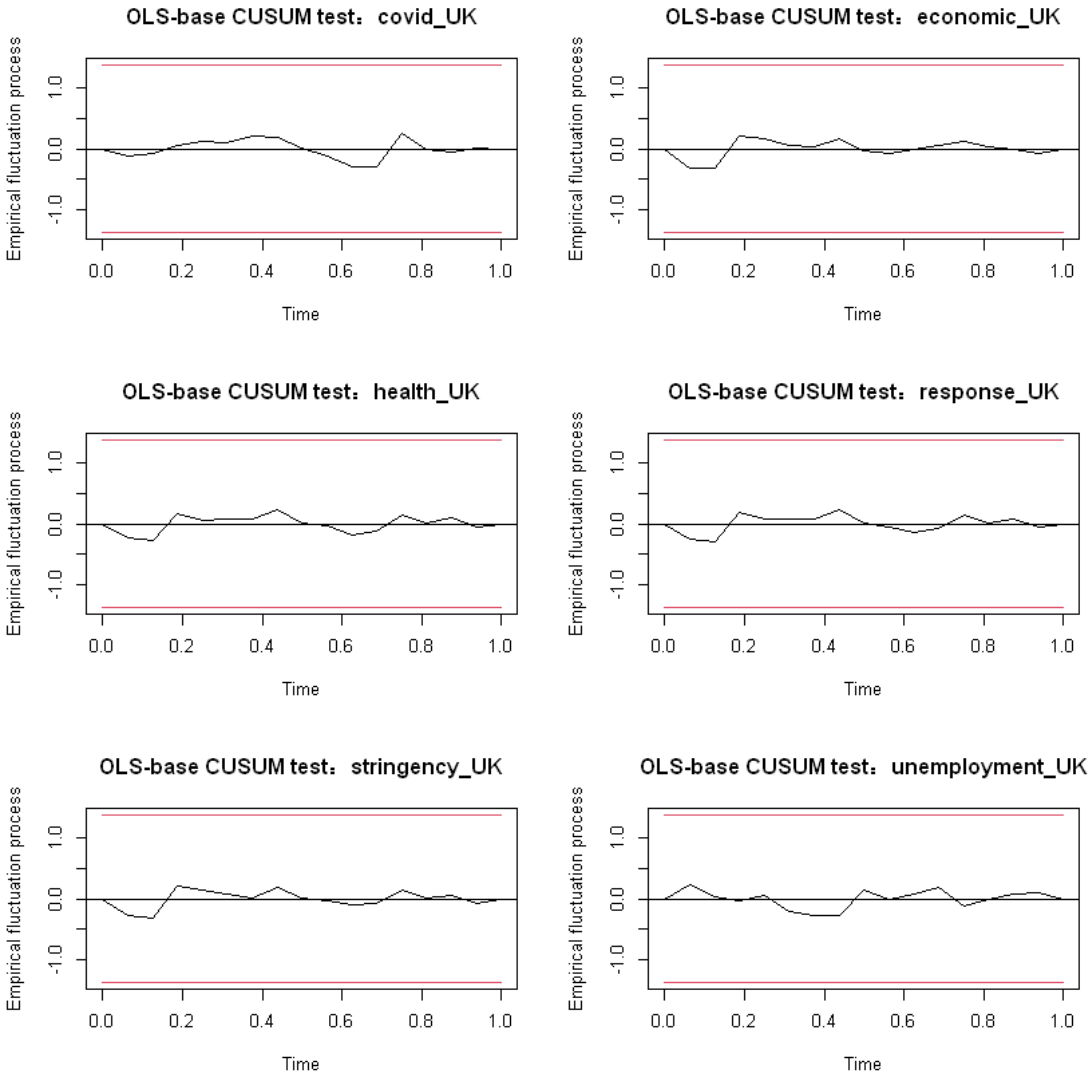

OLS-base CUSUM test：economic_US
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time


OLS-base CUSUM test：health_US
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time


OLS-base CUSUM test：response_US
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time


OLS-base CUSUM test：stringency_US
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time


OLS-base CUSUM test：unemployment_US
Empirical fluctuation process
-1.0
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Time



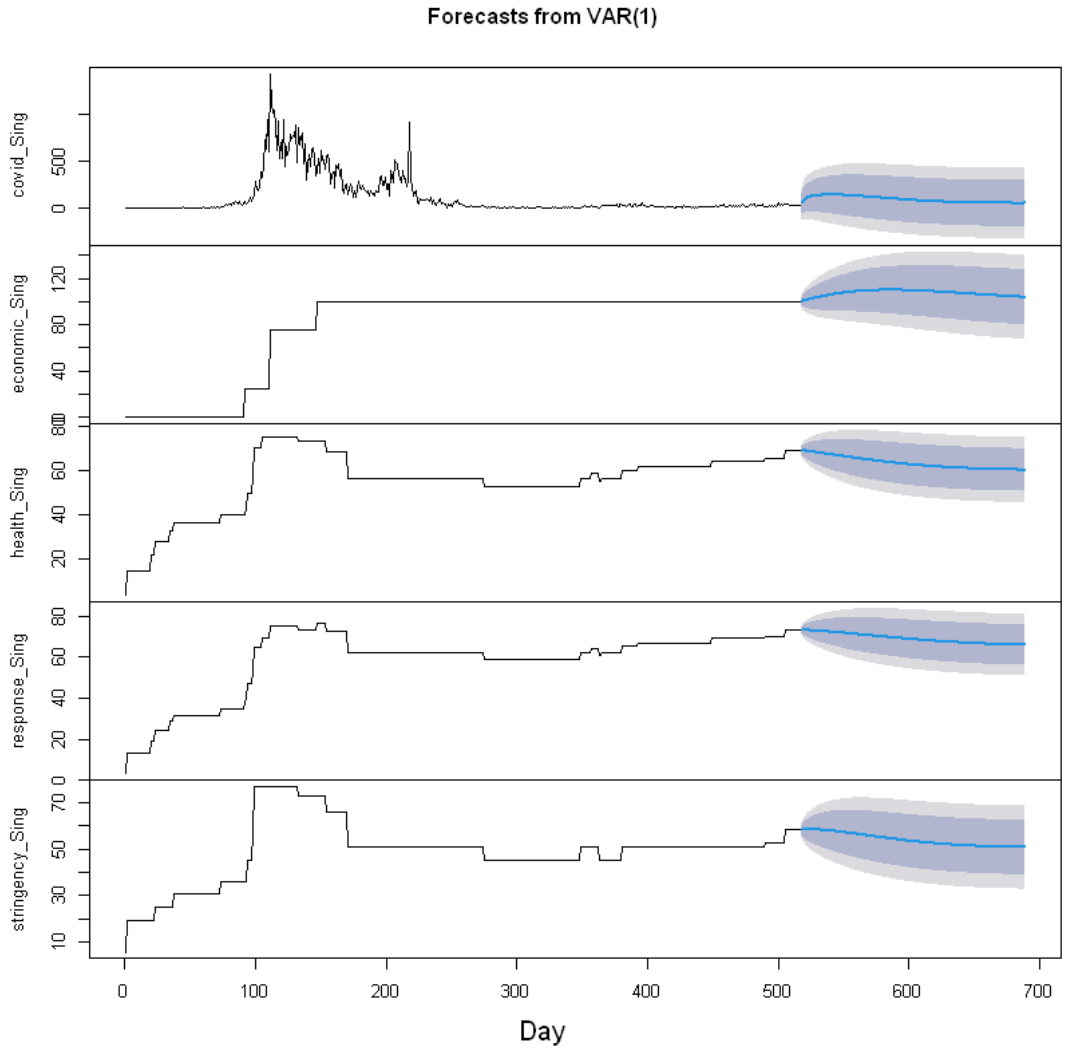
[33]:
```
train_size <- nrow(total)
test_size=floor(nrow(total)/3)
train_ind <- 1:train_size
train_size <- nrow(total)
test_size=floor(nrow(total)/3)
forecast_time=data.frame(Date=as.Date(total[nrow(total),1])+1)
for(i in 2:test_size){
  forecast_time[i,1]=as.Date(total[nrow(total),1])+i
}

total.Sing.train <- total.Sing[train_ind, ]
```

```
VARselect(total.Sing.train[,-1], lag.max=8, type="const")[["selection"]]
total.Sing.var=VAR(as.ts(total.Sing.train[,-1]),p=1,type="const")
serial.test(total.Sing.var,lags.pt = 10, type="PT.asymptotic")
plot(forecast(total.Sing.var,test_size),xlab="Day")
MTSplot(as.ts(total.Sing[,-1]))


forest.total.Sing=forecast(total.Sing.var,test_size)

forest.total.Sing.covid=cbind(forecast_time,forest.total.
 ↪Sing$forecast[1]$covid_Sing)
colnames(forest.total.Sing.
 ↪covid)=c("Date","forecast_Sing_covid","forecast_Sing_covid_low_80","forecast_Sing_covid_hig

write.csv(forest.total.Sing.covid,file="forest_Sing_covid.csv",row.names = F)


forest.total.Sing.economic=cbind(forecast_time,forest.total.
 ↪Sing$forecast[2]$economic_Sing)
colnames(forest.total.Sing.
 ↪economic)=c("Date","forecast_Sing_economic","forecast_Sing_economic_low_80","forecast_Sing_
write.csv(forest.total.Sing.economic,file="forest_Sing_economic.csv",row.names␣
 ↪= F)

forest.total.Sing.health=cbind(forecast_time,forest.total.
 ↪Sing$forecast[3]$health_Sing)
colnames(forest.total.Sing.
 ↪health)=c("Date","forecast_Sing_health","forecast_Sing_health_low_80","forecast_Sing_health
write.csv(forest.total.Sing.health,file="forest_Sing_health.csv",row.names = F)


forest.total.Sing.response=cbind(forecast_time,forest.total.
 ↪Sing$forecast[4]$response_Sing)
colnames(forest.total.Sing.
 ↪response)=c("Date","forecast_Sing_response","forecast_Sing_response_low_80","forecast_Sing_
write.csv(forest.total.Sing.response,file="forest_Sing_response.csv",row.names␣
 ↪= F)

forest.total.Sing.stringency=cbind(forecast_time,forest.total.
 ↪Sing$forecast[5]$stringency_Sing)
colnames(forest.total.Sing.
 ↪stringency)=c("Date","forecast_Sing_stringency","forecast_Sing_stringency_low_80","forecast
write.csv(forest.total.Sing.stringency,file="forest_Sing_strigency.csv",row.
 ↪names = F)
```

```
forest.total.Sing.all=cbind(forest.total.Sing.covid,forest.total.Sing.
 ↪economic,forest.total.Sing.health,forest.total.Sing.response,forest.total.
 ↪Sing.stringency)
forest.total.Sing=cbind(forest.total.Sing.covid[,c(1,2)],forest.total.Sing.
 ↪economic[,c(1,2)],forest.total.Sing.health[,c(1,2)],forest.total.Sing.
 ↪response[,c(1,2)],forest.total.Sing.stringency[,c(1,2)])


forest.total.Sing=forest.total.Sing[,c(1,2,4,6,8,10)]

write.csv(forest.total.Sing,file="forest_Sing.csv",row.names = F)
head(forest.total.Sing.covid[,-1])
head(forest.total.Sing.economic[,-1])
head(forest.total.Sing.health[,-1])
head(forest.total.Sing.response[,-1])
head(forest.total.Sing.stringency[,-1])
```

AIC(n) 7 **HQ(n)** 2 **SC(n)** 2 **FPE(n)** 7

```
        Portmanteau Test (asymptotic)

data:  Residuals of VAR object total.Sing.var
Chi-squared = 587.25, df = 225, p-value < 2.2e-16

$serial

        Portmanteau Test (asymptotic)

data:  Residuals of VAR object total.Sing.var
Chi-squared = 587.25, df = 225, p-value < 2.2e-16
```



A data.frame: 6 × 5

	forecast__Sing__covid <dbl>	forecast__Sing__covid__low__80 <dbl>	forecast__Sing__covid__high__80 <dbl>
1	52.65123	-54.30205	159.6045
2	73.62751	-56.04098	203.2960
3	88.67736	-51.43282	228.7875
4	99.65689	-46.64322	245.9570
5	107.82070	-43.07487	258.7163
6	114.01797	-40.85273	268.8887

A data.frame: 6 × 5

	forecast_Sing_economic <dbl>	forecast_Sing_economic_low_80 <dbl>	forecast_Sing_economic_ <dbl>
1	100.3676	96.96764	103.7676
2	100.7072	95.96089	105.4535
3	101.0268	95.27945	106.7742
4	101.3319	94.76261	107.9013
5	101.6261	94.34927	108.9029
6	101.9116	94.00862	109.8147

A data.frame: 6 × 5

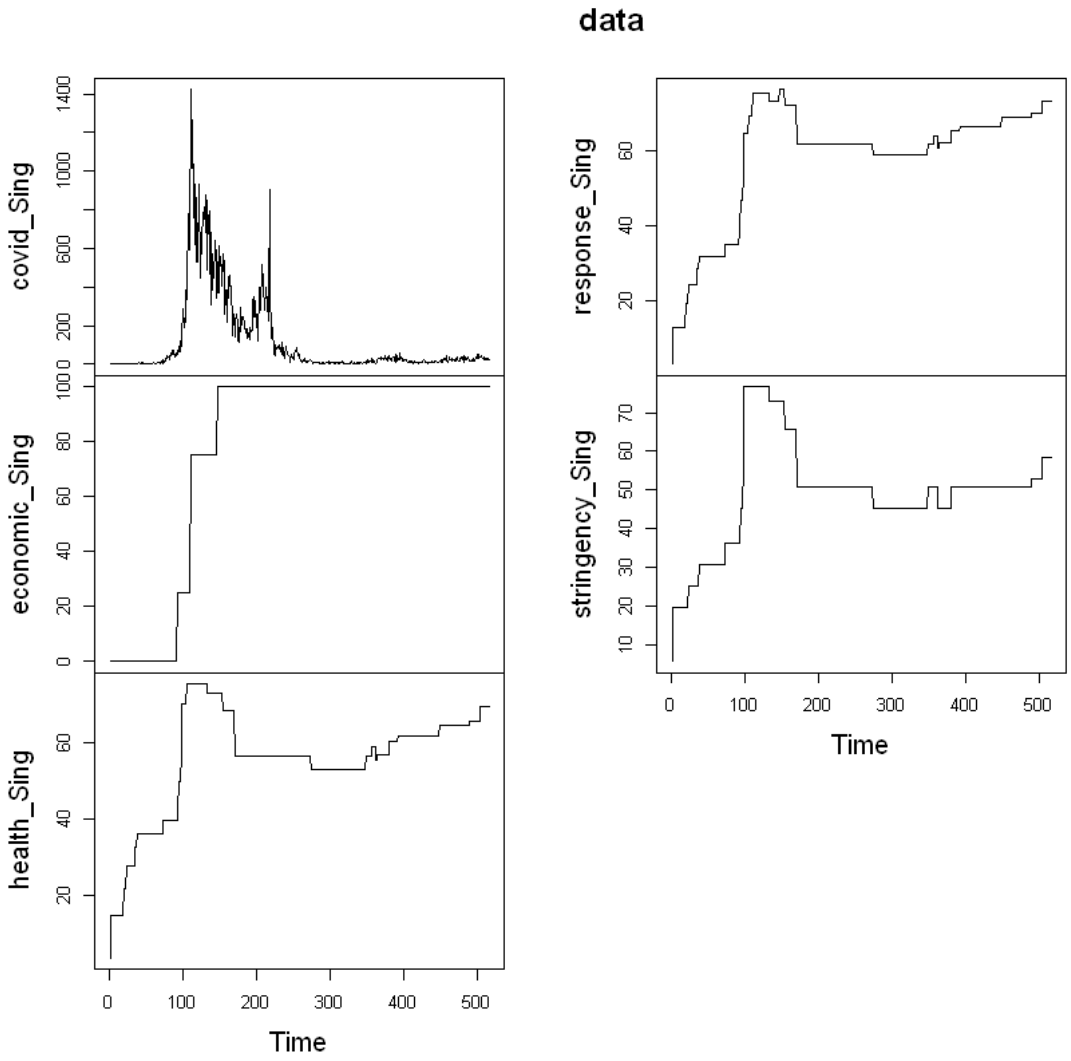
	forecast_Sing_health <dbl>	forecast_Sing_health_low_80 <dbl>	forecast_Sing_health_high_8 <dbl>
1	69.30717	67.71247	70.90186
2	69.21633	66.97403	71.45863
3	69.12683	66.39600	71.85766
4	69.03821	65.90236	72.17406
5	68.95017	65.46335	72.43699
6	68.86251	65.06361	72.66140

A data.frame: 6 × 5

	forecast_Sing_response <dbl>	forecast_Sing_response_low_80 <dbl>	forecast_Sing_response_l <dbl>
1	73.19430	71.74002	74.64858
2	73.15687	71.10668	75.20707
3	73.11815	70.61529	75.62102
4	73.07842	70.19788	75.95895
5	73.03784	69.82812	76.24756
6	72.99654	69.49246	76.50061

A data.frame: 6 × 5

	forecast_Sing_stringency <dbl>	forecast_Sing_stringency_low_80 <dbl>	forecast_Sing_stringen <dbl>
1	58.33782	56.28459	60.39104
2	58.34790	55.47110	61.22470
3	58.35771	54.86460	61.85082
4	58.36564	54.36474	62.36654
5	58.37066	53.93200	62.80933
6	58.37218	53.54596	63.19841



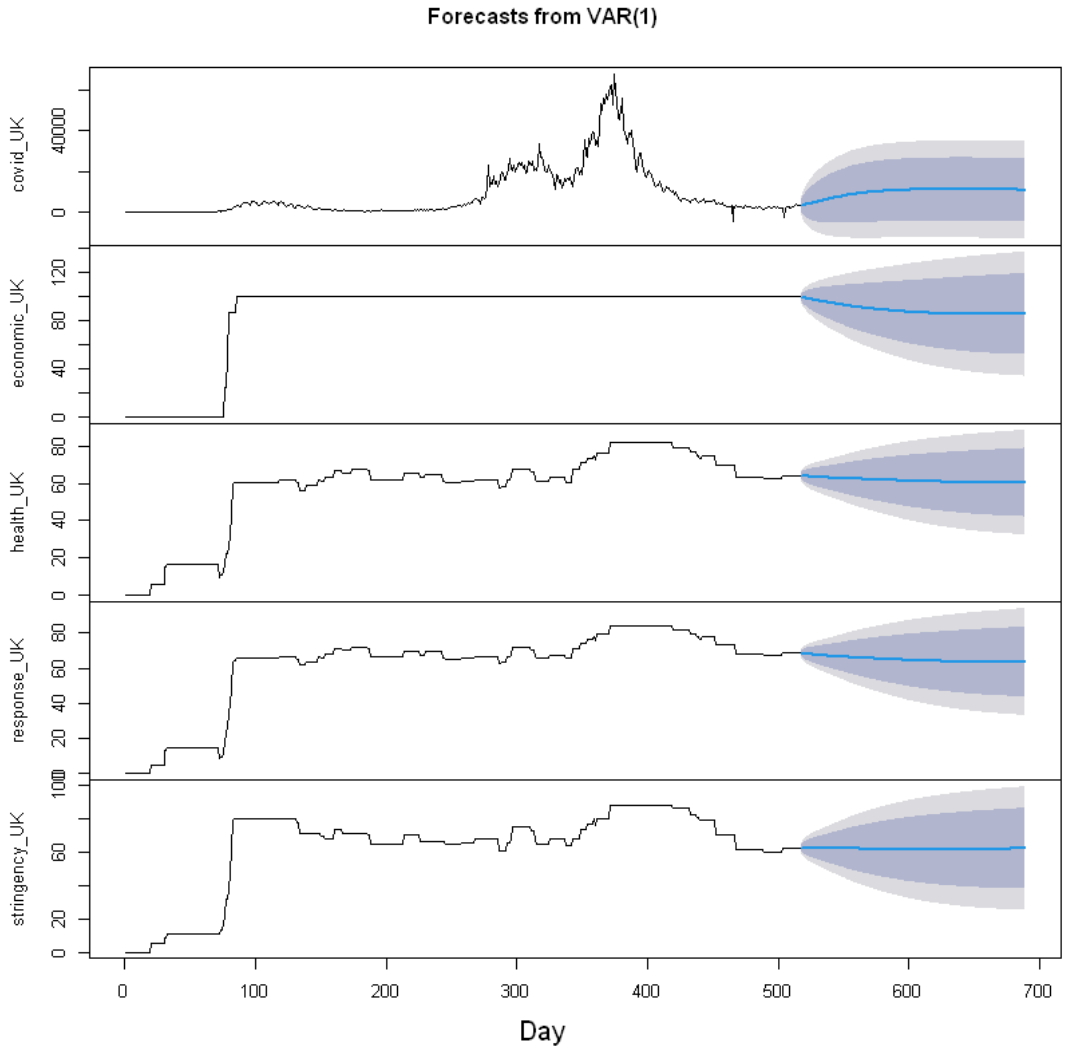
[34]:
```
train_size <- nrow(total)
test_size=floor(nrow(total)/3)
train_ind <- 1:train_size
train_size <- nrow(total)
test_size=floor(nrow(total)/3)
forecast_time=data.frame(Date=as.Date(total[nrow(total),1])+1)
for(i in 2:test_size){
  forecast_time[i,1]=as.Date(total[nrow(total),1])+i
}


total.UK.train <- total.UK[train_ind, ]
```

```
VARselect(total.UK.train[,-1], lag.max=8, type="const")[["selection"]]
total.UK.var=VAR(as.ts(total.UK.train[,-1]),p=1,type="const")
serial.test(total.UK.var,lags.pt = 10, type="PT.asymptotic")
plot(forecast(total.UK.var,test_size),xlab="Day")
MTSplot(as.ts(total.UK[,-1]))
forest.total.UK=forecast(total.UK.var,test_size)

forest.total.UK.covid=cbind(forecast_time,forest.total.UK$forecast[1]$covid_UK)
colnames(forest.total.UK.
 ↪covid)=c("Date","forecast_UK_covid","forecast_UK_covid_low_80","forecast_UK_covid_high_80",

write.csv(forest.total.UK.covid,file="forest_UK_covid.csv",row.names = F)


forest.total.UK.economic=cbind(forecast_time,forest.total.
 ↪UK$forecast[2]$economic_UK)
colnames(forest.total.UK.
 ↪economic)=c("Date","forecast_UK_economic","forecast_UK_economic_low_80","forecast_UK_econom
write.csv(forest.total.UK.economic,file="forest_UK_economic.csv",row.names = F)

forest.total.UK.health=cbind(forecast_time,forest.total.
 ↪UK$forecast[3]$health_UK)
colnames(forest.total.UK.
 ↪health)=c("Date","forecast_UK_health","forecast_UK_health_low_80","forecast_UK_health_high_
write.csv(forest.total.UK.health,file="forest_UK_health.csv",row.names = F)


forest.total.UK.response=cbind(forecast_time,forest.total.
 ↪UK$forecast[4]$response_UK)
colnames(forest.total.UK.
 ↪response)=c("Date","forecast_UK_response","forecast_UK_response_low_80","forecast_UK_respon
write.csv(forest.total.UK.response,file="forest_UK_response.csv",row.names = F)

forest.total.UK.stringency=cbind(forecast_time,forest.total.
 ↪UK$forecast[5]$stringency_UK)
colnames(forest.total.UK.
 ↪stringency)=c("Date","forecast_UK_stringency","forecast_UK_stringency_low_80","forecast_UK_
write.csv(forest.total.UK.stringency,file="forest_UK_strigency.csv",row.names =␣
 ↪F)


forest.total.UK.all=cbind(forest.total.UK.covid,forest.total.UK.economic,forest.
 ↪total.UK.health,forest.total.UK.response,forest.total.UK.stringency)
```

```
forest.total.UK=cbind(forest.total.UK.covid[,c(1,2)],forest.total.UK.
 ↪economic[,c(1,2)],forest.total.UK.health[,c(1,2)],forest.total.UK.
 ↪response[,c(1,2)],forest.total.UK.stringency[,c(1,2)])

forest.total.UK=forest.total.UK[,c(1,2,4,6,8,10)]
write.csv(forest.total.UK,file="forest_UK.csv",row.names = F)
head(forest.total.UK.covid[,-1])
head(forest.total.UK.economic[,-1])
head(forest.total.UK.health[,-1])
head(forest.total.UK.response[,-1])
head(forest.total.UK.stringency[,-1])
```

AIC(n) 8 **HQ(n)** 6 **SC(n)** 2 **FPE(n)** 8

```
        Portmanteau Test (asymptotic)

data:  Residuals of VAR object total.UK.var
Chi-squared = 1078.5, df = 225, p-value < 2.2e-16

$serial

        Portmanteau Test (asymptotic)

data:  Residuals of VAR object total.UK.var
Chi-squared = 1078.5, df = 225, p-value < 2.2e-16
```



A data.frame: 6 × 5

	forecast_UK_covid <dbl>	forecast_UK_covid_low_80 <dbl>	forecast_UK_covid_high_80 <dbl>	fo <c
1	3383.533	362.0155	6405.051	-1
2	3488.946	-749.1776	7727.069	-2
3	3607.614	-1540.9273	8756.156	-4
4	3737.254	-2159.8933	9634.402	-5
5	3875.879	-2664.4944	10416.252	-6
6	4021.760	-3085.6436	11129.163	-6

A data.frame: 6 × 5

	forecast_UK_economic <dbl>	forecast_UK_economic_low_80 <dbl>	forecast_UK_economic_h <dbl>
1	99.69778	96.74493	102.6506
2	99.40768	95.23924	103.5761
3	99.12837	94.03155	104.2252
4	98.85871	92.98236	104.7351
5	98.59770	92.03693	105.1585
6	98.34446	91.16673	105.5222

A data.frame: 6 × 5

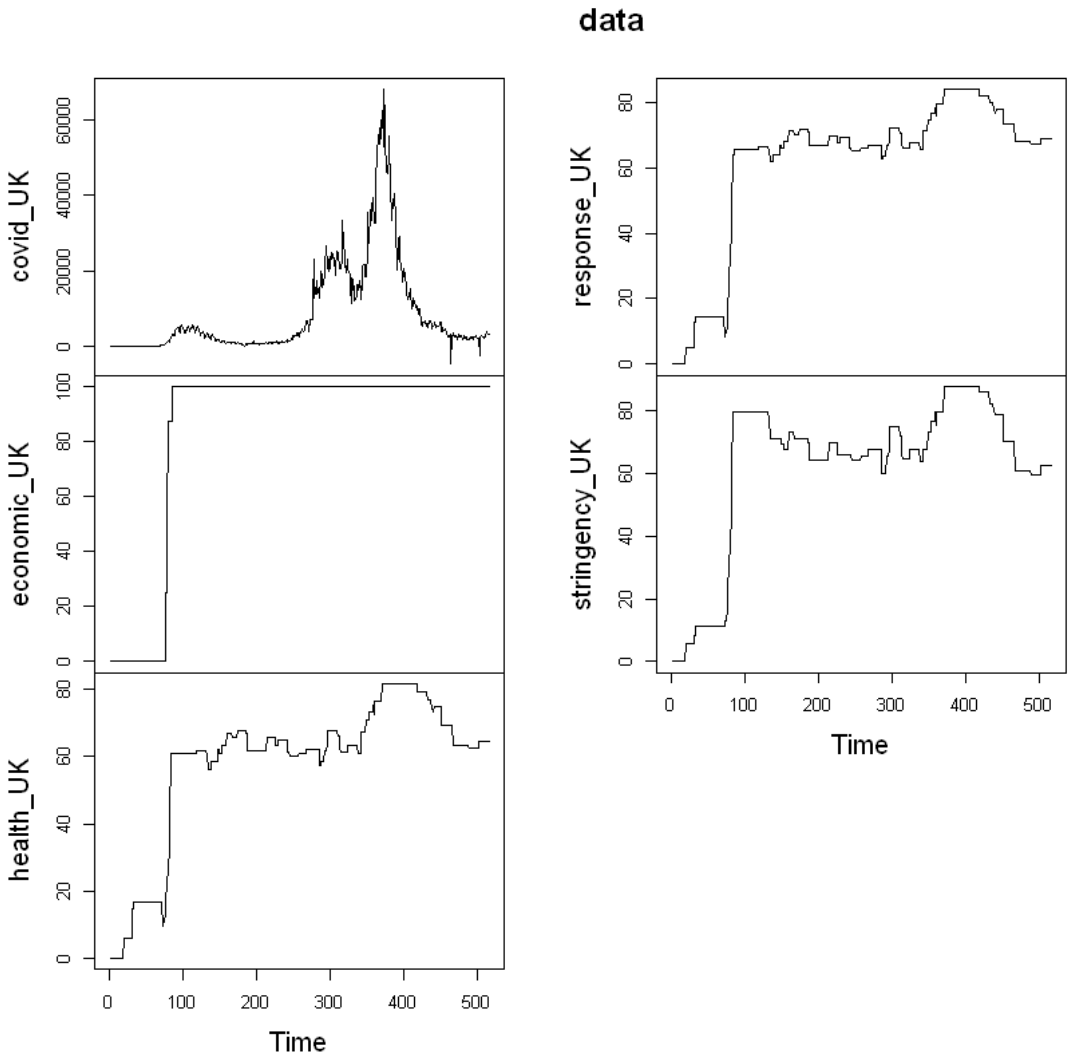
	forecast_UK_health <dbl>	forecast_UK_health_low_80 <dbl>	forecast_UK_health_high_80 <dbl>
1	64.20933	62.41486	66.00381
2	64.08265	61.60757	66.55773
3	63.96829	61.00749	66.92908
4	63.86477	60.52054	67.20901
5	63.77083	60.10798	67.43367
6	63.68530	59.74868	67.62192

A data.frame: 6 × 5

	forecast_UK_response <dbl>	forecast_UK_response_low_80 <dbl>	forecast_UK_response_hig <dbl>
1	68.64004	66.99356	70.28652
2	68.49372	66.21010	70.77734
3	68.35942	65.61190	71.10694
4	68.23574	65.11404	71.35744
5	68.12143	64.68172	71.56113
6	68.01539	64.29610	71.73468

A data.frame: 6 × 5

	forecast_UK_stringency <dbl>	forecast_UK_stringency_low_80 <dbl>	forecast_UK_stringency <dbl>
1	62.48104	60.35187	64.61021
2	62.46079	59.50668	65.41490
3	62.43963	58.88345	65.99582
4	62.41787	58.37435	66.46138
5	62.39575	57.93621	66.85530
6	62.37350	57.54625	67.20075



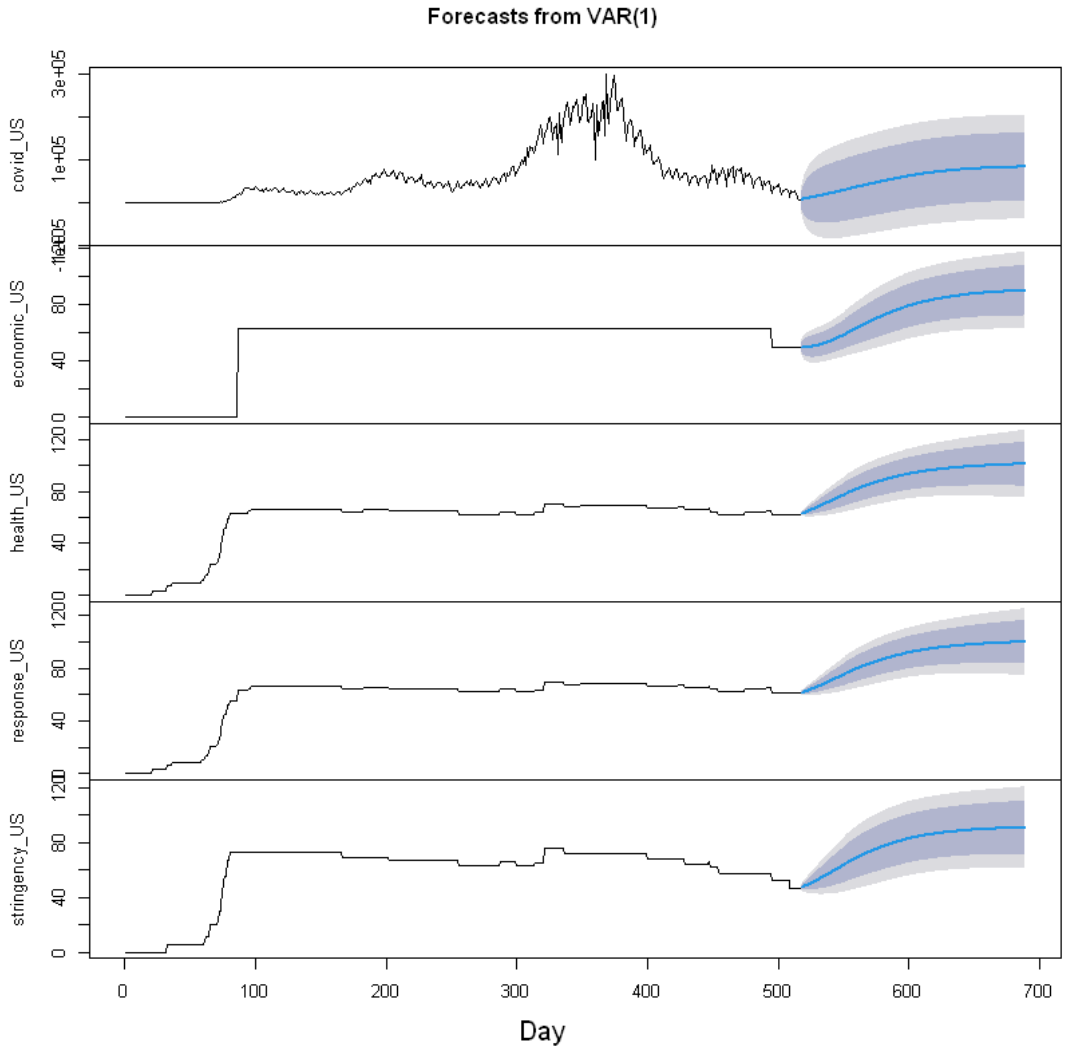
[35]:
```
train_size <- nrow(total)
test_size=floor(nrow(total)/3)
train_ind <- 1:train_size
train_size <- nrow(total)
test_size=floor(nrow(total)/3)
forecast_time=data.frame(Date=as.Date(total[nrow(total),1])+1)
for(i in 2:test_size){
  forecast_time[i,1]=as.Date(total[nrow(total),1])+i
}


total.US.train <- total.US[train_ind, ]
```

```
VARselect(total.US.train[,-1], lag.max=8, type="const")[["selection"]]
total.US.var=VAR(as.ts(total.US.train[,-1]),p=1,type="const")
serial.test(total.US.var,lags.pt = 10, type="PT.asymptotic")
plot(forecast(total.US.var,test_size),xlab="Day")
MTSplot(as.ts(total.US[,-1]))


forest.total.US=forecast(total.US.var,test_size)

forest.total.US.covid=cbind(forecast_time,forest.total.US$forecast[1]$covid_US)
colnames(forest.total.US.
 ↪covid)=c("Date","forecast_US_covid","forecast_US_covid_low_80","forecast_US_covid_high_80",

write.csv(forest.total.US.covid,file="forest_US_covid.csv",row.names = F)


forest.total.US.economic=cbind(forecast_time,forest.total.
 ↪US$forecast[2]$economic_US)
colnames(forest.total.US.
 ↪economic)=c("Date","forecast_US_economic","forecast_US_economic_low_80","forecast_US_econom
write.csv(forest.total.US.economic,file="forest_US_economic.csv",row.names = F)

forest.total.US.health=cbind(forecast_time,forest.total.
 ↪US$forecast[3]$health_US)
colnames(forest.total.US.
 ↪health)=c("Date","forecast_US_health","forecast_US_health_low_80","forecast_US_health_high_
write.csv(forest.total.US.health,file="forest_US_health.csv",row.names = F)


forest.total.US.response=cbind(forecast_time,forest.total.
 ↪US$forecast[4]$response_US)
colnames(forest.total.US.
 ↪response)=c("Date","forecast_US_response","forecast_US_response_low_80","forecast_US_respon
write.csv(forest.total.US.response,file="forest_US_response.csv",row.names = F)

forest.total.US.stringency=cbind(forecast_time,forest.total.
 ↪US$forecast[5]$stringency_US)
colnames(forest.total.US.
 ↪stringency)=c("Date","forecast_US_stringency","forecast_US_stringency_low_80","forecast_US_
write.csv(forest.total.US.stringency,file="forest_US_strigency.csv",row.names =␣
 ↪F)


forest.total.US.all=cbind(forest.total.US.covid,forest.total.US.economic,forest.
 ↪total.US.health,forest.total.US.response,forest.total.US.stringency)
```

```
forest.total.US=cbind(forest.total.US.covid[,c(1,2)],forest.total.US.
 ↪economic[,c(1,2)],forest.total.US.health[,c(1,2)],forest.total.US.
 ↪response[,c(1,2)],forest.total.US.stringency[,c(1,2)])
forest.total.US=forest.total.US[,c(1,2,4,6,8,10)]
write.csv(forest.total.US,file="forest_US.csv",row.names = F)
head(forest.total.US.covid[,-1])
head(forest.total.US.economic[,-1])
head(forest.total.US.health[,-1])
head(forest.total.US.response[,-1])
head(forest.total.US.stringency[,-1])
```

AIC(n) 8 **HQ(n)** 2 **SC(n)** 1 **FPE(n)** 8

```
        Portmanteau Test (asymptotic)

data:  Residuals of VAR object total.US.var
Chi-squared = 640.6, df = 225, p-value < 2.2e-16

$serial

        Portmanteau Test (asymptotic)

data:  Residuals of VAR object total.US.var
Chi-squared = 640.6, df = 225, p-value < 2.2e-16
```



A data.frame: 6 × 5

	forecast_US_covid <dbl>	forecast_US_covid_low_80 <dbl>	forecast_US_covid_high_80 <dbl>	fore <db
1	6447.290	-15507.91	28402.49	-271
2	7111.281	-23230.70	37453.26	-392
3	7768.917	-28560.20	44098.04	-477
4	8421.139	-32605.16	49447.44	-543
5	9068.873	-35808.48	53946.23	-595
6	9713.018	-38404.00	57830.04	-638

A data.frame: 6 × 5

	forecast_US_economic <dbl>	forecast_US_economic_low_80 <dbl>	forecast_US_economic_hig
1	49.87013	46.40169	53.33856
2	49.77872	45.06672	54.49073
3	49.72418	44.17763	55.27072
4	49.70490	43.54572	55.86407
5	49.71932	43.09237	56.34627
6	49.76593	42.77403	56.75782

A data.frame: 6 × 5

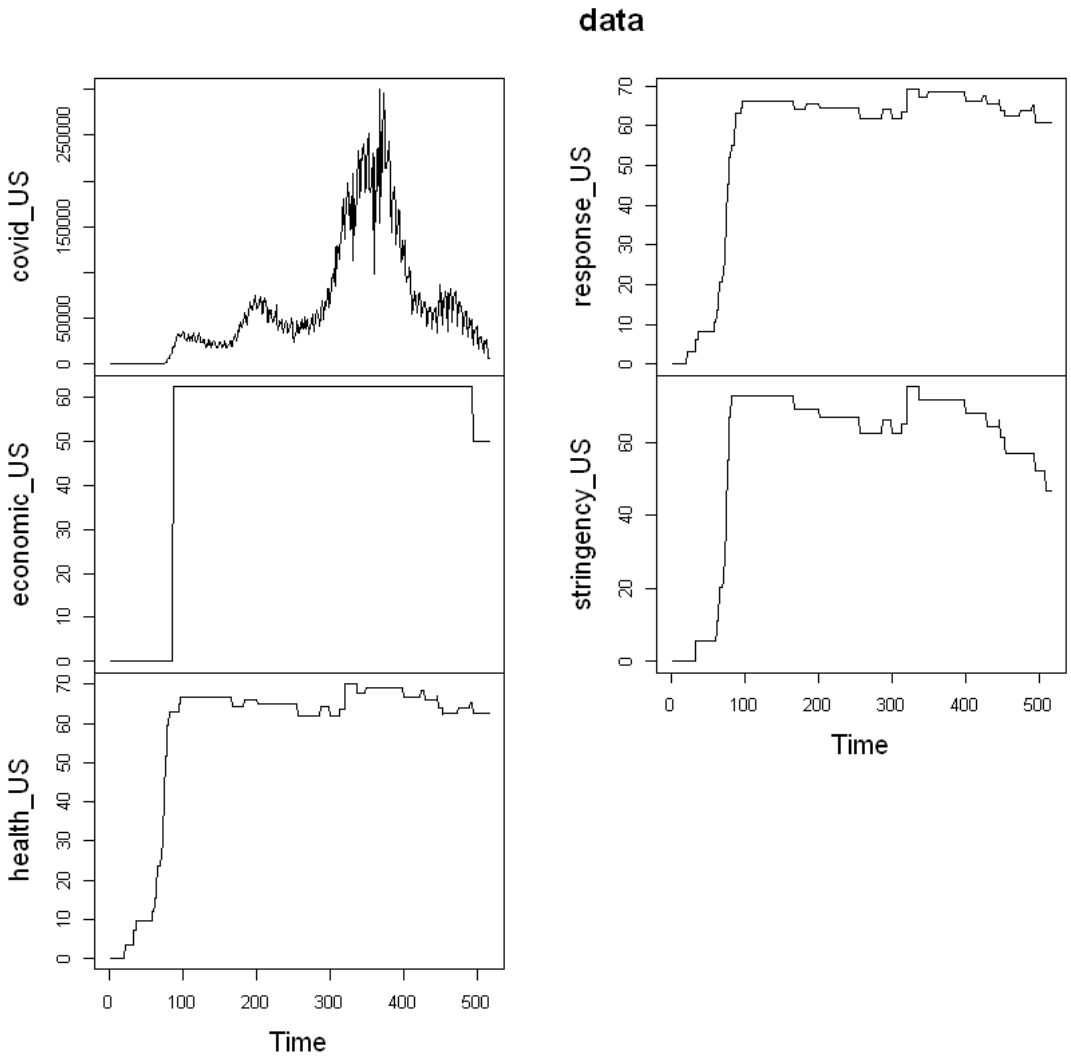
	forecast_US_health <dbl>	forecast_US_health_low_80 <dbl>	forecast_US_health_high_80 <dbl>	f
1	62.87734	61.79746	63.95721	6
2	63.26612	61.71454	64.81770	6
3	63.66555	61.73208	65.59903	6
4	64.07486	61.80117	66.34854	6
5	64.49326	61.90309	67.08344	6
6	64.92004	62.02847	67.81161	6

A data.frame: 6 × 5

	forecast_US_response <dbl>	forecast_US_response_low_80 <dbl>	forecast_US_response_high_
1	61.25357	60.23938	62.26776
2	61.58201	60.15349	63.01053
3	61.92440	60.17310	63.67570
4	62.27987	60.24685	64.31288
5	62.64754	60.35415	64.94093
6	63.02658	60.48436	65.56879

A data.frame: 6 × 5

	forecast_US_stringency <dbl>	forecast_US_stringency_low_80 <dbl>	forecast_US_stringency_ <dbl>
1	47.13441	45.55468	48.71415
2	47.52667	45.25817	49.79517
3	47.93563	45.11058	50.76068
4	48.36019	45.04022	51.68016
5	48.79928	45.01961	52.57896
6	49.25186	45.03494	53.46879

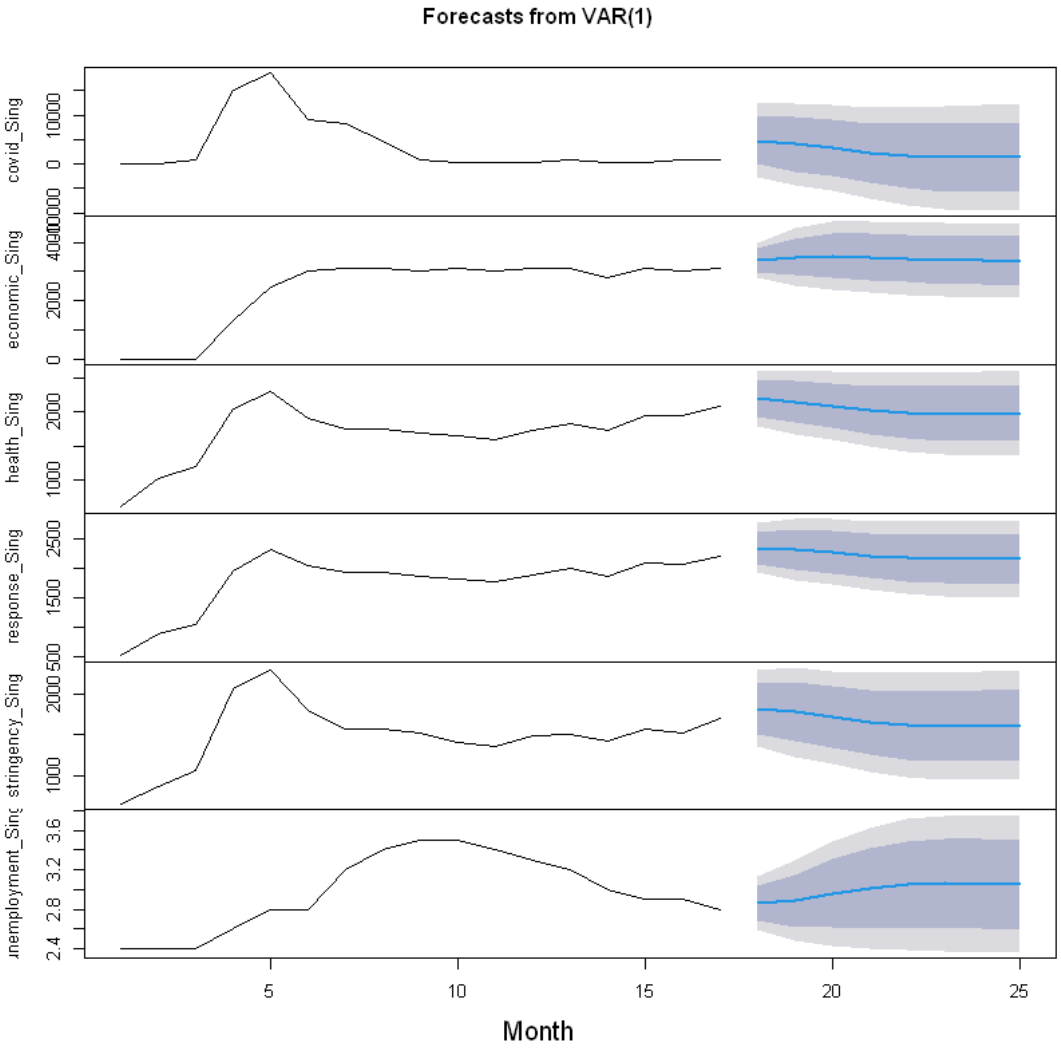


[24]:
```
forest.total=cbind(forest.total.Sing,forest.total.UK[,-1],forest.total.US[,-1])
write.csv(forest.total,file = "forest_total.csv",row.names = F)
```

[25]:
```
train_size <- nrow(totalbymonth)
test_size=floor(nrow(totalbymonth)/2)
train_ind <- 1:train_size
forecast_time=data.frame(Month=totalbymonth[nrow(totalbymonth),1]+1)
for(i in 2:test_size){
  forecast_time[i,1]=totalbymonth[nrow(totalbymonth),1]+i
}

totalbymonth.Sing.train <- totalbymonth.Sing[train_ind, ]
```

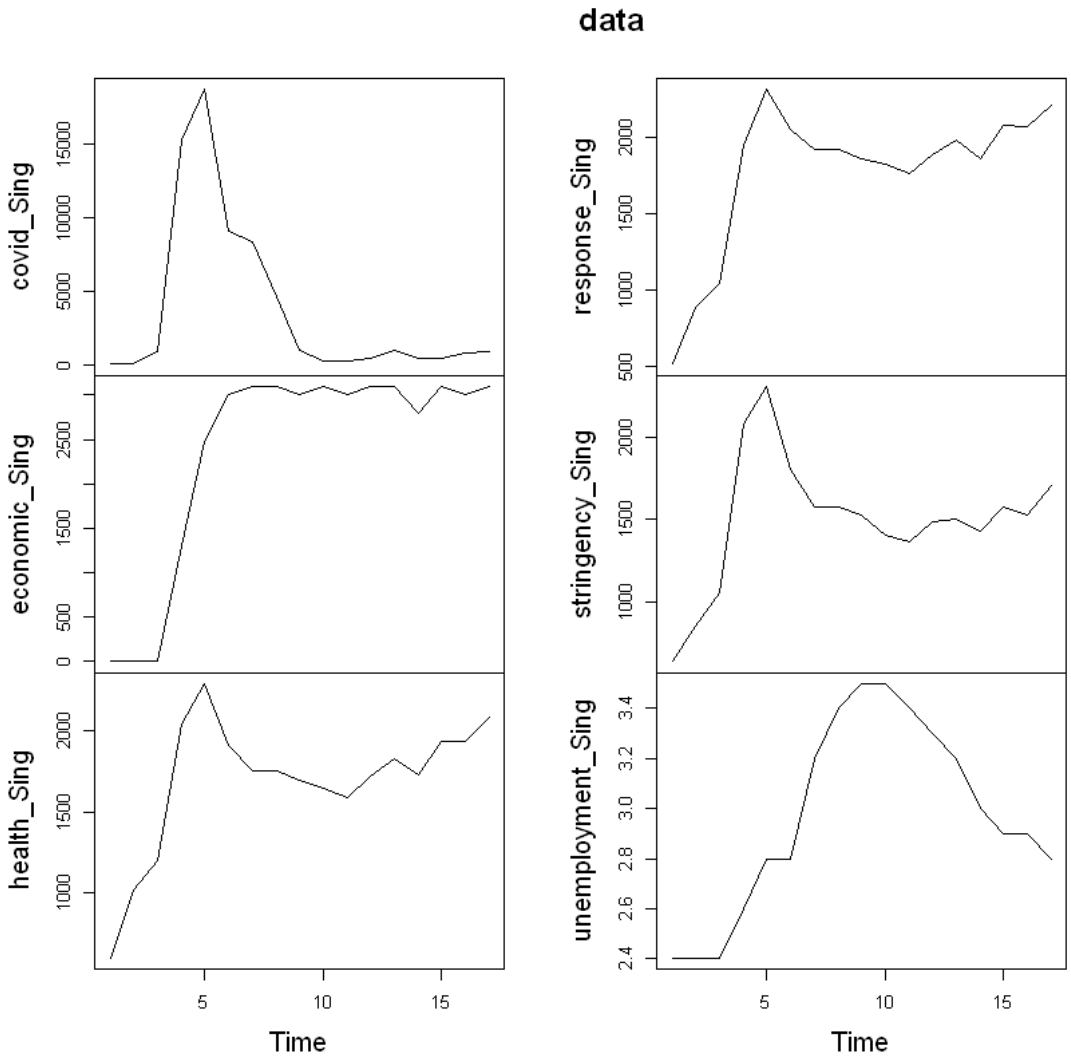
```
VARselect(totalbymonth.Sing.train[,-1], lag.max=8, type="const")[["selection"]]
totalbymonth.Sing.var=VAR(as.ts(totalbymonth.Sing.train[,-1]),p=1,type="const")
forecast.totalbymonth.Sing.var=forecast(totalbymonth.Sing.var,test_size)
plot(forecast.totalbymonth.Sing.var,xlab="Month")
MTSplot(as.ts(totalbymonth.Sing[,-1]))



totalbymonth.UK.train <- totalbymonth.UK[train_ind, ]

VARselect(totalbymonth.UK.train[,-1], lag.max=8, type="const")[["selection"]]
totalbymonth.UK.var=VAR(as.ts(totalbymonth.UK.train[,-1]),p=1,type="const")
forecast.totalbymonth.UK.var=forecast(totalbymonth.UK.var,test_size)
plot(forecast.totalbymonth.UK.var,xlab="Month")
MTSplot(as.ts(totalbymonth.UK[,-1]))



totalbymonth.US.train <- totalbymonth.US[train_ind, ]
VARselect(totalbymonth.US.train[,-1], lag.max=8, type="const")[["selection"]]
totalbymonth.US.var=VAR(as.ts(totalbymonth.US.train[,-1]),p=1,type="const")
forecast.totalbymonth.US.var=forecast(totalbymonth.US.var,test_size)
plot(forecast.totalbymonth.US.var,xlab="Month")
MTSplot(as.ts(totalbymonth.US[,-1]))
```

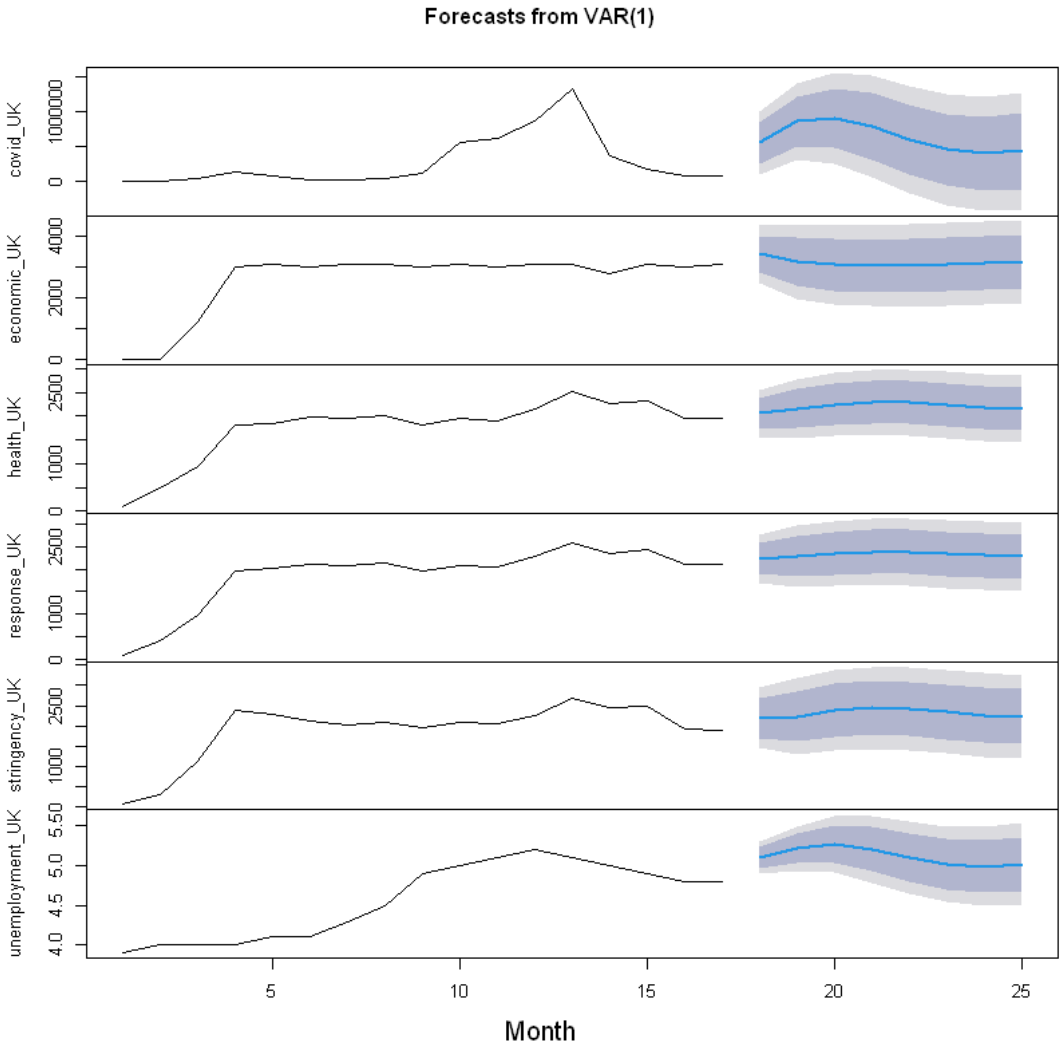
AIC(n) 2 **HQ(n)** 2 **SC(n)** 2 **FPE(n)** 2



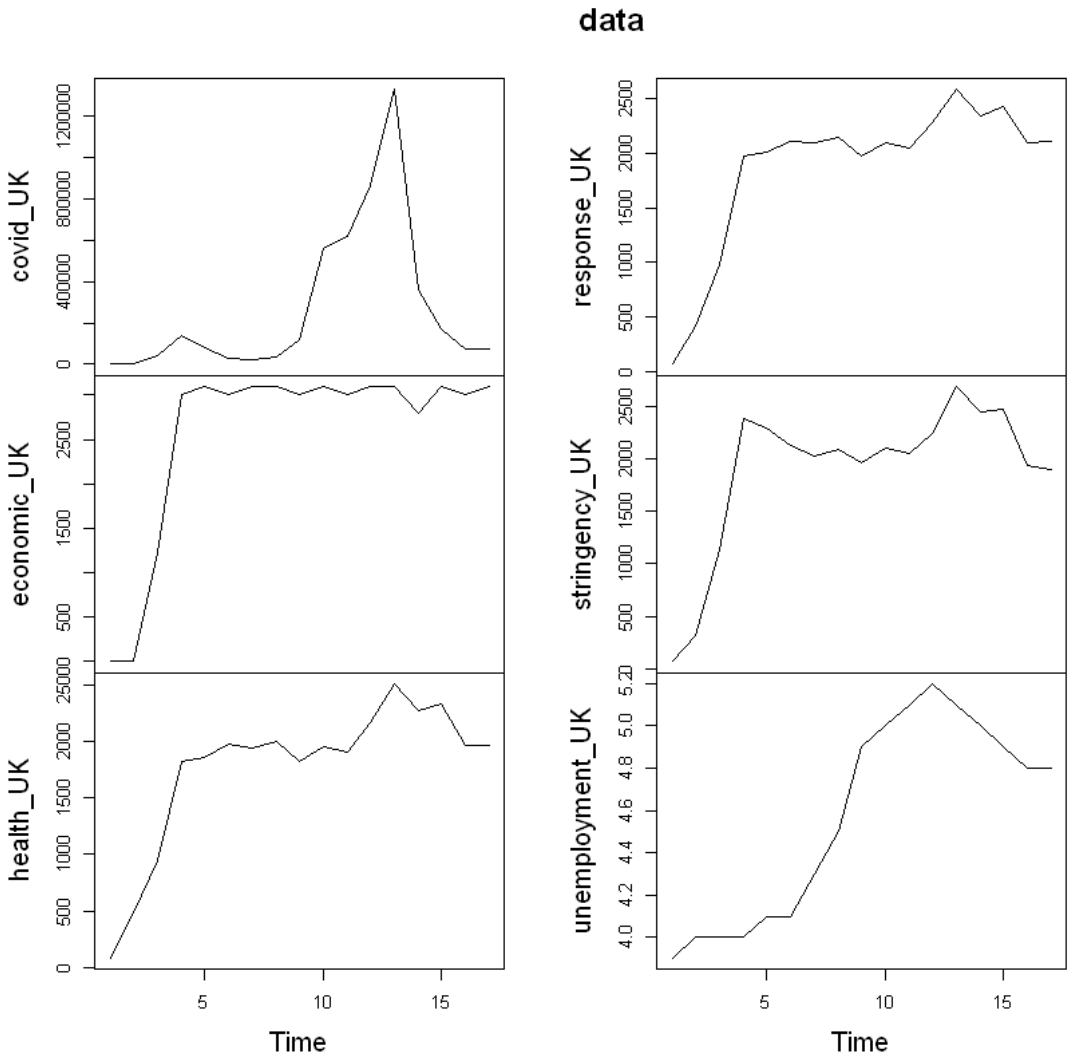

```
Warning message in log(sigma.det):
"  NaNs"
Warning message in log(sigma.det):
"  NaNs"
Warning message in log(sigma.det):
"  NaNs"
```

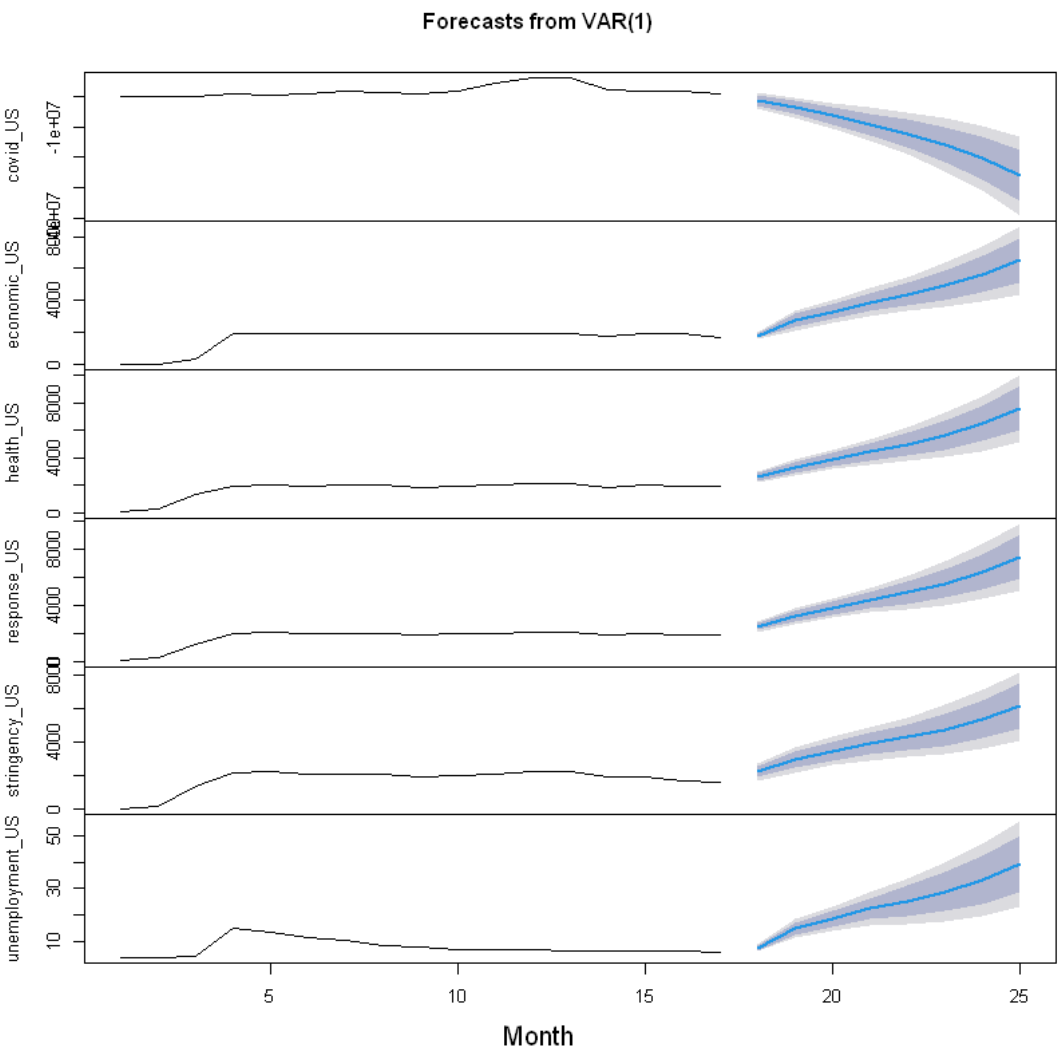
AIC(n)	2	**HQ(n)**	2 **SC(n)**	2 **FPE(n)** 1

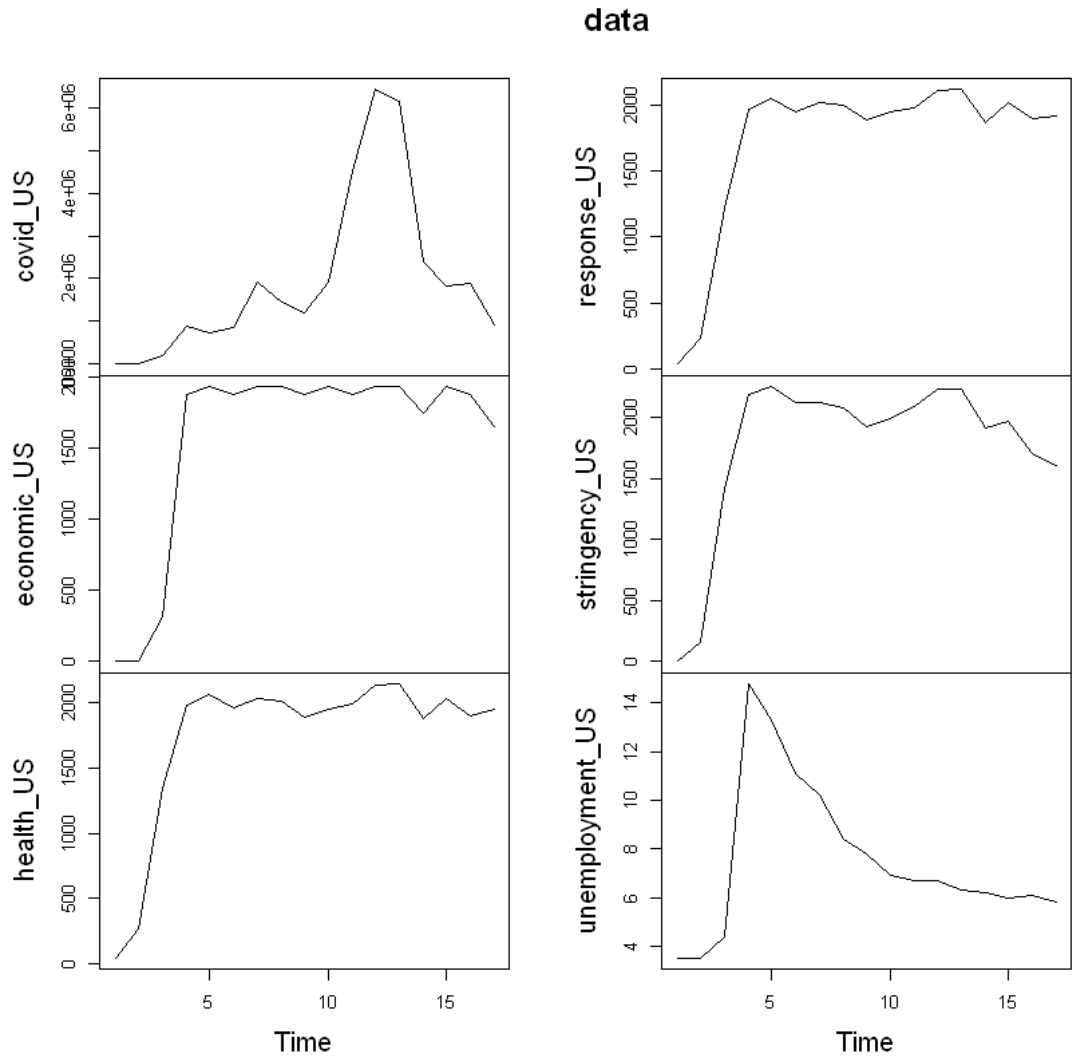

data
covid_Sing
economic_Sing
health_Sing
response_Sing
stringency_Sing
unemployment_Sing
Time
Time



AIC(n) 2 **HQ(n)** 2 **SC(n)** 2 **FPE(n)** 2


data
covid_UK
economic_UK
health_UK
response_UK
stringency_UK
unemployment_UK
Time
Time


Forecasts from VAR(1)
covid_US
economic_US
health_US
response_US
stringency_US
unemployment_US
-1e+07
4000
8000
0
50
30
10
5
10
15
20
25
Month



[26]:
```
forecast.totalbymonth.US.var$forecast[6]$unemployment_US
forecast.totalbymonth.Sing.var$forecast[6]$unemployment_Sing
forecast.totalbymonth.UK.var$forecast[6]$unemployment_UK
```

	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
18	7.31768	6.480471	8.154889	6.037279	8.598081
19	14.86883	12.582801	17.154854	11.372652	18.365003
20	18.48227	15.561928	21.402610	14.015993	22.948545
21	22.33748	18.264843	26.410123	16.108917	28.566049
22	25.34794	19.676952	31.018930	16.674911	34.020970
23	28.88373	21.482005	36.285446	17.563771	40.203680
24	33.40140	24.311678	42.491122	19.499870	47.302930
25	39.50307	28.717310	50.288826	23.007674	55.998462

```
   Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
18       2.864618 2.685116 3.044119 2.590094 3.139142
19       2.885192 2.619862 3.150521 2.479405 3.290978
20       2.958403 2.613084 3.303721 2.430284 3.486521
21       3.011324 2.610408 3.412240 2.398175 3.624472
22       3.048003 2.613023 3.482983 2.382759 3.713248
23       3.059497 2.610676 3.508319 2.373084 3.745910
24       3.057031 2.604817 3.509244 2.365430 3.748632
25       3.047803 2.594991 3.500615 2.355287 3.740319
```

```
   Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
18       5.100881 4.969302 5.232461 4.899647 5.302116
19       5.218235 5.036208 5.400261 4.939849 5.496620
20       5.272435 5.037203 5.507666 4.912680 5.632190
21       5.207019 4.929609 5.484429 4.782757 5.631281
22       5.101732 4.803077 5.400387 4.644978 5.558486
23       5.018940 4.706230 5.331650 4.540691 5.497189
24       4.991461 4.664294 5.318629 4.491102 5.491821
25       5.016459 4.677483 5.355435 4.498040 5.534878
```

[27]:
```
forecast.US.unemployment=data.frame(forecast.totalbymonth.US.
 ↪var$forecast[6]$unemployment_US)

forecast.Sing.unemployment=data.frame(forecast.totalbymonth.Sing.
 ↪var$forecast[6]$unemployment_Sing)

forecast.UK.unemployment=data.frame(forecast.totalbymonth.UK.
 ↪var$forecast[6]$unemployment_UK)
colnames(forecast.US.
 ↪unemployment)==c("unemploymeny_US","unemploymeny_US_low80","unemploymeny_US_high80","unempl
colnames(forecast.Sing.
 ↪unemployment)=c("unemploymeny_Sing","unemploymeny_Sing_low80","unemploymeny_Sing_high80","u
colnames(forecast.UK.
 ↪unemployment)=c("unemploymeny_UK","unemploymeny_UK_low80","unemploymeny_UK_high80","unemplo
```

1. FALSE 2. FALSE 3. FALSE 4. FALSE 5. FALSE

[28]:
```
Month=data.
 ↪frame(Month=c("2021-06","2021-07","2021-08","2021-09","2021-10","2021-11","2021-12","2022-0

forecast.unemployment.all=cbind(Month,forecast.Sing.unemployment,forecast.UK.
 ↪unemployment,forecast.US.unemployment)
head(forecast.unemployment.all)
```

A data.frame: 6 × 16

	Month <chr>	unemploymeny_Sing <dbl>	unemploymeny_Sing_low80 <dbl>	unemploymeny_Sing_ <dbl>
18	2021-06	2.864618	2.685116	3.044119
19	2021-07	2.885192	2.619862	3.150521
20	2021-08	2.958403	2.613084	3.303721
21	2021-09	3.011324	2.610408	3.412240
22	2021-10	3.048003	2.613023	3.482983
23	2021-11	3.059497	2.610676	3.508319

[29]:
```
forecast.unemployment=forecast.unemployment.all[,c(1,2,7,12)]
colnames(forecast.unemployment)[4]="unemploymeny_US"
write.csv(forecast.unemployment,file = "forecast_unemployment.csv",row.names =␣
↪F)
```

[ ]:
```

```