

# VAR analysis - Granger-Causality-Initial Comparisons

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Required tools to be loaded

```
library(dlookr)
```

```
##  
## Attaching package: 'dlookr'  
  
## The following object is masked from 'package:base':  
##  
##      transform
```

```
library(lubridate)
```

```
##  
## Attaching package: 'lubridate'  
  
## The following objects are masked from 'package:base':  
##  
##      date, intersect, setdiff, union
```

```
library(dplyr)
```

```
##  
## Attaching package: 'dplyr'  
  
## The following objects are masked from 'package:stats':  
##  
##      filter, lag  
  
## The following objects are masked from 'package:base':  
##  
##      intersect, setdiff, setequal, union
```

```
library(ggpubr)
```

```
## Loading required package: ggplot2
```

```
library(forecast)
```

```
## Registered S3 method overwritten by 'quantmod':  
##   method           from  
##   as.zoo.data.frame zoo  
  
##  
## Attaching package: 'forecast'  
  
## The following object is masked from 'package:ggpubr':  
##  
##   gghistogram
```

```
library(funModeling)
```

```
## Loading required package: Hmisc  
  
## Loading required package: lattice  
  
## Loading required package: survival  
  
## Loading required package: Formula  
  
##  
## Attaching package: 'Hmisc'  
  
## The following objects are masked from 'package:dplyr':  
##  
##   src, summarize  
  
## The following object is masked from 'package:dlookr':  
##  
##   describe  
  
## The following objects are masked from 'package:base':  
##  
##   format.pval, units  
  
## funModeling v.1.9.4 :)  
## Examples and tutorials at livebook.datascienceheroes.com  
## / Now in Spanish: librovivodecienciadedatos.ai
```

```
require(ggfortify)
```

```
## Loading required package: ggfortify
```

```
## Registered S3 methods overwritten by 'ggfortify':
##   method                from
##   autoplot.Arima         forecast
##   autoplot.acf           forecast
##   autoplot.ar            forecast
##   autoplot.bats          forecast
##   autoplot.decomposed.ts forecast
##   autoplot.ets           forecast
##   autoplot.forecast      forecast
##   autoplot.stl           forecast
##   autoplot.ts            forecast
##   fitted.ar              forecast
##   fortify.ts             forecast
##   residuals.ar           forecast
```

```
require(tseries)
```

```
## Loading required package: tseries
```

```
require(MTS)
```

```
## Loading required package: MTS
```

```
require(vars)
```

```
## Loading required package: vars
```

```
## Loading required package: MASS
```

```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##   select
```

```
## Loading required package: strucchange
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##   as.Date, as.Date.numeric
```

```
## Loading required package: sandwich
```

```

## Loading required package: urca

## Loading required package: lmtest

##
## Attaching package: 'vars'

## The following object is masked from 'package:MTS':
##
##      VAR

## The following object is masked from 'package:dlookr':
##
##      normality

require(fUnitRoots)

## Loading required package: fUnitRoots

## Loading required package: timeDate

##
## Attaching package: 'timeDate'

## The following objects are masked from 'package:dlookr':
##
##      kurtosis, skewness

## Loading required package: timeSeries

##
## Attaching package: 'timeSeries'

## The following object is masked from 'package:zoo':
##
##      time<-

## Loading required package: fBasics

##
## Attaching package: 'fUnitRoots'

## The following objects are masked from 'package:urca':
##
##      punitroot, qunitroot, unitrootTable

require(lattice)

```

Import both Clean datasets

```
Covid_monthly <- read.csv("C:/Users/Katie Schilling/Downloads/covid_monthly_clean.csv")
Vital_Events <- read.csv("C:/Users/Katie Schilling/Downloads/vital_events_clean.csv")
```

Combine the vital events data with the Covid Monthly data

```
Final_dataset <- merge(x=Vital_Events, y=Covid_monthly, all = TRUE)
```

Check the data and ensure data merged properly

```
summary(Final_dataset)
```

```
##      Date      Births      Marriages      Deaths
## Length:336      Min.   :10020      Min.   :  597      Min.   : 5926
## Class :character 1st Qu.:11260      1st Qu.: 2596      1st Qu.: 6706
## Mode  :character Median :11818      Median : 3559      Median : 7326
##              Mean  :11763      Mean  : 5085      Mean  : 7500
##              3rd Qu.:12288      3rd Qu.: 7627      3rd Qu.: 8094
##              Max.   :13398      Max.   :11532      Max.   :11390
##              NA's   :6          NA's   :6          NA's   :6
## Stillbirths      Covid
## Min.   : 0.00      Min.   :  11
## 1st Qu.: 73.00      1st Qu.: 22889
## Median : 90.50      Median : 75935
## Mean   : 90.74      Mean   : 95144
## 3rd Qu.:114.00      3rd Qu.:134128
## Max.   :156.00      Max.   :395815
## NA's   :6          NA's   :313
```

Change the N/A in the Covid Positive Cases to 0 so that the data is not omitted from the predictions

```
Final_dataset$Covid[is.na(Final_dataset$Covid)] = 0
```

See if there are anymore NA's in the dataset

```
Final_dataset %>% filter_all(any_vars(is.na(.)))
```

```
##      Date Births Marriages Deaths Stillbirths Covid
## 1 2021-07-1    NA        NA      NA          NA 15968
## 2 2021-08-1    NA        NA      NA          NA 67913
## 3 2021-09-1    NA        NA      NA          NA 125560
## 4 2021-10-1    NA        NA      NA          NA 91834
## 5 2021-11-1    NA        NA      NA          NA 75935
## 6 2021-12-1    NA        NA      NA          NA 395815
```

Remove rows with NA as they will skew the results

```
Final_dataset <- na.omit(Final_dataset)
```

Check for NA's to confirm all have been removed

```
Final_dataset %>% filter_all(any_vars(is.na(.)))
```

```
## [1] Date      Births      Marriages    Deaths      Stillbirths Covid
## <0 rows> (or 0-length row.names)
```

```
summary(Final_dataset)
```

```
##      Date      Births      Marriages      Deaths
## Length:330      Min.    :10020      Min.    : 597      Min.    : 5926
## Class :character 1st Qu.:11260      1st Qu.: 2596      1st Qu.: 6706
## Mode  :character Median :11818      Median : 3559      Median : 7326
##                      Mean  :11763      Mean   : 5085      Mean   : 7500
##                      3rd Qu.:12288      3rd Qu.: 7627      3rd Qu.: 8094
##                      Max.   :13398      Max.   :11532      Max.   :11390
## Stillbirths      Covid
## Min.    : 0.00      Min.    : 0
## 1st Qu.: 73.00      1st Qu.: 0
## Median : 90.50      Median : 0
## Mean    : 90.74      Mean    : 4289
## 3rd Qu.:114.00      3rd Qu.: 0
## Max.    :156.00      Max.    :237308
```

```
Final_dataset$Date <- as.Date(Final_dataset$Date,"%Y-%m-%d")
```

```
glimpse(Final_dataset)
```

```
## Rows: 330
## Columns: 6
## $ Date      <date> 1994-01-01, 1994-02-01, 1994-03-01, 1994-04-01, 1994-05-0~
## $ Births    <int> 11631, 11254, 13003, 12576, 13240, 13072, 13045, 12982, 12~
## $ Marriages <int> 2078, 2650, 2557, 3967, 6493, 7754, 9264, 9194, 8540, 7400~
## $ Deaths   <int> 8094, 6428, 6503, 6224, 6483, 6187, 6196, 5926, 6062, 6515~
## $ Stillbirths <int> 75, 62, 73, 74, 67, 66, 70, 79, 60, 59, 56, 43, 78, 84, 75~
## $ Covid     <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0~
```

Normalize the Data

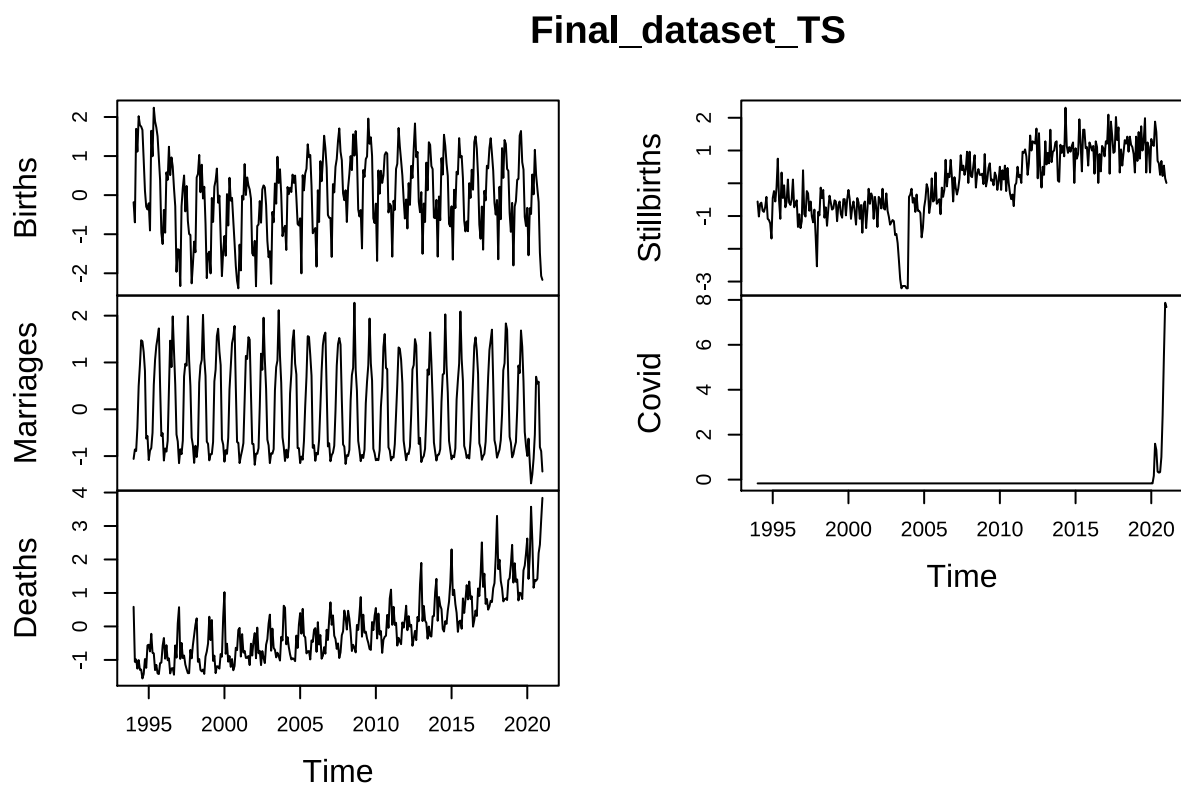
```
Final_dataset_standardized <- Final_dataset %>% mutate_each(list(~scale(.) %>% as.vector),
  vars = c("Births", "Marriages", "Deaths", "Stillbirths", "Covid"))
```

```
## Warning: 'mutate_each()' was deprecated in dplyr 0.7.0.
## Please use 'across()' instead.
## This warning is displayed once every 8 hours.
## Call 'lifecycle::last_lifecycle_warnings()' to see where this warning was generated.
```

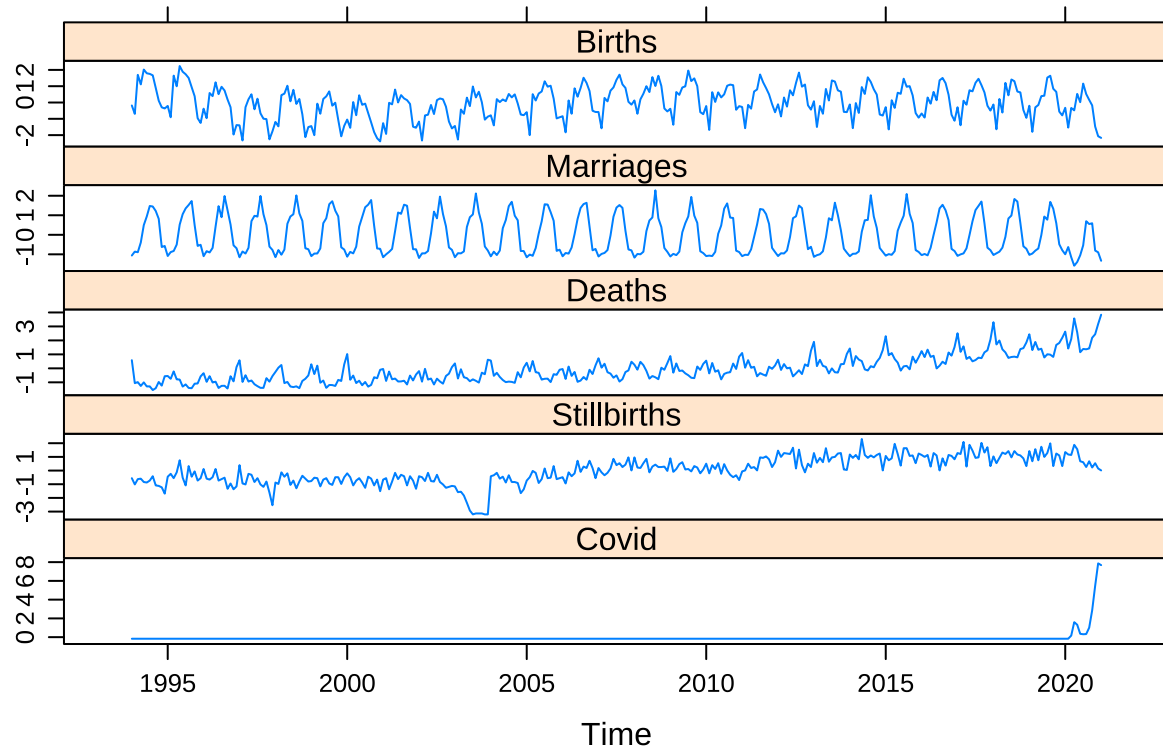
Convert data frame to a time series

```
Final_dataset_TS <- ts(Final_dataset_standardized[2:6], frequency = 12, start = 1994, end = 2021)
```

```
plot(Final_dataset_TS)
```



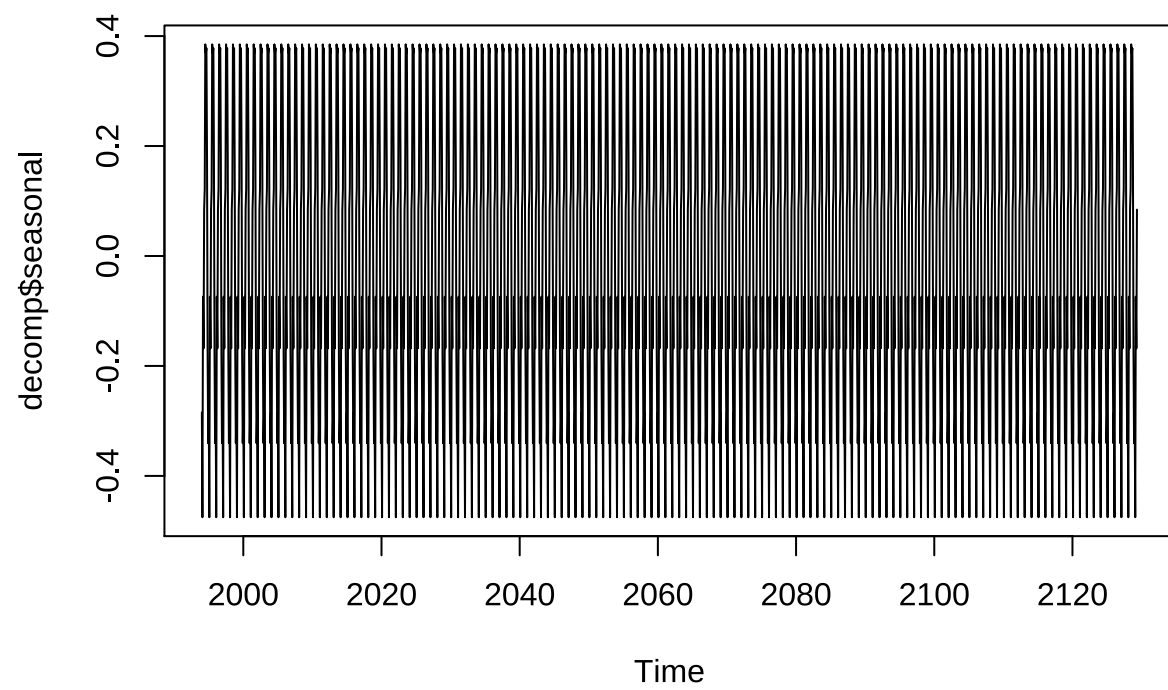
```
xyplot.ts(Final_dataset_TS)
```



decompose data and display results

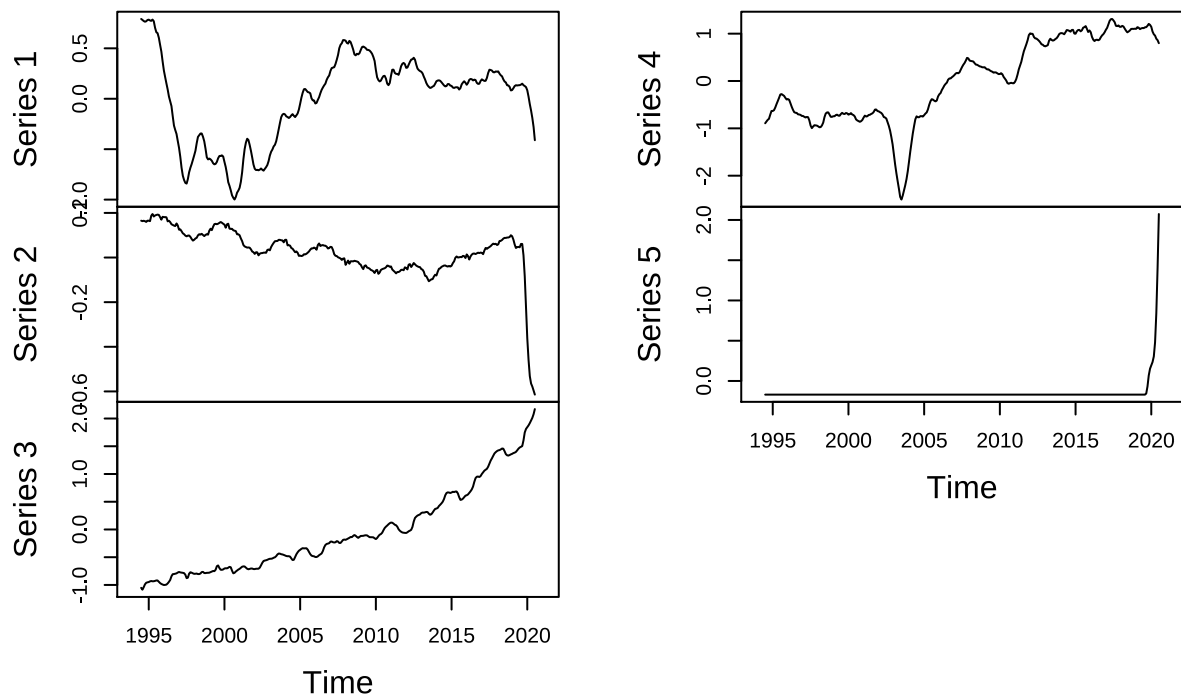
```
decomp <- decompose(Final_dataset_TS)
plot(decomp$seasonal)
```



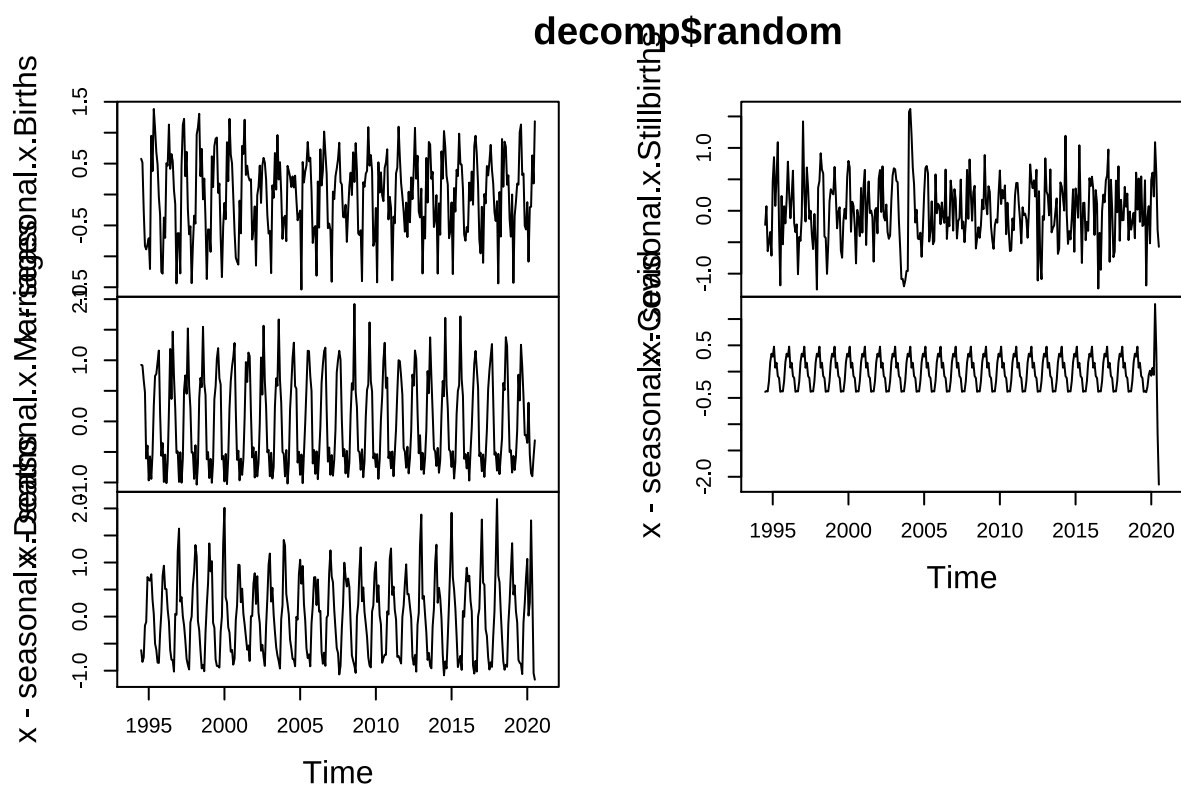


```
plot(decomp$trend)
```

## decomp\$trend

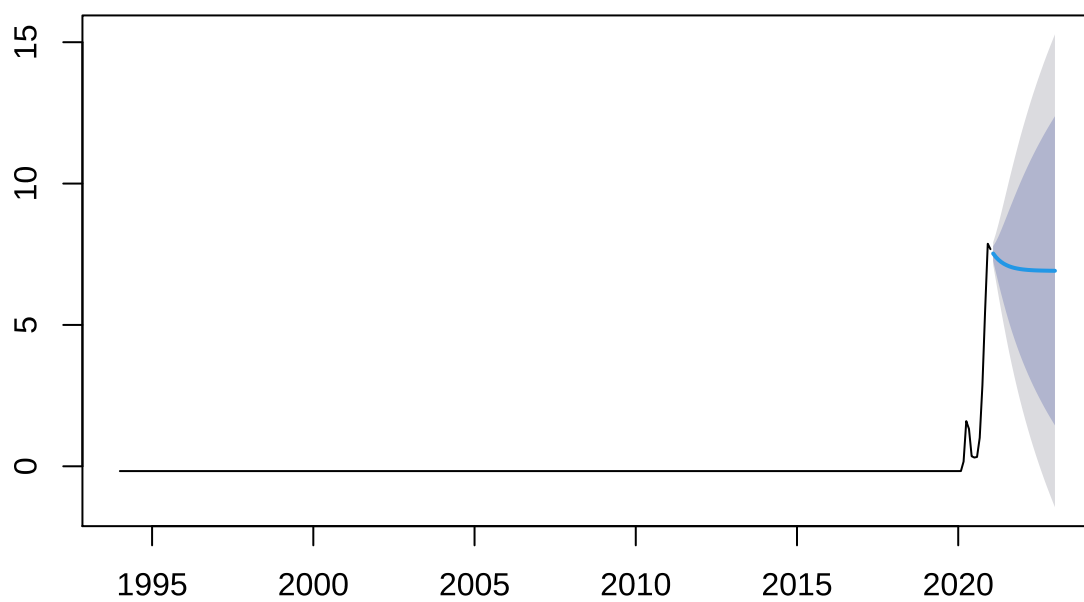


```
plot(decomp$random)
```



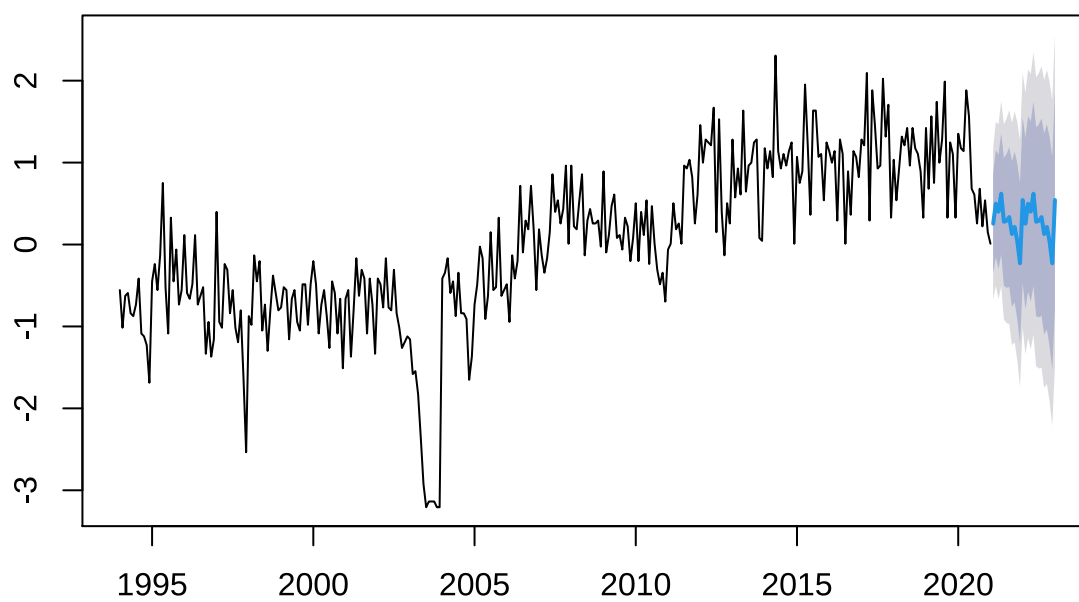
```
Covid <- forecast(Final_dataset_TS[,5])
plot(Covid, main = "Covid Forecast")
```

## Covid Forecast



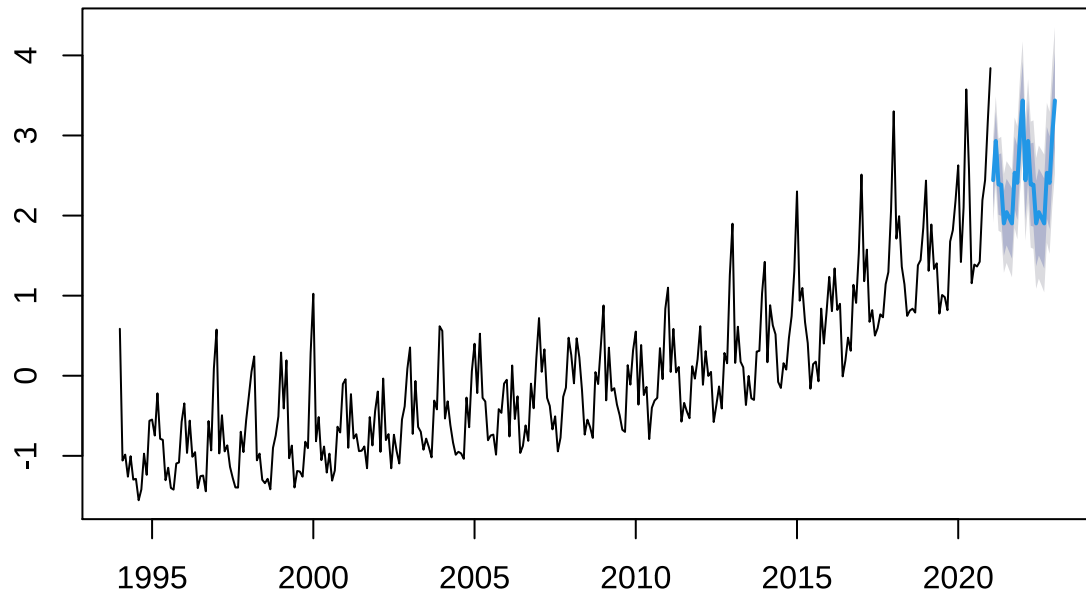
```
Stillbirths <- forecast(Final_dataset_TS[,4])  
plot(Stillbirths, main = "Stillbirths Forecast")
```

## Stillbirths Forecast



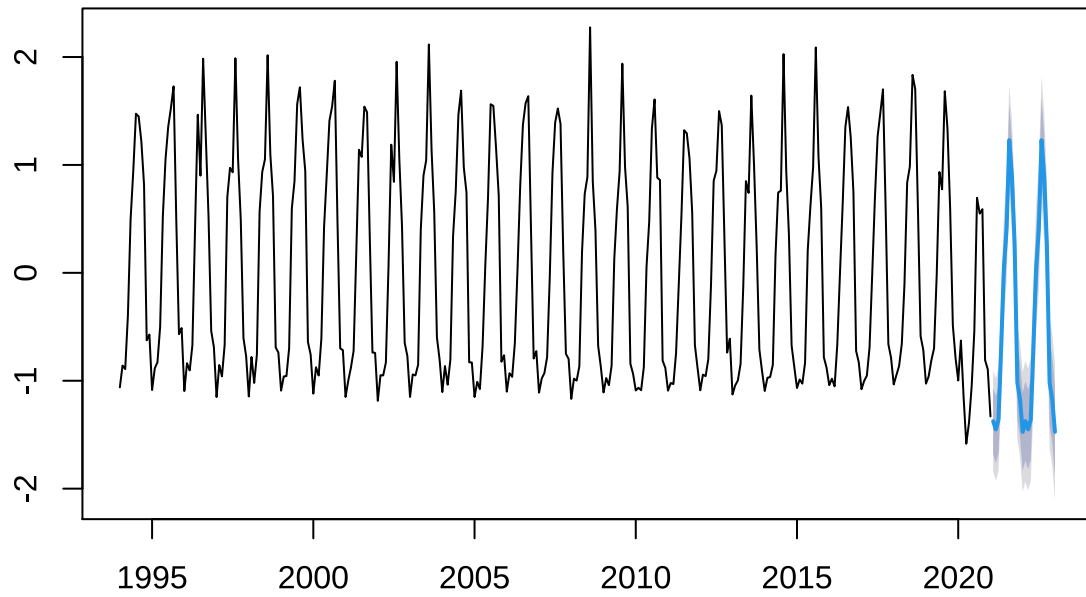
```
Deaths <- forecast(Final_dataset_TS[,3])  
plot(Deaths, main = "Deaths Forecast")
```

## Deaths Forecast



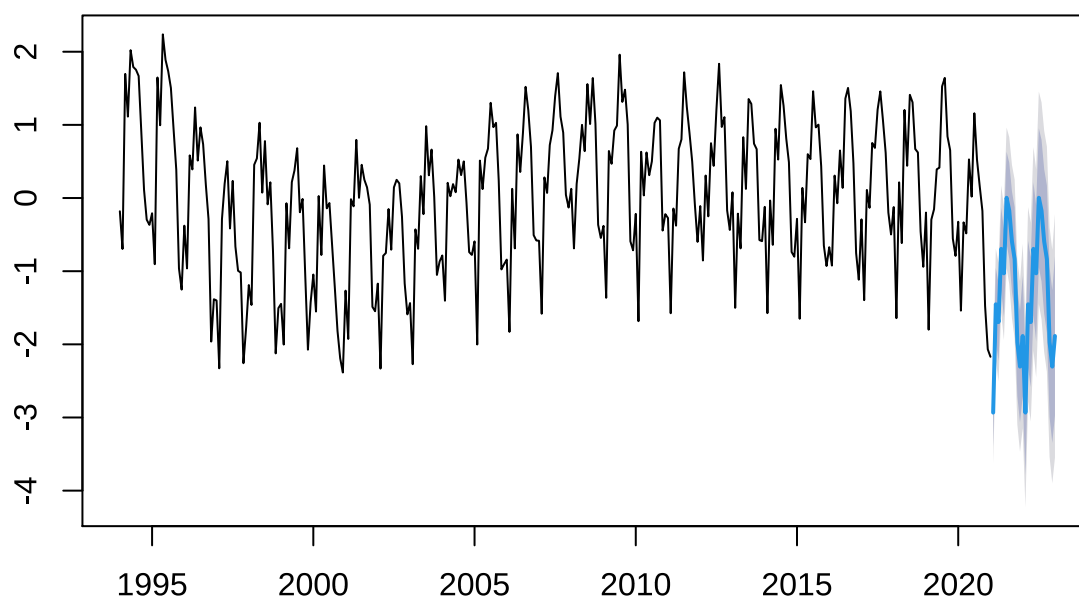
```
Marriages <- forecast(Final_dataset_TS[,2])  
plot(Marriages, main = "Marriages Forecast")
```

## Marriages Forecast



```
Births <- forecast(Final_dataset_TS[,1])  
plot(Births, main = "Births Forecast")
```

## Births Forecast



---

——VAR time series forecasting for multivariate

```
apply(Final_dataset_TS, 2, adf.test)
```

```
## Warning in FUN(newX[, i], ...): p-value smaller than printed p-value
```

```
## Warning in FUN(newX[, i], ...): p-value smaller than printed p-value
```

```
## Warning in FUN(newX[, i], ...): p-value smaller than printed p-value
```

```
## Warning in FUN(newX[, i], ...): p-value greater than printed p-value
```

```
## $Births
```

```
##
```

```
## Augmented Dickey-Fuller Test
```

```
##
```

```
## data: newX[, i]
```

```
## Dickey-Fuller = -6.1948, Lag order = 6, p-value = 0.01
```

```
## alternative hypothesis: stationary
```

```
##
```

```
##
```

```
## $Marriages
```

```
##
```

```
## Augmented Dickey-Fuller Test
```



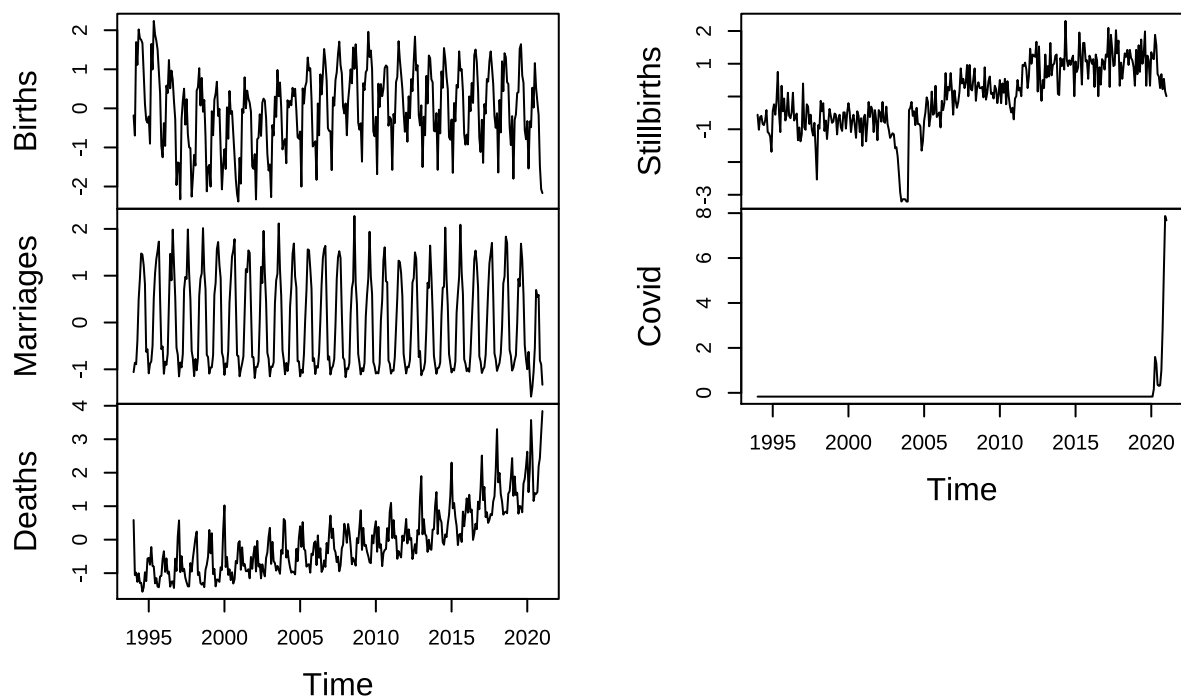
```

##
## data: newX[, i]
## Dickey-Fuller = -16.005, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
##
##
## $Deaths
##
## Augmented Dickey-Fuller Test
##
## data: newX[, i]
## Dickey-Fuller = -5.7218, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
##
##
## $Stillbirths
##
## Augmented Dickey-Fuller Test
##
## data: newX[, i]
## Dickey-Fuller = -3.9612, Lag order = 6, p-value = 0.01129
## alternative hypothesis: stationary
##
##
## $Covid
##
## Augmented Dickey-Fuller Test
##
## data: newX[, i]
## Dickey-Fuller = 25.849, Lag order = 6, p-value = 0.99
## alternative hypothesis: stationary

plot.ts(Final_dataset_TS)

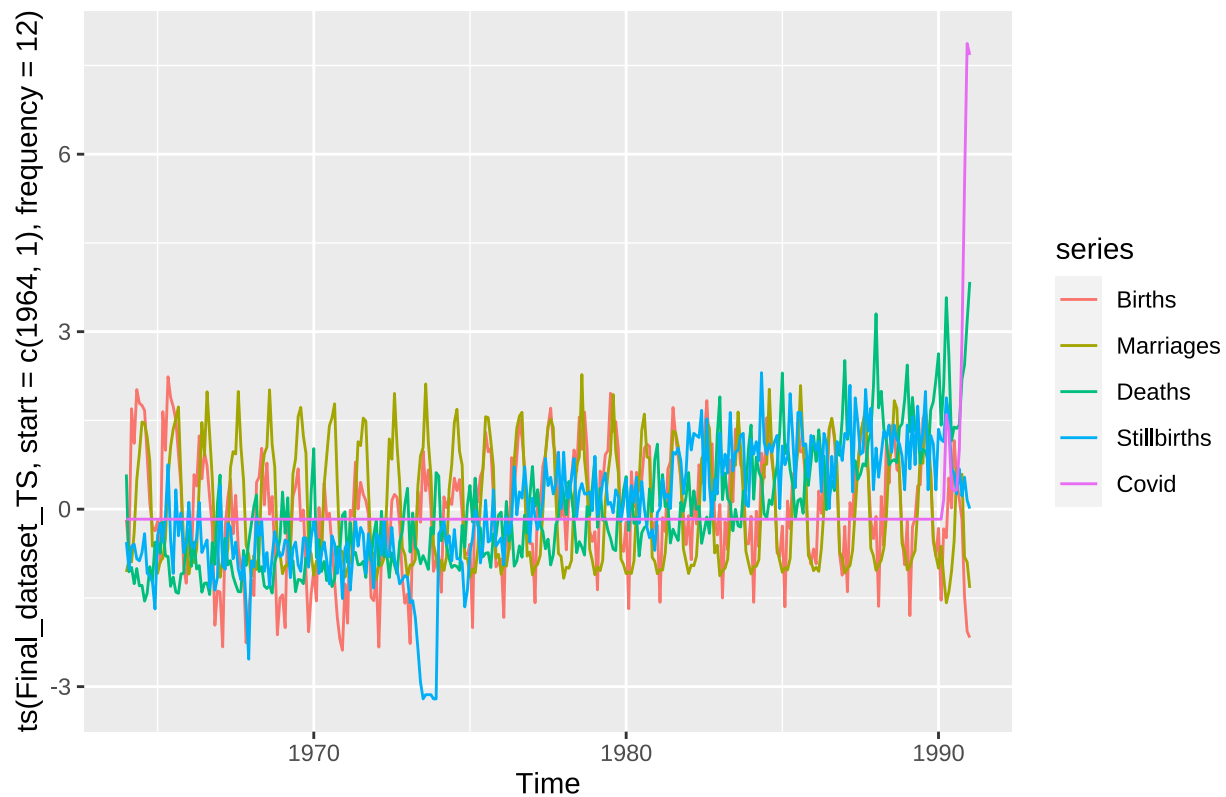
```

## Final\_dataset\_TS



```
autoplot(ts(Final_dataset_TS,
            start = c(1964,1),
            frequency = 12)) +
ggtitle("Time Series Plot of the stationary `Final Dataset' Time-Series")
```

Time Series Plot of the stationary `Final Dataset' Time-Series



```
VARselect(Final_dataset_TS,
          type = "none",
          lag.max = 6) #highest lag order
```

```
## $selection
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      6      6      5      6
##
## $criteria
##           1           2           3           4           5
## AIC(n) -7.9539879985 -9.832017e+00 -1.052832e+01 -1.074349e+01 -1.123767e+01
## HQ(n)  -7.8361450045 -9.596331e+00 -1.017479e+01 -1.027212e+01 -1.064846e+01
## SC(n)  -7.6589103259 -9.241862e+00 -9.643086e+00 -9.563176e+00 -9.762285e+00
## FPE(n)  0.0003512631  5.370984e-05  2.677687e-05  2.160332e-05  1.318985e-05
##
##           6
## AIC(n) -1.149644e+01
## HQ(n)  -1.078938e+01
## SC(n)  -9.725971e+00
## FPE(n)  1.019462e-05
```

```
# Creating a VAR model with vars
final_ts_var <- vars::VAR(Final_dataset_TS,
                          lag.max = 6, #highest lag order for lag length selection according to the chosen ic
                          ic = "AIC", #information criterion
                          type = "none") #type of deterministic regressors to include
summary(final_ts_var)
```

```

##
## VAR Estimation Results:
## =====
## Endogenous variables: Births, Marriages, Deaths, Stillbirths, Covid
## Deterministic variables: none
## Sample size: 319
## Log Likelihood: -279.525
## Roots of the characteristic polynomial:
## 1.171 1.171 1.078 1.007 0.9922 0.9922 0.9285 0.9113 0.9113 0.8973 0.8333 0.8333 0.811 0.811 0.7965 0
## Call:
## vars::VAR(y = Final_dataset_TS, type = "none", lag.max = 6, ic = "AIC")
##
##
## Estimation results for equation Births:
## =====
## Births = Births.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Covid.l1 + Births.l2 + Marriages.l2
##
##           Estimate Std. Error t value Pr(>|t|)
## Births.l1      0.3613204  0.0728518   4.960 1.21e-06 ***
## Marriages.l1    0.1198967  0.0858027   1.397 0.163379
## Deaths.l1      -0.2864318  0.1074822  -2.665 0.008133 **
## Stillbirths.l1 -0.2247097  0.0598794  -3.753 0.000211 ***
## Covid.l1        0.0564754  0.2296196   0.246 0.805894
## Births.l2       0.2768972  0.0835936   3.312 0.001043 **
## Marriages.l2    -0.2652306  0.0962650  -2.755 0.006238 **
## Deaths.l2       0.2469497  0.1213473   2.035 0.042757 *
## Stillbirths.l2  0.2951634  0.0649615   4.544 8.13e-06 ***
## Covid.l2        -0.5803091  0.5113091  -1.135 0.257338
## Births.l3       0.0599751  0.0869189   0.690 0.490740
## Marriages.l3    -0.0513760  0.0952354  -0.539 0.589983
## Deaths.l3       0.0288513  0.1262045   0.229 0.819335
## Stillbirths.l3  0.0359538  0.0700894   0.513 0.608364
## Covid.l3        0.7587551  0.6027819   1.259 0.209134
## Births.l4       0.0002279  0.0861075   0.003 0.997890
## Marriages.l4    -0.2761566  0.0947453  -2.915 0.003838 **
## Deaths.l4       0.0124139  0.1285781   0.097 0.923152
## Stillbirths.l4 -0.0631502  0.0701334  -0.900 0.368642
## Covid.l4        -0.6743317  0.5815164  -1.160 0.247165
## Births.l5       -0.0686324  0.0793759  -0.865 0.387948
## Marriages.l5     0.1148929  0.0908586   1.265 0.207061
## Deaths.l5       0.1432148  0.1293279   1.107 0.269052
## Stillbirths.l5 -0.0016869  0.0697981  -0.024 0.980735
## Covid.l5        0.1126069  0.5525104   0.204 0.838646
## Births.l6       0.0893316  0.0582349   1.534 0.126127
## Marriages.l6    -0.2331871  0.0913557  -2.553 0.011209 *
## Deaths.l6      -0.1838122  0.1045713  -1.758 0.079846 .
## Stillbirths.l6 -0.0013157  0.0646382  -0.020 0.983774
## Covid.l6        -0.0031953  0.3664678  -0.009 0.993049
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##

```

```
## Residual standard error: 0.4866 on 289 degrees of freedom
## Multiple R-Squared: 0.7805, Adjusted R-squared: 0.7577
## F-statistic: 34.25 on 30 and 289 DF, p-value: < 2.2e-16
```

```
##
##
```

```
## Estimation results for equation Marriages:
```

```
## =====
```

```
## Marriages = Births.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Covid.l1 + Births.l2 + Marriages
```

```
##
```

	Estimate	Std. Error	t value	Pr(> t )	
## Births.l1	0.187976	0.043093	4.362	1.79e-05	***
## Marriages.l1	0.546878	0.050754	10.775	< 2e-16	***
## Deaths.l1	-0.359760	0.063578	-5.659	3.67e-08	***
## Stillbirths.l1	0.019666	0.035420	0.555	0.579172	
## Covid.l1	0.105431	0.135825	0.776	0.438250	
## Births.l2	-0.297225	0.049447	-6.011	5.55e-09	***
## Marriages.l2	0.006705	0.056943	0.118	0.906352	
## Deaths.l2	0.374197	0.071779	5.213	3.54e-07	***
## Stillbirths.l2	-0.163245	0.038426	-4.248	2.91e-05	***
## Covid.l2	-0.452621	0.302450	-1.497	0.135611	
## Births.l3	0.070403	0.051414	1.369	0.171959	
## Marriages.l3	-0.185814	0.056334	-3.298	0.001094	**
## Deaths.l3	-0.277851	0.074653	-3.722	0.000238	***
## Stillbirths.l3	0.094663	0.041459	2.283	0.023140	*
## Covid.l3	0.625188	0.356558	1.753	0.080594	.
## Births.l4	0.200370	0.050934	3.934	0.000105	***
## Marriages.l4	-0.186382	0.056044	-3.326	0.000996	***
## Deaths.l4	-0.050059	0.076057	-0.658	0.510950	
## Stillbirths.l4	0.139629	0.041485	3.366	0.000867	***
## Covid.l4	-0.242613	0.343979	-0.705	0.481183	
## Births.l5	0.141108	0.046952	3.005	0.002886	**
## Marriages.l5	-0.025104	0.053745	-0.467	0.640788	
## Deaths.l5	0.101177	0.076500	1.323	0.187022	
## Stillbirths.l5	-0.033501	0.041287	-0.811	0.417799	
## Covid.l5	-0.025735	0.326821	-0.079	0.937291	
## Births.l6	-0.320182	0.034447	-9.295	< 2e-16	***
## Marriages.l6	-0.102175	0.054039	-1.891	0.059655	.
## Deaths.l6	0.146564	0.061856	2.369	0.018472	*
## Stillbirths.l6	-0.063354	0.038235	-1.657	0.098608	.
## Covid.l6	-0.305537	0.216773	-1.409	0.159770	

```
## ---
```

```
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
##
```

```
## Residual standard error: 0.2878 on 289 degrees of freedom
## Multiple R-Squared: 0.9252, Adjusted R-squared: 0.9175
## F-statistic: 119.2 on 30 and 289 DF, p-value: < 2.2e-16
```

```
##
##
```

```
## Estimation results for equation Deaths:
```

```
## =====
```

```
## Deaths = Births.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Covid.l1 + Births.l2 + Marriages.l2
```

```
##
```

	Estimate	Std. Error	t value	Pr(> t )
--	----------	------------	---------	----------

```

## Births.l1      -0.16899    0.04819   -3.507  0.000525 ***
## Marriages.l1   -0.13120    0.05675   -2.312  0.021496 *
## Deaths.l1      0.31548    0.07109    4.438  1.29e-05 ***
## Stillbirths.l1 -0.15536    0.03961   -3.923  0.000110 ***
## Covid.l1       0.81763    0.15188    5.384  1.51e-07 ***
## Births.l2      0.03074    0.05529    0.556  0.578635
## Marriages.l2    0.03556    0.06367    0.559  0.576918
## Deaths.l2      0.17919    0.08026    2.233  0.026343 *
## Stillbirths.l2  0.13052    0.04297    3.038  0.002601 **
## Covid.l2       -1.43040    0.33820   -4.229  3.15e-05 ***
## Births.l3      0.07508    0.05749    1.306  0.192579
## Marriages.l3    0.15021    0.06299    2.385  0.017742 *
## Deaths.l3      0.30715    0.08348    3.680  0.000279 ***
## Stillbirths.l3 -0.01896    0.04636   -0.409  0.682901
## Covid.l3       0.82916    0.39870    2.080  0.038436 *
## Births.l4      0.10697    0.05695    1.878  0.061363 .
## Marriages.l4    0.03703    0.06267    0.591  0.555077
## Deaths.l4      -0.04246    0.08505   -0.499  0.617987
## Stillbirths.l4  0.02640    0.04639    0.569  0.569694
## Covid.l4       -0.56373    0.38463   -1.466  0.143838
## Births.l5      -0.08491    0.05250   -1.617  0.106889
## Marriages.l5    0.24087    0.06010    4.008  7.80e-05 ***
## Deaths.l5      0.26664    0.08554    3.117  0.002010 **
## Stillbirths.l5  0.05770    0.04617    1.250  0.212352
## Covid.l5       0.46483    0.36545    1.272  0.204417
## Births.l6      -0.02991    0.03852   -0.777  0.438012
## Marriages.l6    -0.11565    0.06043   -1.914  0.056627 .
## Deaths.l6      -0.06001    0.06917   -0.868  0.386345
## Stillbirths.l6  0.01363    0.04275    0.319  0.750136
## Covid.l6       -0.19674    0.24239   -0.812  0.417662
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.3218 on 289 degrees of freedom
## Multiple R-Squared:  0.904,    Adjusted R-squared:  0.894
## F-statistic: 90.69 on 30 and 289 DF,  p-value: < 2.2e-16
##
##
## Estimation results for equation Stillbirths:
## =====
## Stillbirths = Births.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Covid.l1 + Births.l2 + Marriages.l2 + Deaths.l2 + Stillbirths.l2 + Covid.l2
##
##
##           Estimate Std. Error t value Pr(>|t|)
## Births.l1      0.010740  0.073792   0.146  0.88438
## Marriages.l1    0.079343  0.086910   0.913  0.36204
## Deaths.l1      0.181609  0.108869   1.668  0.09637 .
## Stillbirths.l1  0.301729  0.060652   4.975  1.12e-06 ***
## Covid.l1       0.077033  0.232583   0.331  0.74073
## Births.l2     -0.002436  0.084672  -0.029  0.97707
## Marriages.l2   -0.043289  0.097507  -0.444  0.65741
## Deaths.l2     -0.113469  0.122913  -0.923  0.35669
## Stillbirths.l2  0.291146  0.065800   4.425  1.37e-05 ***
## Covid.l2      -0.214709  0.517908  -0.415  0.67876

```

```

## Births.l3      -0.016587    0.088041   -0.188  0.85069
## Marriages.l3   -0.165829    0.096464   -1.719  0.08667 .
## Deaths.l3      0.115423    0.127833    0.903  0.36732
## Stillbirths.l3 0.192404    0.070994    2.710  0.00713 **
## Covid.l3       -0.184805    0.610561   -0.303  0.76235
## Births.l4      0.056592    0.087219    0.649  0.51695
## Marriages.l4   -0.121522    0.095968   -1.266  0.20643
## Deaths.l4      0.081611    0.130237    0.627  0.53140
## Stillbirths.l4 0.024779    0.071039    0.349  0.72748
## Covid.l4       -0.259194    0.589021   -0.440  0.66024
## Births.l5      0.017965    0.080400    0.223  0.82335
## Marriages.l5    0.393798    0.092031    4.279  2.56e-05 ***
## Deaths.l5      0.091231    0.130997    0.696  0.48672
## Stillbirths.l5 0.012393    0.070699    0.175  0.86098
## Covid.l5       0.161683    0.559641    0.289  0.77286
## Births.l6      0.056757    0.058986    0.962  0.33676
## Marriages.l6   -0.304778    0.092535   -3.294  0.00111 **
## Deaths.l6      -0.203902    0.105921   -1.925  0.05521 .
## Stillbirths.l6 -0.031051    0.065472   -0.474  0.63568
## Covid.l6       0.182574    0.371197    0.492  0.62320
## ---

```

```

## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```

##
##

```

```

## Residual standard error: 0.4929 on 289 degrees of freedom
## Multiple R-Squared: 0.7831, Adjusted R-squared: 0.7606
## F-statistic: 34.78 on 30 and 289 DF, p-value: < 2.2e-16
##
##

```

```

## Estimation results for equation Covid:

```

```

## =====

```

```

## Covid = Births.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Covid.l1 + Births.l2 + Marriages.l2 +

```

```

##

```

```

##          Estimate Std. Error t value Pr(>|t|)
## Births.l1      -0.003058   0.022243  -0.137 0.890750
## Marriages.l1    -0.031319   0.026198  -1.195 0.232883
## Deaths.l1      -0.077225   0.032817  -2.353 0.019282 *
## Stillbirths.l1 -0.018264   0.018283  -0.999 0.318635
## Covid.l1        2.047698   0.070109  29.208 < 2e-16 ***
## Births.l2      -0.007576   0.025523  -0.297 0.766814
## Marriages.l2     0.035272   0.029392   1.200 0.231097
## Deaths.l2       0.029260   0.037050   0.790 0.430332
## Stillbirths.l2 -0.027923   0.019834  -1.408 0.160265
## Covid.l2       -1.732644   0.156115 -11.098 < 2e-16 ***
## Births.l3      -0.021335   0.026539  -0.804 0.422109
## Marriages.l3    -0.022357   0.029078  -0.769 0.442601
## Deaths.l3       0.106546   0.038533   2.765 0.006058 **
## Stillbirths.l3  0.001641   0.021400   0.077 0.938917
## Covid.l3        0.694246   0.184044   3.772 0.000196 ***
## Births.l4       0.048926   0.026291   1.861 0.063764 .
## Marriages.l4     0.024346   0.028928   0.842 0.400696
## Deaths.l4      -0.039781   0.039258  -1.013 0.311761
## Stillbirths.l4 -0.004744   0.021413  -0.222 0.824809
## Covid.l4       -0.661884   0.177551  -3.728 0.000232 ***

```

```
## Births.l5      0.007830    0.024235    0.323 0.746871
## Marriages.l5   -0.032374    0.027741   -1.167 0.244174
## Deaths.l5      -0.009696    0.039487   -0.246 0.806201
## Stillbirths.l5 0.030102    0.021311    1.413 0.158874
## Covid.l5       0.564143    0.168695    3.344 0.000934 ***
## Births.l6      -0.010839    0.017781   -0.610 0.542599
## Marriages.l6    0.002306    0.027893    0.083 0.934179
## Deaths.l6      0.035573    0.031928    1.114 0.266138
## Stillbirths.l6 -0.002869    0.019736   -0.145 0.884508
## Covid.l6       0.194930    0.111892    1.742 0.082550 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.1486 on 289 degrees of freedom
## Multiple R-Squared:  0.9633, Adjusted R-squared:  0.9594
## F-statistic: 252.6 on 30 and 289 DF,  p-value: < 2.2e-16
##
##
## Covariance matrix of residuals:
##      Births Marriages Deaths Stillbirths Covid
## Births      0.234571  0.009973  0.075940  0.0662057 -0.0142680
## Marriages    0.009973  0.082391 -0.001135  0.0036373 -0.0058415
## Deaths       0.075940 -0.001135  0.103586  0.0355507  0.0060386
## Stillbirths  0.066206  0.003637  0.035551  0.2425669  0.0001468
## Covid        -0.014268 -0.005841  0.006039  0.0001468  0.0208296
##
## Correlation matrix of residuals:
##      Births Marriages Deaths Stillbirths Covid
## Births      1.00000  0.07174  0.48717  0.277551 -0.204119
## Marriages    0.07174  1.00000 -0.01229  0.025729 -0.141008
## Deaths       0.48717 -0.01229  1.00000  0.224276  0.130000
## Stillbirths  0.27755  0.02573  0.22428  1.000000  0.002065
## Covid        -0.20412 -0.14101  0.13000  0.002065  1.000000
```

```
serial.test(final_ts_var)
```

```
##
## Portmanteau Test (asymptotic)
##
## data: Residuals of VAR object final_ts_var
## Chi-squared = 608.1, df = 250, p-value < 2.2e-16
```

VAR model causality test for each variable against all other variables

```
causality(final_ts_var,
  cause = c("Deaths"))
```

```
## $Granger
##
## Granger causality H0: Deaths do not Granger-cause Births Marriages
## Stillbirths Covid
```



```
##
## data: VAR object final_ts_var
## F-Test = 5.2353, df1 = 24, df2 = 1445, p-value = 5.551e-15
##
##
## $Instant
##
## H0: No instantaneous causality between: Deaths and Births Marriages
## Stillbirths Covid
##
## data: VAR object final_ts_var
## Chi-squared = 73.373, df = 4, p-value = 4.441e-15
```

```
causality(final_ts_var,
          cause = c("Births"))
```

```
## $Granger
##
## Granger causality H0: Births do not Granger-cause Marriages Deaths
## Stillbirths Covid
##
## data: VAR object final_ts_var
## F-Test = 7.1094, df1 = 24, df2 = 1445, p-value < 2.2e-16
##
##
## $Instant
##
## H0: No instantaneous causality between: Births and Marriages Deaths
## Stillbirths Covid
##
## data: VAR object final_ts_var
## Chi-squared = 81.696, df = 4, p-value < 2.2e-16
```

```
causality(final_ts_var,
          cause = c("Covid"))
```

```
## $Granger
##
## Granger causality H0: Covid do not Granger-cause Births Marriages
## Deaths Stillbirths
##
## data: VAR object final_ts_var
## F-Test = 3.4647, df1 = 24, df2 = 1445, p-value = 3.555e-08
##
##
## $Instant
##
## H0: No instantaneous causality between: Covid and Births Marriages
## Deaths Stillbirths
##
## data: VAR object final_ts_var
## Chi-squared = 38.1, df = 4, p-value = 1.069e-07
```

```
causality(final_ts_var,
          cause = c("Marriages"))
```

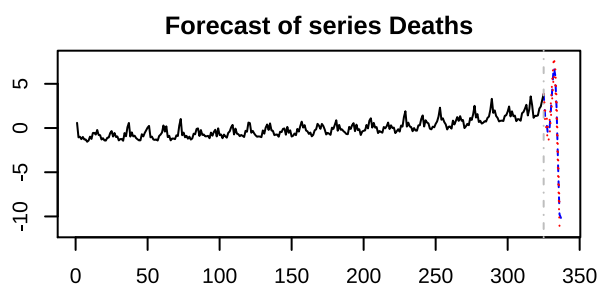
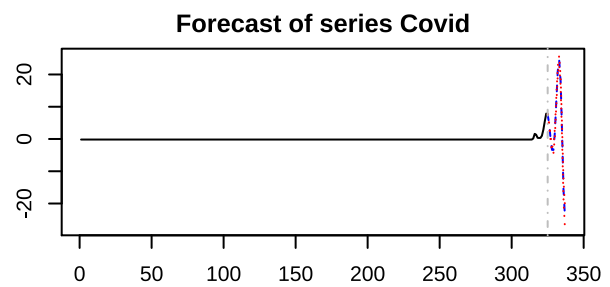
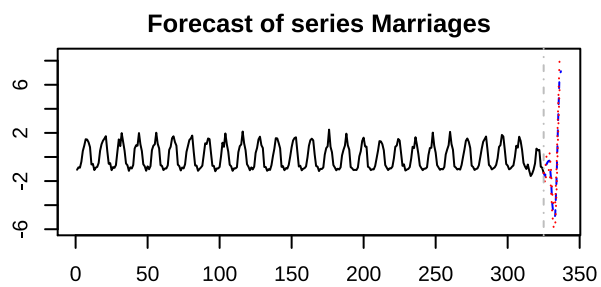
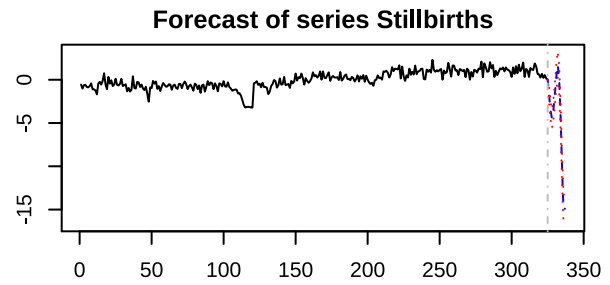
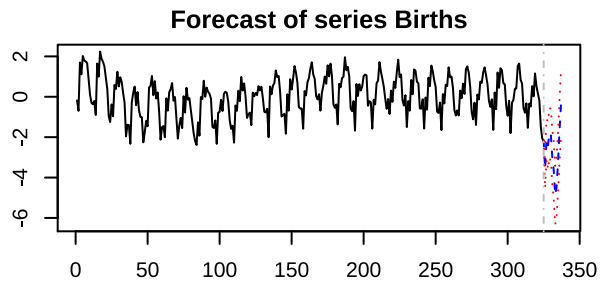
```
## $Granger
##
## Granger causality H0: Marriages do not Granger-cause Births Deaths
## Stillbirths Covid
##
## data: VAR object final_ts_var
## F-Test = 11.115, df1 = 24, df2 = 1445, p-value < 2.2e-16
##
##
## $Instant
##
## H0: No instantaneous causality between: Marriages and Births Deaths
## Stillbirths Covid
##
## data: VAR object final_ts_var
## Chi-squared = 8.2446, df = 4, p-value = 0.08302
```

```
causality(final_ts_var,
          cause = c("Stillbirths"))
```

```
## $Granger
##
## Granger causality H0: Stillbirths do not Granger-cause Births
## Marriages Deaths Covid
##
## data: VAR object final_ts_var
## F-Test = 3.5358, df1 = 24, df2 = 1445, p-value = 1.948e-08
##
##
## $Instant
##
## H0: No instantaneous causality between: Stillbirths and Births
## Marriages Deaths Covid
##
## data: VAR object final_ts_var
## Chi-squared = 26.236, df = 4, p-value = 2.836e-05
```

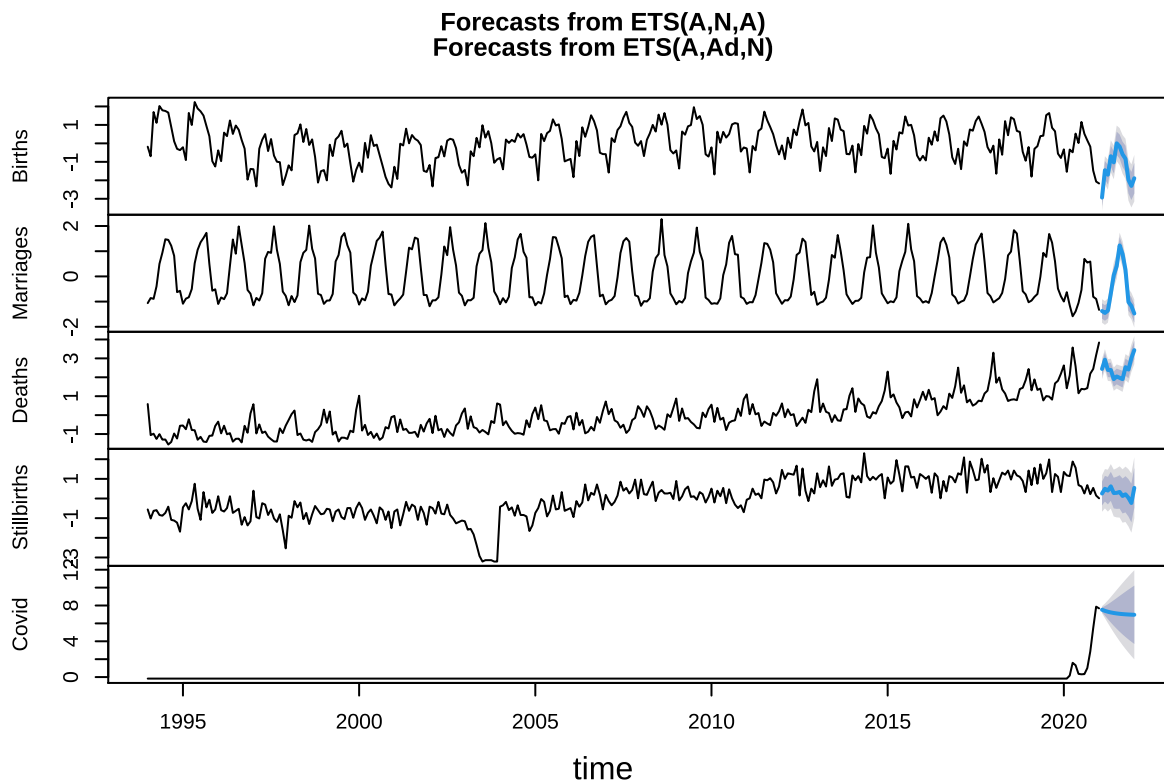
prediction for final dataset including covid

```
fcast = predict(final_ts_var, n.ahead = 12, ci = 0.95) # predicting the 12 months after the data ends
par(mar = c(2,2,2,2))
plot(fcast)
```



forecast for final dataset including covid

```
Final_forecast <- forecast(Final_dataset_TS, h=12 )
par(mar = c(2,2,2,2))
plot(Final_forecast)
```



```
accuracy(Final_forecast,d= NULL, D=NULL)
```

```
##                                ME      RMSE      MAE      MPE
## Births Training set    -0.014130235  0.3479423  0.27933198  -46.0942233
## Marriages Training set -0.011107093  0.2328504  0.15196554   50.5651928
## Deaths Training set    0.037151266  0.2659665  0.18345434  -25.6909986
## Stillbirths Training set 0.009317692  0.4623692  0.35346547 -105.4319544
## Covid Training set      0.006281351  0.2006431  0.03323288   -0.1606386
##                                MAPE      MASE      ACF1
## Births Training set    131.206921  0.7110069  0.14569361
## Marriages Training set   80.188605  1.0119131  0.04818972
## Deaths Training set    122.522534  0.6594540  0.24665371
## Stillbirths Training set 196.875237  0.6044408  0.02177374
## Covid Training set       4.609062  0.3372176  0.09847719
```

Create forecast for vital events excluding Covid to see if the introduction of covid had a large impact on the other variables

```
Vital_Events$Date <- as.Date(Final_dataset$Date,"%Y-%m-%d")
```

```
glimpse(Vital_Events)
```

```
## Rows: 330
## Columns: 5
```

```
## $ Date      <date> 1994-01-01, 1994-02-01, 1994-03-01, 1994-04-01, 1994-05-0~
## $ Births    <int> 11631, 11254, 13003, 12576, 13240, 13072, 13045, 12982, 12~
## $ Marriages <int> 2078, 2650, 2557, 3967, 6493, 7754, 9264, 9194, 8540, 7400~
## $ Deaths    <int> 8094, 6428, 6503, 6224, 6483, 6187, 6196, 5926, 6062, 6515~
## $ Stillbirths <int> 75, 62, 73, 74, 67, 66, 70, 79, 60, 59, 56, 43, 78, 84, 75~
```

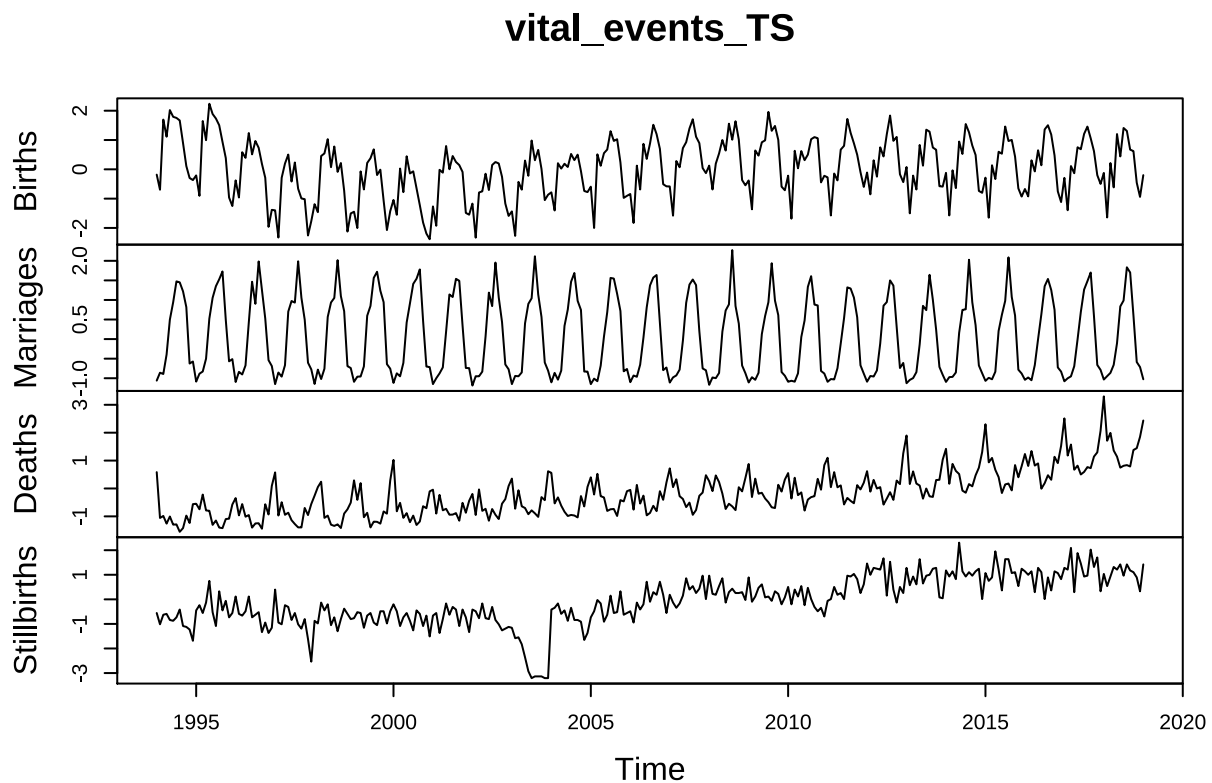
Normalize the Data

```
Vital_Events_standardized <- Final_dataset %>% mutate_each(list(~scale(.) %>% as.vector),
  vars = c("Births", "Marriages", "Deaths", "Stillbirths"))
```

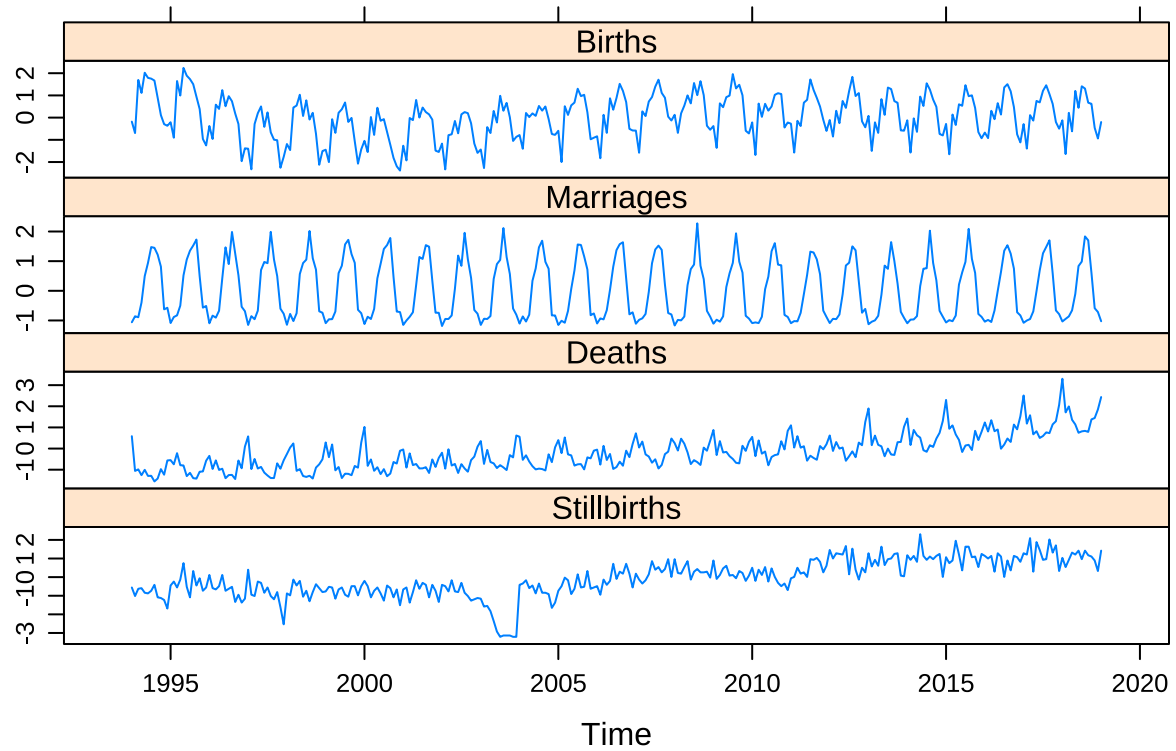
Convert data frame to a time series up to 2019, so that I can compare predictions for 2021-2021 to actual observed numbers

```
vital_events_TS <- ts(Vital_Events_standardized[2:5], frequency = 12, start = 1994, end = 2019)
```

```
plot(vital_events_TS)
```

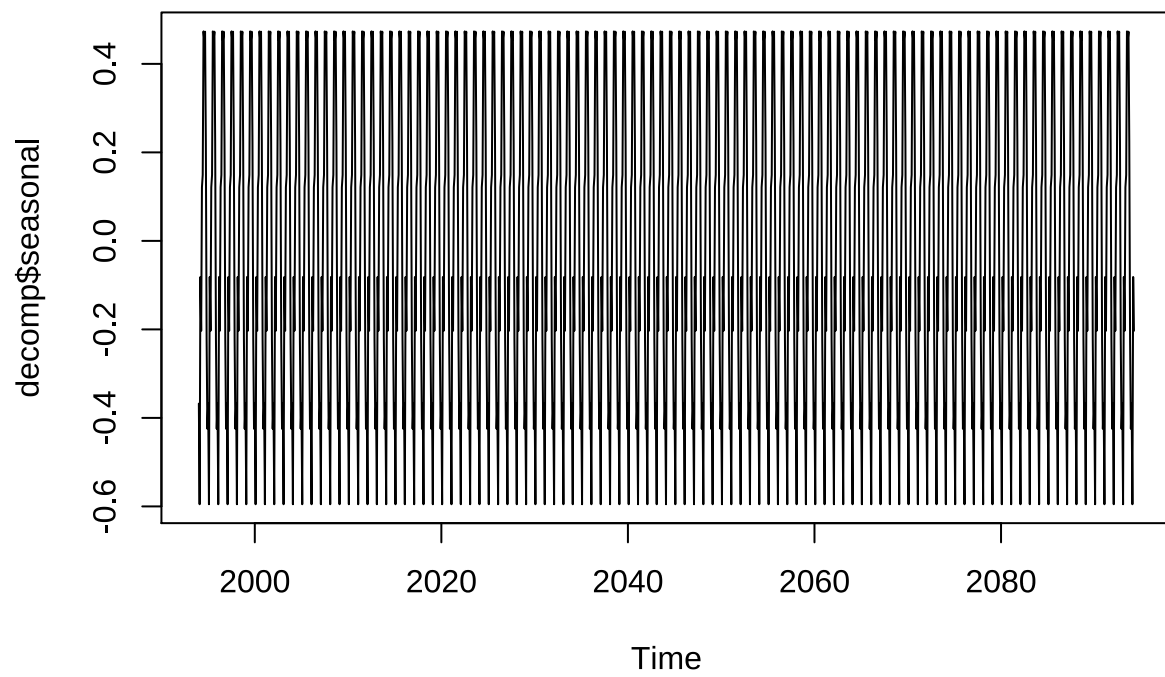


```
xyplot.ts(vital_events_TS)
```

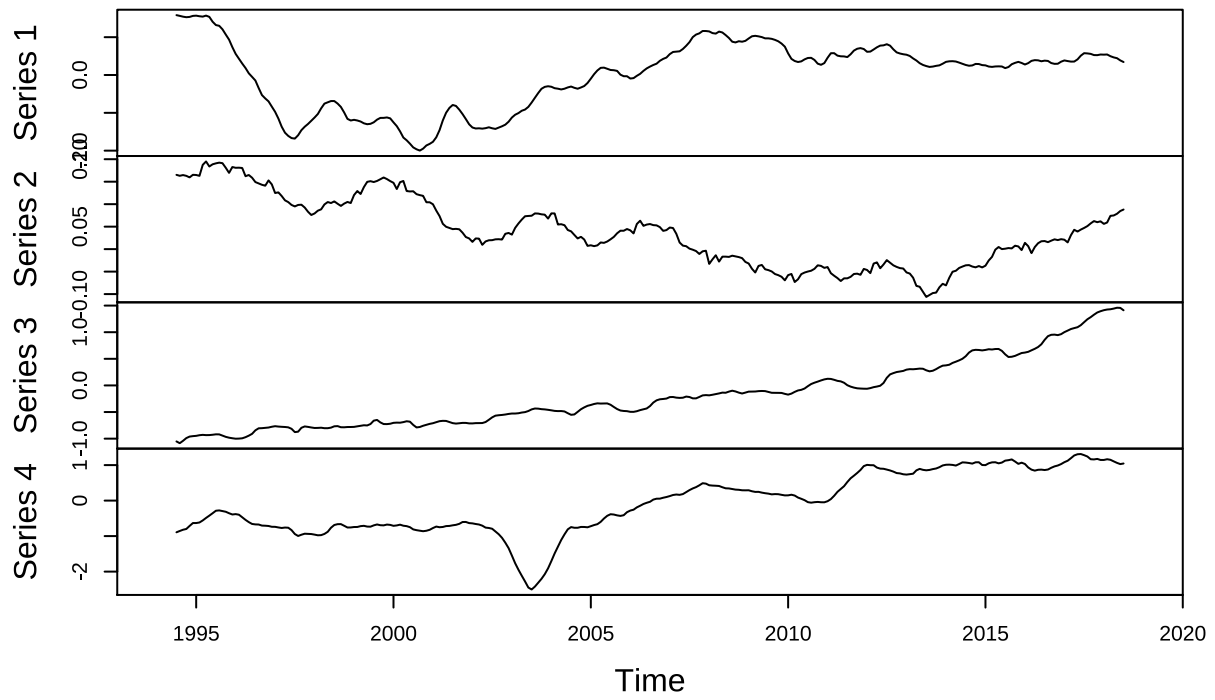


decompose data and display results vital events without covid

```
decomp <- decompose(vital_events_TS)
plot(decomp$seasonal)
```

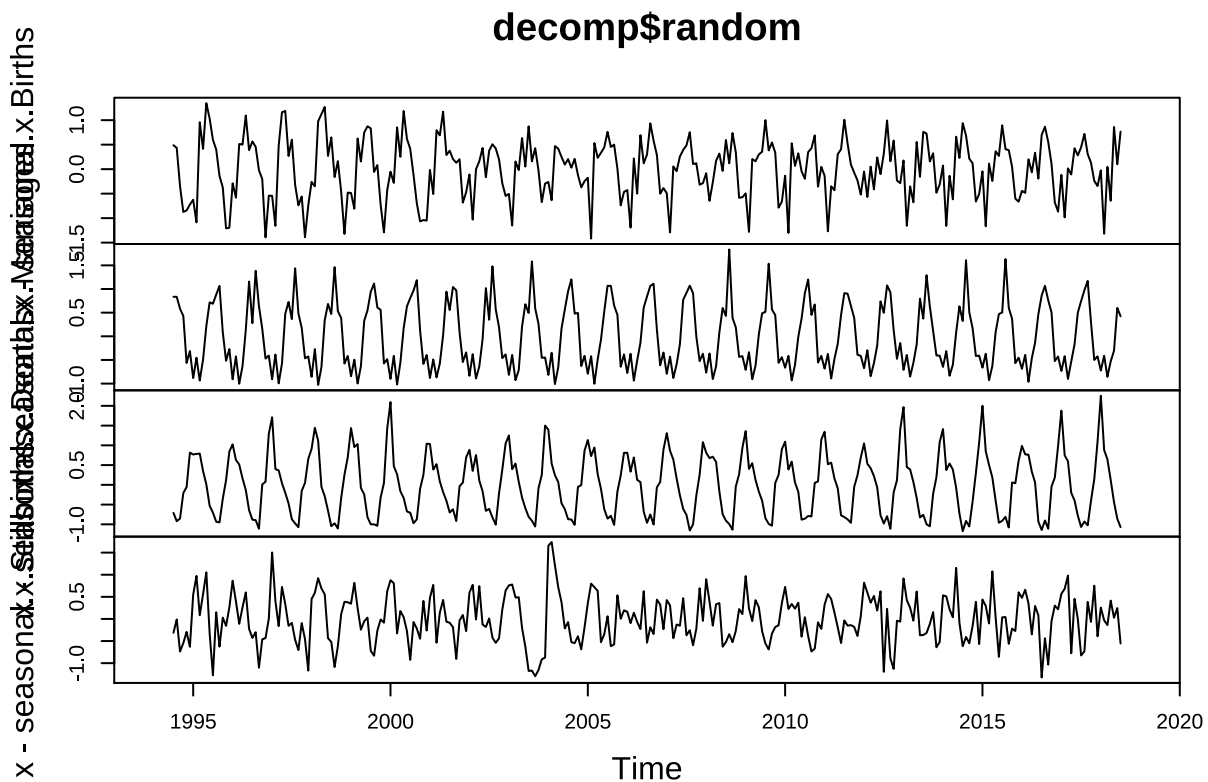


```
plot(decomp$trend)
```

**decomp\$trend**

```
plot(decomp$random)
```





Dicky-Fuller test

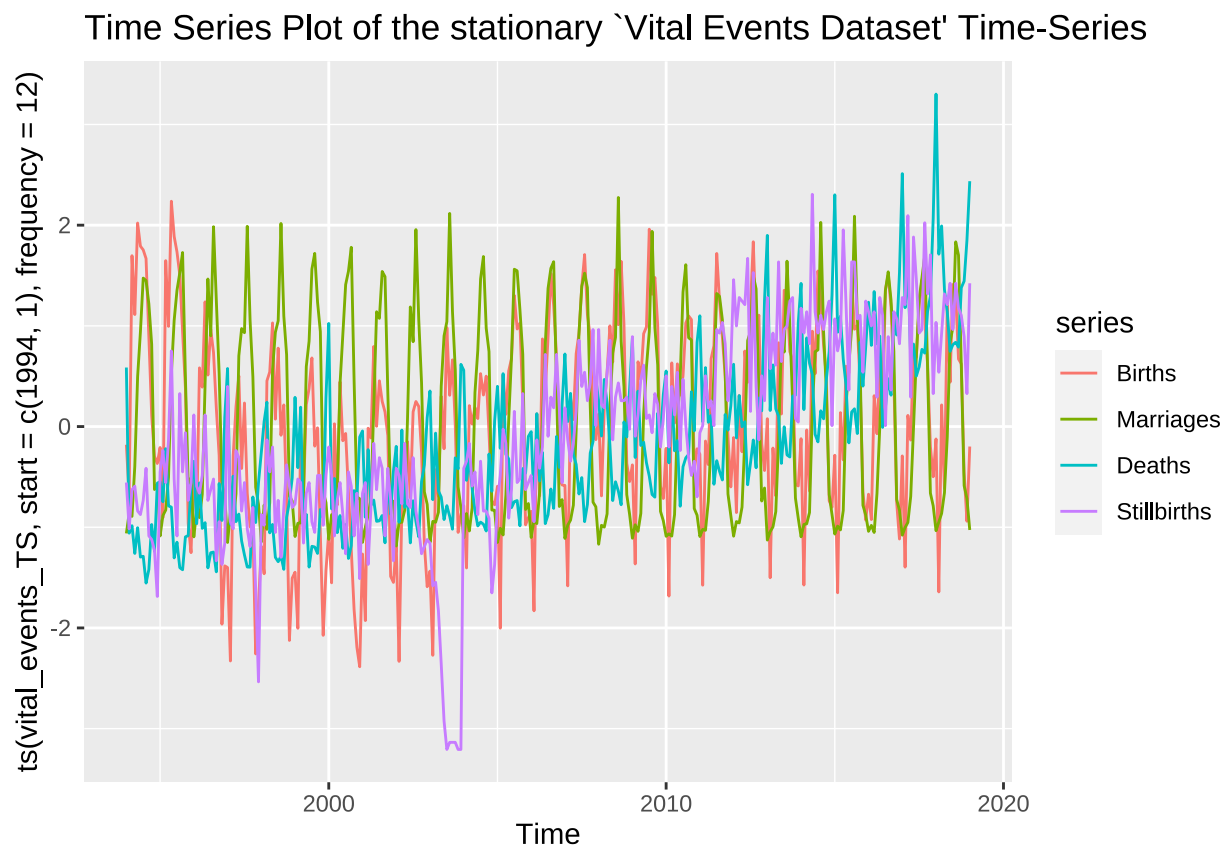
```
apply(vital_events_TS, 2, adf.test)
```

```
## Warning in FUN(newX[, i], ...): p-value smaller than printed p-value
## Warning in FUN(newX[, i], ...): p-value smaller than printed p-value
## Warning in FUN(newX[, i], ...): p-value smaller than printed p-value
## Warning in FUN(newX[, i], ...): p-value smaller than printed p-value

## $Births
##
##   Augmented Dickey-Fuller Test
##
## data:  newX[, i]
## Dickey-Fuller = -6.3124, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
##
##
## $Marriages
##
##   Augmented Dickey-Fuller Test
##
## data:  newX[, i]
```

```
## Dickey-Fuller = -17.897, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
##
##
## $Deaths
##
## Augmented Dickey-Fuller Test
##
## data: newX[, i]
## Dickey-Fuller = -7.4351, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
##
##
## $Stillbirths
##
## Augmented Dickey-Fuller Test
##
## data: newX[, i]
## Dickey-Fuller = -4.0556, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
```

```
autoplot(ts(vital_events_TS,
            start = c(1994,1),
            frequency = 12)) +
  ggtitle("Time Series Plot of the stationary `Vital Events Dataset' Time-Series")
```



```
VARselect(vital_events_TS,
          type = "none", lag.max = 6)
```

```
## $selection
## AIC(n)  HQ(n)  SC(n) FPE(n)
##      6      6      6      6
##
## $criteria
##              1              2              3              4              5
## AIC(n) -5.021713826 -6.562103521 -7.1098670961 -7.365551730 -7.6173167343
## HQ(n)  -4.941640222 -6.401956313 -6.8696462847 -7.045257315 -7.2169487153
## SC(n)  -4.821742281 -6.162160431 -6.5099524619 -6.565665551 -6.6174590105
## FPE(n)  0.006593261  0.001412986  0.0008171504  0.000632946  0.0004922699
##
##              6
## AIC(n) -7.9365349663
## HQ(n)  -7.4560933436
## SC(n)  -6.7367056978
## FPE(n)  0.0003579586
```

Creating a VAR model with vars

```
vital_ts_var <- vars::VAR(vital_events_TS,
                          lag.max = 6,
                          ic = "AIC",
                          type = "none")
summary(vital_ts_var)
```

```
##
## VAR Estimation Results:
## =====
## Endogenous variables: Births, Marriages, Deaths, Stillbirths
## Deterministic variables: none
## Sample size: 295
## Log Likelihood: -407.709
## Roots of the characteristic polynomial:
## 0.9935 0.9935 0.9921 0.9285 0.9128 0.9128 0.896 0.8374 0.8374 0.8285 0.8285 0.7939 0.7939 0.7797 0.6
## Call:
## vars::VAR(y = vital_events_TS, type = "none", lag.max = 6, ic = "AIC")
##
##
## Estimation results for equation Births:
## =====
## Births = Births.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Births.l2 + Marriages.l2 + Deaths.l
##
##              Estimate Std. Error t value Pr(>|t|)
## Births.l1      0.365715   0.073082   5.004 1.01e-06 ***
## Marriages.l1    0.136588   0.089150   1.532  0.12666
## Deaths.l1     -0.335390   0.109737  -3.056  0.00246 **
## Stillbirths.l1 -0.250673   0.060472  -4.145 4.54e-05 ***
## Births.l2       0.270189   0.084291   3.205  0.00151 **
## Marriages.l2    -0.259441   0.098403  -2.636  0.00886 **
## Deaths.l2       0.291704   0.121616   2.399  0.01714 *
```

```

## Stillbirths.12  0.274422  0.066447  4.130 4.84e-05 ***
## Births.13      0.056977  0.088660  0.643 0.52100
## Marriages.13   -0.083387  0.096414 -0.865 0.38786
## Deaths.13     0.076731  0.127968  0.600 0.54927
## Stillbirths.13 0.030466  0.070685  0.431 0.66681
## Births.14     0.027638  0.088342  0.313 0.75463
## Marriages.14   -0.264438  0.095557 -2.767 0.00604 **
## Deaths.14     -0.013943  0.130771 -0.107 0.91517
## Stillbirths.14 -0.043111  0.070653 -0.610 0.54226
## Births.15     -0.064941  0.080277 -0.809 0.41925
## Marriages.15    0.115026  0.092278  1.247 0.21365
## Deaths.15     0.139710  0.130846  1.068 0.28659
## Stillbirths.15 -0.001272  0.070875 -0.018 0.98570
## Births.16     0.089896  0.058505  1.537 0.12557
## Marriages.16   -0.223793  0.093468 -2.394 0.01733 *
## Deaths.16     -0.166313  0.105895 -1.571 0.11746
## Stillbirths.16 0.011824  0.064916  0.182 0.85561
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.4772 on 271 degrees of freedom
## Multiple R-Squared: 0.7834, Adjusted R-squared: 0.7643
## F-statistic: 40.85 on 24 and 271 DF, p-value: < 2.2e-16
##
##
## Estimation results for equation Marriages:
## =====
## Marriages = Births.11 + Marriages.11 + Deaths.11 + Stillbirths.11 + Births.12 + Marriages.12 + Deaths.12 +
##
##
##           Estimate Std. Error t value Pr(>|t|)
## Births.11    0.169253  0.042127  4.018 7.62e-05 ***
## Marriages.11  0.489528  0.051388  9.526 < 2e-16 ***
## Deaths.11   -0.328043  0.063256 -5.186 4.21e-07 ***
## Stillbirths.11 0.009327  0.034858  0.268 0.789228
## Births.12   -0.303776  0.048588 -6.252 1.57e-09 ***
## Marriages.12  0.023323  0.056722  0.411 0.681264
## Deaths.12    0.391482  0.070103  5.584 5.70e-08 ***
## Stillbirths.12 -0.155644  0.038302 -4.064 6.33e-05 ***
## Births.13    0.089269  0.051106  1.747 0.081815 .
## Marriages.13  -0.160989  0.055576 -2.897 0.004078 **
## Deaths.13   -0.285342  0.073764 -3.868 0.000137 ***
## Stillbirths.13 0.080485  0.040745  1.975 0.049244 *
## Births.14    0.217961  0.050923  4.280 2.59e-05 ***
## Marriages.14  -0.221063  0.055082 -4.013 7.75e-05 ***
## Deaths.14   -0.084982  0.075380 -1.127 0.260577
## Stillbirths.14 0.155205  0.040726  3.811 0.000171 ***
## Births.15    0.131916  0.046274  2.851 0.004697 **
## Marriages.15  -0.062135  0.053191 -1.168 0.243777
## Deaths.15    0.074042  0.075423  0.982 0.327130
## Stillbirths.15 -0.023608  0.040854 -0.578 0.563837
## Births.16   -0.320439  0.033724 -9.502 < 2e-16 ***
## Marriages.16  -0.128101  0.053877 -2.378 0.018117 *
## Deaths.16    0.174122  0.061041  2.853 0.004671 **

```

```

## Stillbirths.16 -0.079489    0.037419  -2.124 0.034554 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.2751 on 271 degrees of freedom
## Multiple R-Squared: 0.9312, Adjusted R-squared: 0.9251
## F-statistic: 152.7 on 24 and 271 DF, p-value: < 2.2e-16
##
##
## Estimation results for equation Deaths:
## =====
## Deaths = Births.11 + Marriages.11 + Deaths.11 + Stillbirths.11 + Births.12 + Marriages.12 + Deaths.12
##
##           Estimate Std. Error t value Pr(>|t|)
## Births.11      -0.166115    0.047578  -3.491 0.000561 ***
## Marriages.11    -0.128792    0.058037  -2.219 0.027307 *
## Deaths.11       0.338831    0.071440   4.743 3.41e-06 ***
## Stillbirths.11 -0.144012    0.039368  -3.658 0.000305 ***
## Births.12       0.045533    0.054874   0.830 0.407395
## Marriages.12     0.011435    0.064062   0.178 0.858465
## Deaths.12       0.203972    0.079174   2.576 0.010517 *
## Stillbirths.12  0.113077    0.043258   2.614 0.009448 **
## Births.13       0.055496    0.057719   0.961 0.337164
## Marriages.13     0.144884    0.062767   2.308 0.021736 *
## Deaths.13       0.299109    0.083308   3.590 0.000392 ***
## Stillbirths.13 -0.004528    0.046016  -0.098 0.921692
## Births.14       0.110414    0.057512   1.920 0.055927 .
## Marriages.14     0.046564    0.062209   0.749 0.454800
## Deaths.14       -0.079049    0.085133  -0.929 0.353955
## Stillbirths.14  0.029107    0.045996   0.633 0.527387
## Births.15       -0.070343    0.052261  -1.346 0.179430
## Marriages.15     0.243496    0.060074   4.053 6.60e-05 ***
## Deaths.15       0.241997    0.085182   2.841 0.004840 **
## Stillbirths.15  0.046596    0.046141   1.010 0.313460
## Births.16       -0.042412    0.038088  -1.114 0.266466
## Marriages.16    -0.150996    0.060849  -2.481 0.013690 *
## Deaths.16       -0.060801    0.068939  -0.882 0.378580
## Stillbirths.16  0.019205    0.042261   0.454 0.649874
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.3107 on 271 degrees of freedom
## Multiple R-Squared: 0.8772, Adjusted R-squared: 0.8664
## F-statistic: 80.7 on 24 and 271 DF, p-value: < 2.2e-16
##
##
## Estimation results for equation Stillbirths:
## =====
## Stillbirths = Births.11 + Marriages.11 + Deaths.11 + Stillbirths.11 + Births.12 + Marriages.12 + Deaths.12
##
##           Estimate Std. Error t value Pr(>|t|)
## Births.11       0.008826    0.075574   0.117 0.907117

```

```

## Marriages.l1      0.086975    0.092188    0.943 0.346293
## Deaths.l1        0.195574    0.113478    1.723 0.085946 .
## Stillbirths.l1   0.332266    0.062533    5.313 2.25e-07 ***
## Births.l2        -0.016003    0.087164   -0.184 0.854467
## Marriages.l2     -0.094394    0.101758   -0.928 0.354425
## Deaths.l2       -0.066864    0.125762   -0.532 0.595386
## Stillbirths.l2   0.255414    0.068712    3.717 0.000245 ***
## Births.l3         0.024999    0.091682    0.273 0.785310
## Marriages.l3     -0.134402    0.099701   -1.348 0.178764
## Deaths.l3        0.067335    0.132330    0.509 0.611277
## Stillbirths.l3   0.188957    0.073094    2.585 0.010257 *
## Births.l4         0.012673    0.091354    0.139 0.889767
## Marriages.l4     -0.122002    0.098814   -1.235 0.218025
## Deaths.l4        0.103712    0.135228    0.767 0.443783
## Stillbirths.l4   0.037943    0.073061    0.519 0.603950
## Births.l5         0.050556    0.083013    0.609 0.543029
## Marriages.l5      0.382954    0.095423    4.013 7.76e-05 ***
## Deaths.l5        0.017792    0.135306    0.131 0.895479
## Stillbirths.l5  -0.007106    0.073291   -0.097 0.922834
## Births.l6         0.046125    0.060500    0.762 0.446487
## Marriages.l6     -0.332645    0.096654   -3.442 0.000670 ***
## Deaths.l6       -0.156392    0.109504   -1.428 0.154391
## Stillbirths.l6  -0.016714    0.067129   -0.249 0.803568
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
##
## Residual standard error: 0.4935 on 271 degrees of freedom
## Multiple R-Squared: 0.7766, Adjusted R-squared: 0.7568
## F-statistic: 39.24 on 24 and 271 DF, p-value: < 2.2e-16
##
##
## Covariance matrix of residuals:
##           Births Marriages Deaths Stillbirths
## Births      0.227193  0.006047 0.079729    0.066371
## Marriages    0.006047  0.074110 0.001473    0.001439
## Deaths      0.079729  0.001473 0.096435    0.032393
## Stillbirths 0.066371  0.001439 0.032393    0.242524
##
## Correlation matrix of residuals:
##           Births Marriages Deaths Stillbirths
## Births      1.00000    0.04661 0.53864    0.28275
## Marriages    0.04661    1.00000 0.01742    0.01073
## Deaths      0.53864    0.01742 1.00000    0.21182
## Stillbirths 0.28275    0.01073 0.21182    1.00000

```

```

causality(vital_ts_var,
  cause = c("Deaths"))

```

```

## $Granger
##
## Granger causality H0: Deaths do not Granger-cause Births Marriages
## Stillbirths

```

```
##
## data: VAR object vital_ts_var
## F-Test = 5.7512, df1 = 18, df2 = 1084, p-value = 2.627e-13
##
##
## $Instant
##
## H0: No instantaneous causality between: Deaths and Births Marriages
## Stillbirths
##
## data: VAR object vital_ts_var
## Chi-squared = 67.145, df = 3, p-value = 1.743e-14
```

```
causality(vital_ts_var,
           cause = c("Births"))
```

```
## $Granger
##
## Granger causality H0: Births do not Granger-cause Marriages Deaths
## Stillbirths
##
## data: VAR object vital_ts_var
## F-Test = 9.293, df1 = 18, df2 = 1084, p-value < 2.2e-16
##
##
## $Instant
##
## H0: No instantaneous causality between: Births and Marriages Deaths
## Stillbirths
##
## data: VAR object vital_ts_var
## Chi-squared = 71.948, df = 3, p-value = 1.665e-15
```

```
causality(vital_ts_var,
           cause = c("Marriages"))
```

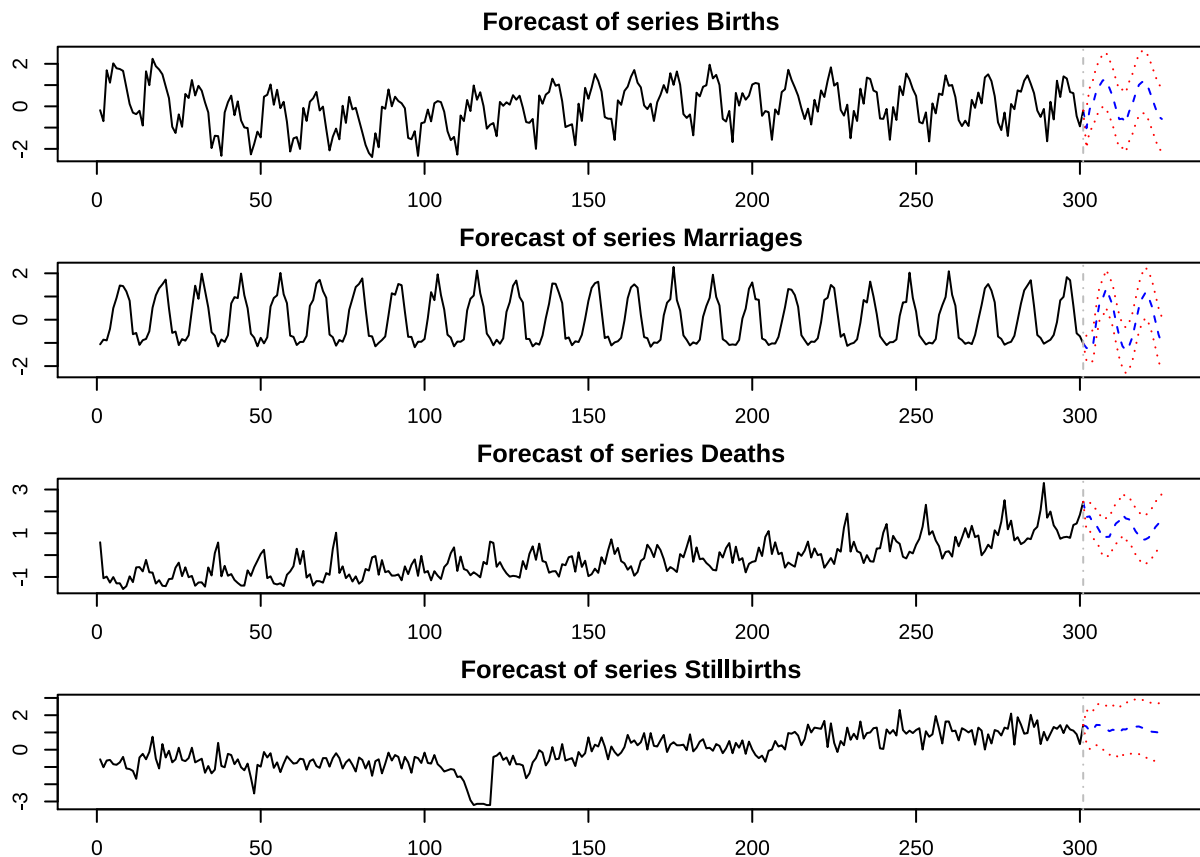
```
## $Granger
##
## Granger causality H0: Marriages do not Granger-cause Births Deaths
## Stillbirths
##
## data: VAR object vital_ts_var
## F-Test = 14.545, df1 = 18, df2 = 1084, p-value < 2.2e-16
##
##
## $Instant
##
## H0: No instantaneous causality between: Marriages and Births Deaths
## Stillbirths
##
## data: VAR object vital_ts_var
## Chi-squared = 0.86135, df = 3, p-value = 0.8347
```

```
causality(vital_ts_var,
          cause = c("Stillbirths"))
```

```
## $Granger
##
## Granger causality H0: Stillbirths do not Granger-cause Births
## Marriages Deaths
##
## data:  VAR object vital_ts_var
## F-Test = 4.1624, df1 = 18, df2 = 1084, p-value = 1.407e-08
##
##
## $Instant
##
## H0: No instantaneous causality between: Stillbirths and Births
## Marriages Deaths
##
## data:  VAR object vital_ts_var
## Chi-squared = 23.425, df = 3, p-value = 3.293e-05
```

prediction of vital events without covid

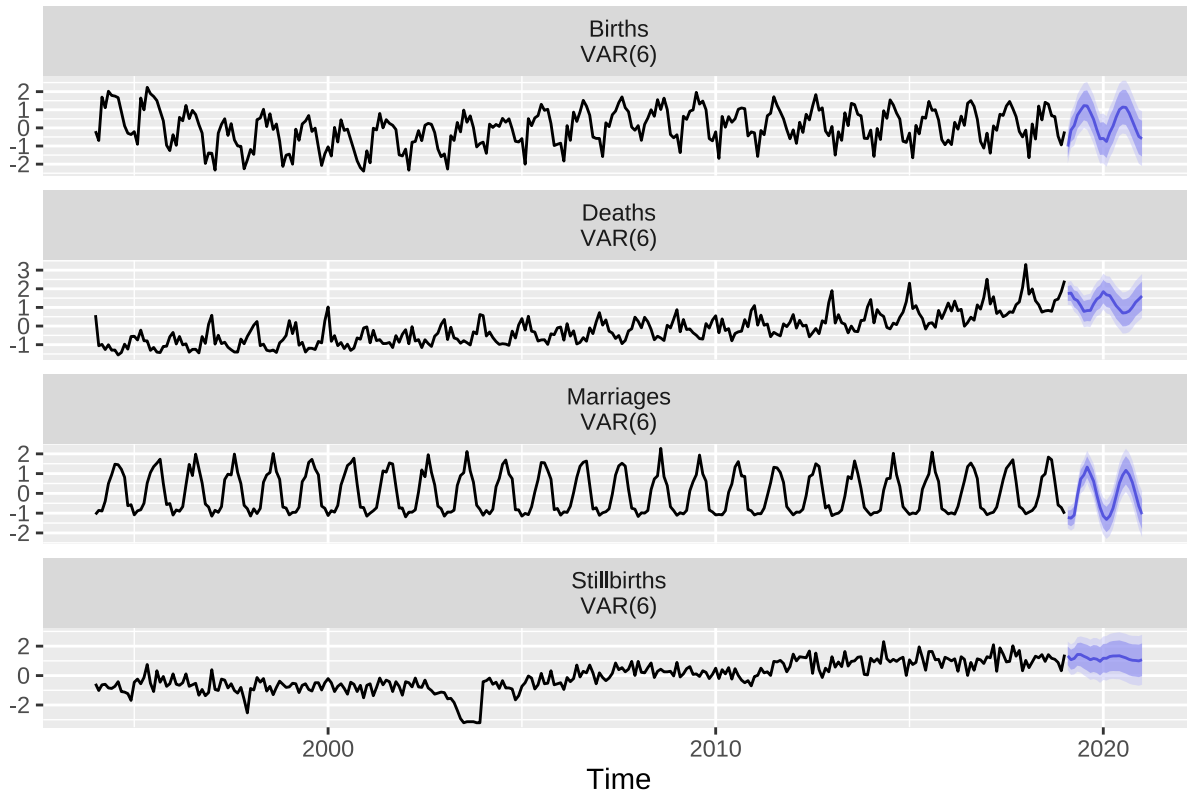
```
fcast2 = predict(vital_ts_var, n.ahead = 24) # predicting the 12 months after the data ends
par(mar = c(2,2,2,2))
plot(fcast2)
```





forecast for just the vital events, without covid

```
vital_forecast <- forecast(vital_ts_var, h=24 ) #Forecasting 12 months ahead
par(mar=c(5.1,4.1,4.1,2.1))
autoplot(vital_forecast, alpha = 0.5)
```



checking accuracy of both forecasts

```
accuracy(vital_forecast,d= NULL, D=NULL)
```

##		ME	RMSE	MAE	MPE	MAPE
##	Births Training set	0.02259086	0.4574059	0.3709170	-61.066715	184.76294
##	Marriages Training set	0.03790753	0.2636616	0.2060437	1.301786	35.74744
##	Deaths Training set	0.00901560	0.2977767	0.2351803	-51.179029	202.93874
##	Stillbirths Training set	0.03055049	0.4729972	0.3740873	-98.071811	190.45415
##		MASE	ACF1			
##	Births Training set	0.9590394	0.04126637			
##	Marriages Training set	1.6096819	-0.09314783			
##	Deaths Training set	0.8959361	0.05630330			
##	Stillbirths Training set	0.6353059	0.04488906			

```
accuracy(Final_forecast,d= NULL, D=NULL)
```

##		ME	RMSE	MAE	MPE
##	Births Training set	-0.014130235	0.3479423	0.27933198	-46.0942233

```
## Marriages Training set -0.011107093 0.2328504 0.15196554 50.5651928
## Deaths Training set 0.037151266 0.2659665 0.18345434 -25.6909986
## Stillbirths Training set 0.009317692 0.4623692 0.35346547 -105.4319544
## Covid Training set 0.006281351 0.2006431 0.03323288 -0.1606386
##
## MAPE MASE ACF1
## Births Training set 131.206921 0.7110069 0.14569361
## Marriages Training set 80.188605 1.0119131 0.04818972
## Deaths Training set 122.522534 0.6594540 0.24665371
## Stillbirths Training set 196.875237 0.6044408 0.02177374
## Covid Training set 4.609062 0.3372176 0.09847719
```

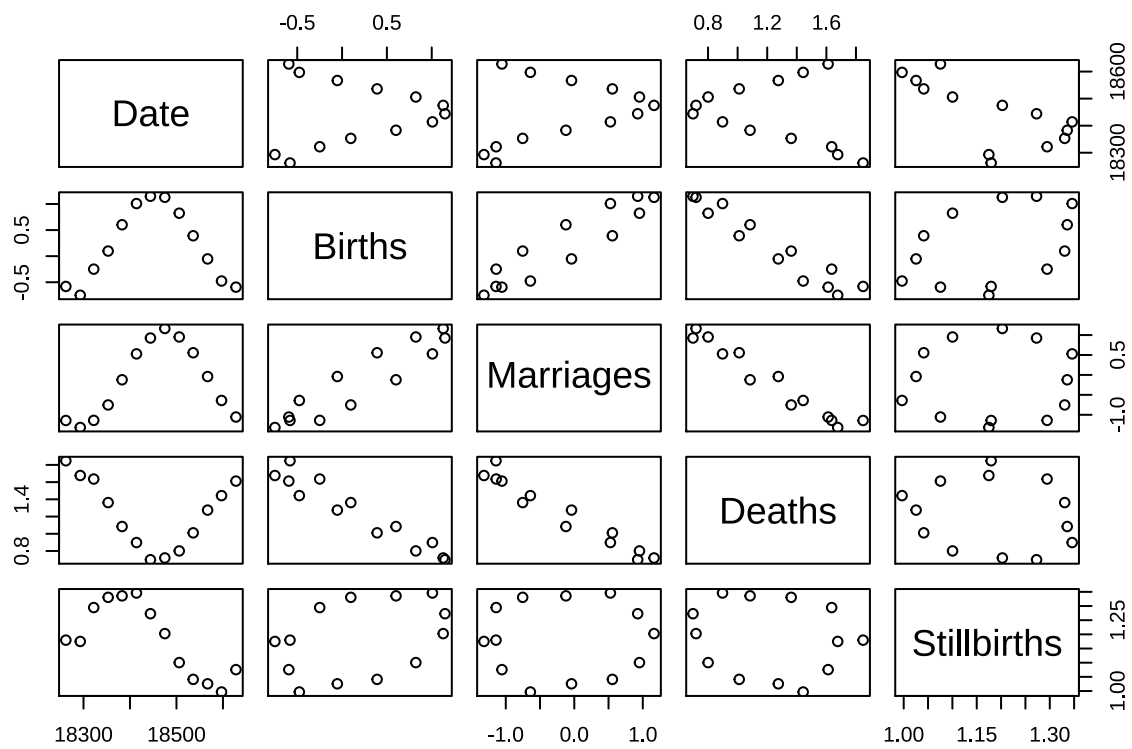
Create dataframes for both actual values and predicted values for comparison This is for vital events only, without the introduction of Covid to see how the predicted compared, and how much variance there is between the 2 and the impact covid had on the actual numbers

```
library(modelr)
actuals <- as.data.frame(Final_dataset_standardized[1:5])

actuals <- actuals[313:325,]

predicted <- fortify(stats::predict(vital_ts_var, n.ahead = 24))
predicted <- predicted[313:325,]
predicted <- predicted[c(1,6,10,14,18)]
colnames(predicted)<- c("Date","Births","Marriages","Deaths", "Stillbirths")

plot(predicted)
```



```
plot(actuals)
```

