

```

##  

## 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]  

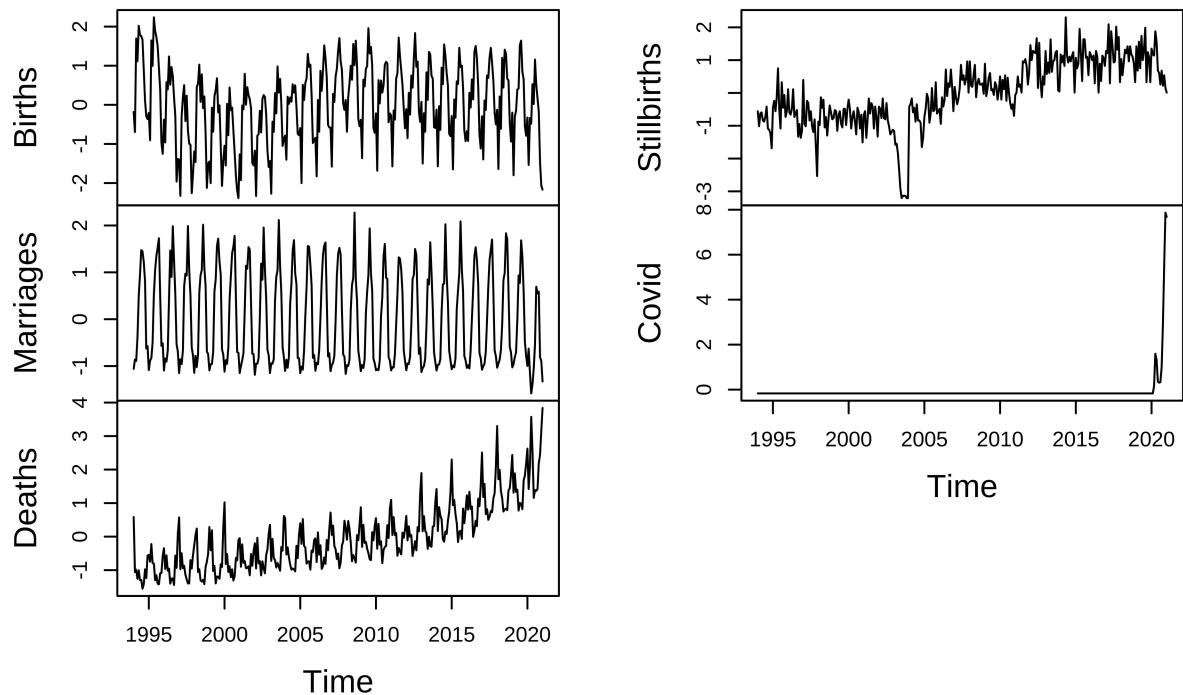
## Dickey-Fuller = 25.849, Lag order = 6, p-value = 0.99  

## alternative hypothesis: stationary

plot.ts(Final_dataset_TS, main= "Final Dataset Timeseries")

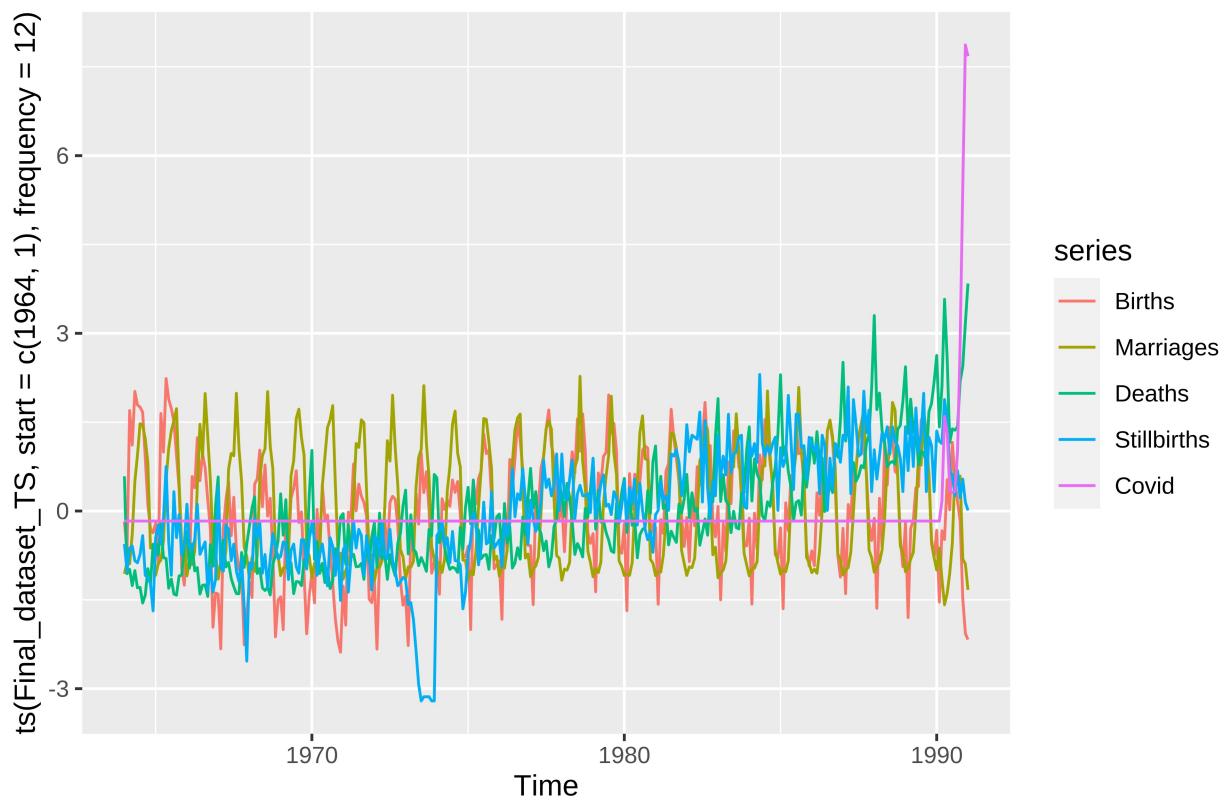
```

## Final Dataset Timeseries



```
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.11      -0.16899   0.04819  -3.507 0.000525 ***
## Marriages.11   -0.13120   0.05675  -2.312 0.021496 *
## Deaths.11      0.31548   0.07109   4.438 1.29e-05 ***
## Stillbirths.11 -0.15536   0.03961  -3.923 0.000110 ***
## Covid.11        0.81763   0.15188   5.384 1.51e-07 ***
## Births.12       0.03074   0.05529   0.556 0.578635
## Marriages.12    0.03556   0.06367   0.559 0.576918
## Deaths.12       0.17919   0.08026   2.233 0.026343 *
## Stillbirths.12  0.13052   0.04297   3.038 0.002601 **
## Covid.12         -1.43040  0.33820  -4.229 3.15e-05 ***
## Births.13        0.07508   0.05749   1.306 0.192579
## Marriages.13    0.15021   0.06299   2.385 0.017742 *
## Deaths.13        0.30715   0.08348   3.680 0.000279 ***
## Stillbirths.13  -0.01896   0.04636  -0.409 0.682901
## Covid.13         0.82916   0.39870   2.080 0.038436 *
## Births.14        0.10697   0.05695   1.878 0.061363 .
## Marriages.14    0.03703   0.06267   0.591 0.555077
## Deaths.14        -0.04246  0.08505  -0.499 0.617987
## Stillbirths.14  0.02640   0.04639   0.569 0.569694
## Covid.14          -0.56373  0.38463  -1.466 0.143838
## Births.15        -0.08491  0.05250  -1.617 0.106889
## Marriages.15     0.24087   0.06010   4.008 7.80e-05 ***
## Deaths.15        0.26664   0.08554   3.117 0.002010 **
## Stillbirths.15  0.05770   0.04617   1.250 0.212352
## Covid.15          0.46483   0.36545   1.272 0.204417
## Births.16        -0.02991  0.03852  -0.777 0.438012
## Marriages.16     -0.11565  0.06043  -1.914 0.056627 .
## Deaths.16        -0.06001  0.06917  -0.868 0.386345
## Stillbirths.16   0.01363   0.04275   0.319 0.750136
## Covid.16          -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.11 + Marriages.11 + Deaths.11 + Stillbirths.11 + Covid.11 + Births.12 + Marriag
##
##           Estimate Std. Error t value Pr(>|t|)
## Births.11      0.010740  0.073792  0.146  0.88438
## Marriages.11   0.079343  0.086910  0.913  0.36204
## Deaths.11      0.181609  0.108869  1.668  0.09637 .
## Stillbirths.11  0.301729  0.060652  4.975 1.12e-06 ***
## Covid.11        0.077033  0.232583  0.331  0.74073
## Births.12      -0.002436  0.084672 -0.029  0.97707
## Marriages.12   -0.043289  0.097507 -0.444  0.65741
## Deaths.12      -0.113469  0.122913 -0.923  0.35669
## Stillbirths.12  0.291146  0.065800  4.425 1.37e-05 ***
## Covid.12        -0.214709  0.517908 -0.415  0.67876

```

```

## Births.13      -0.016587  0.088041  -0.188  0.85069
## Marriages.13   -0.165829  0.096464  -1.719  0.08667 .
## Deaths.13      0.115423  0.127833  0.903  0.36732
## Stillbirths.13  0.192404  0.070994  2.710  0.00713 **
## Covid.13        -0.184805  0.610561  -0.303  0.76235
## Births.14        0.056592  0.087219  0.649  0.51695
## Marriages.14    -0.121522  0.095968  -1.266  0.20643
## Deaths.14        0.081611  0.130237  0.627  0.53140
## Stillbirths.14   0.024779  0.071039  0.349  0.72748
## Covid.14         -0.259194  0.589021  -0.440  0.66024
## Births.15        0.017965  0.080400  0.223  0.82335
## Marriages.15     0.393798  0.092031  4.279  2.56e-05 ***
## Deaths.15        0.091231  0.130997  0.696  0.48672
## Stillbirths.15   0.012393  0.070699  0.175  0.86098
## Covid.15          0.161683  0.559641  0.289  0.77286
## Births.16        0.056757  0.058986  0.962  0.33676
## Marriages.16     -0.304778  0.092535  -3.294  0.00111 **
## Deaths.16        -0.203902  0.105921  -1.925  0.05521 .
## Stillbirths.16   -0.031051  0.065472  -0.474  0.63568
## Covid.16          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.11 + Marriages.11 + Deaths.11 + Stillbirths.11 + Covid.11 + Births.12 + Marriages.12 ...
## 
##           Estimate Std. Error t value Pr(>|t|)
## Births.11      -0.003058  0.022243 -0.137 0.890750
## Marriages.11    -0.031319  0.026198 -1.195 0.232883
## Deaths.11       -0.077225  0.032817 -2.353 0.019282 *
## Stillbirths.11  -0.018264  0.018283 -0.999 0.318635
## Covid.11         2.047698  0.070109 29.208 < 2e-16 ***
## Births.12       -0.007576  0.025523 -0.297 0.766814
## Marriages.12     0.035272  0.029392  1.200 0.231097
## Deaths.12        0.029260  0.037050  0.790 0.430332
## Stillbirths.12   -0.027923  0.019834 -1.408 0.160265
## Covid.12         -1.732644  0.156115 -11.098 < 2e-16 ***
## Births.13       -0.021335  0.026539 -0.804 0.422109
## Marriages.13     -0.022357  0.029078 -0.769 0.442601
## Deaths.13        0.106546  0.038533  2.765 0.006058 **
## Stillbirths.13   0.001641  0.021400  0.077 0.938917
## Covid.13          0.694246  0.184044  3.772 0.000196 ***
## Births.14        0.048926  0.026291  1.861 0.063764 .
## Marriages.14     0.024346  0.028928  0.842 0.400696
## Deaths.14        -0.039781  0.039258 -1.013 0.311761
## Stillbirths.14   -0.004744  0.021413 -0.222 0.824809
## Covid.14          -0.661884  0.177551 -3.728 0.000232 ***

```

```

## Births.15      0.007830  0.024235  0.323 0.746871
## Marriages.15 -0.032374  0.027741 -1.167 0.244174
## Deaths.15     -0.009696  0.039487 -0.246 0.806201
## Stillbirths.15 0.030102  0.021311  1.413 0.158874
## Covid.15       0.564143  0.168695  3.344 0.000934 ***
## Births.16      -0.010839  0.017781 -0.610 0.542599
## Marriages.16   0.002306  0.027893  0.083 0.934179
## Deaths.16      0.035573  0.031928  1.114 0.266138
## Stillbirths.16 -0.002869  0.019736 -0.145 0.884508
## Covid.16        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

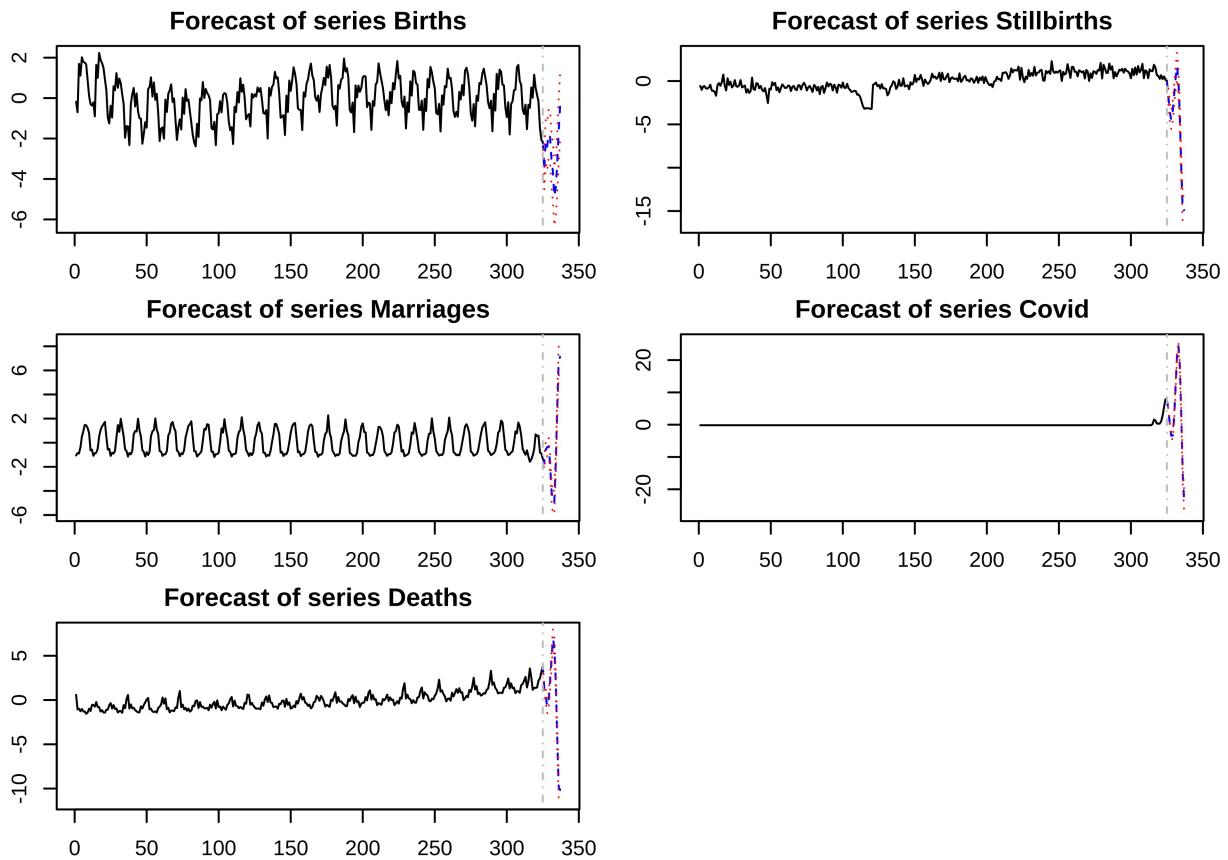
```

prediction for final dataset including covid

```

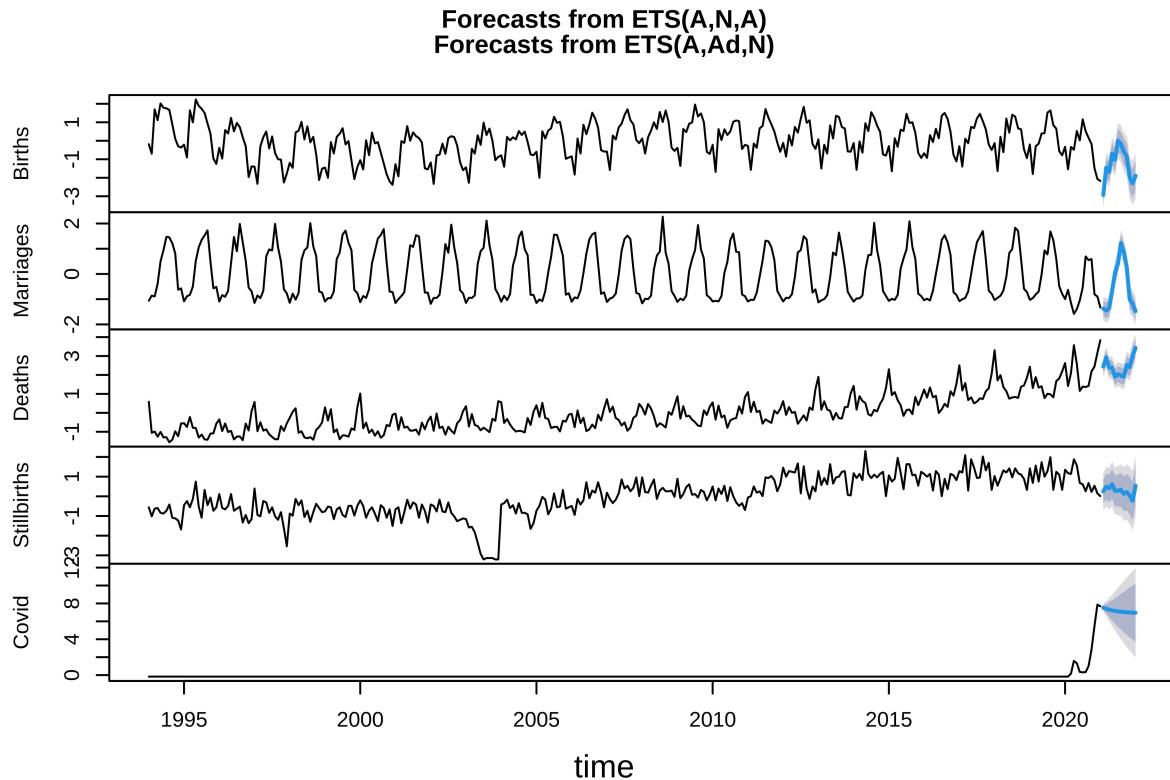
fcast = predict(final_ts_var, n.ahead = 12, ci = 0.95) # predicting the 12 months after the data ends
par(mar = c(2,2,2,2))
plot(fcast)

```



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

```

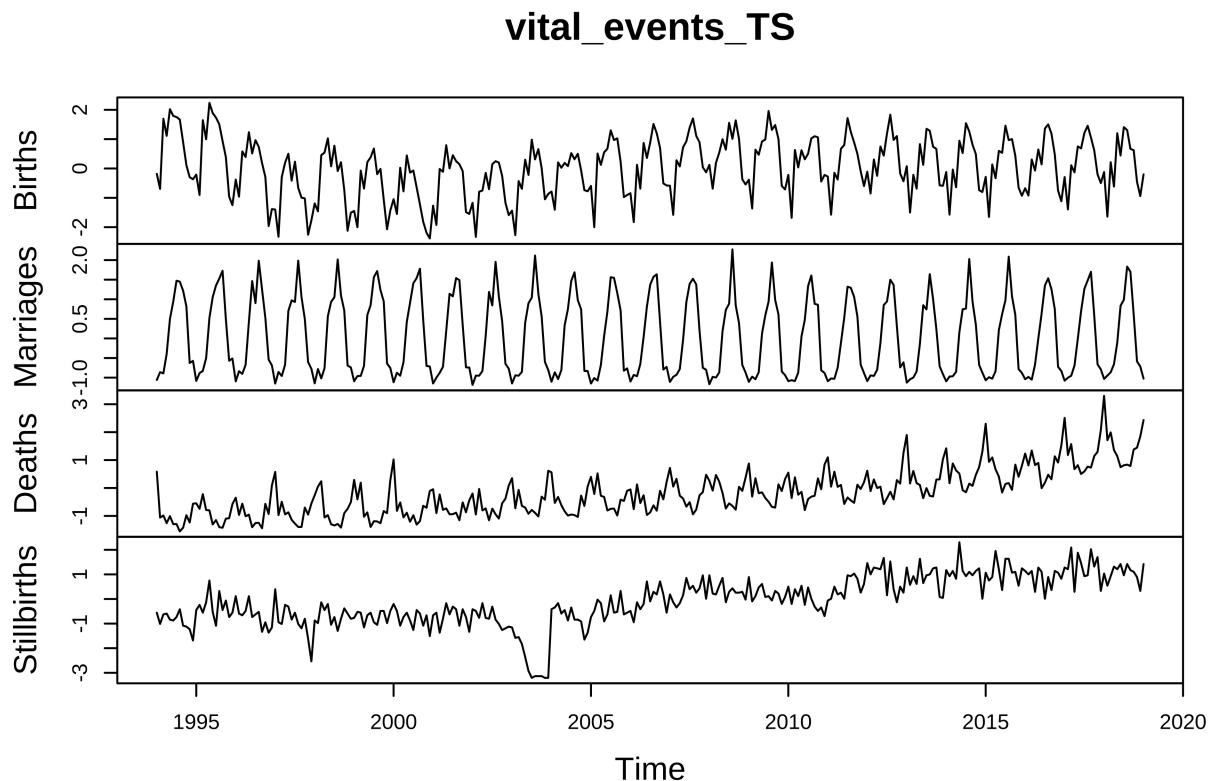
Vital_Events_standardized <- Final_dataset %>% mutate_each_(list(~scale(.) %>% as.vector),
                                                 vars = c("Births","Marriages","Deaths","Stillbirths"))

```

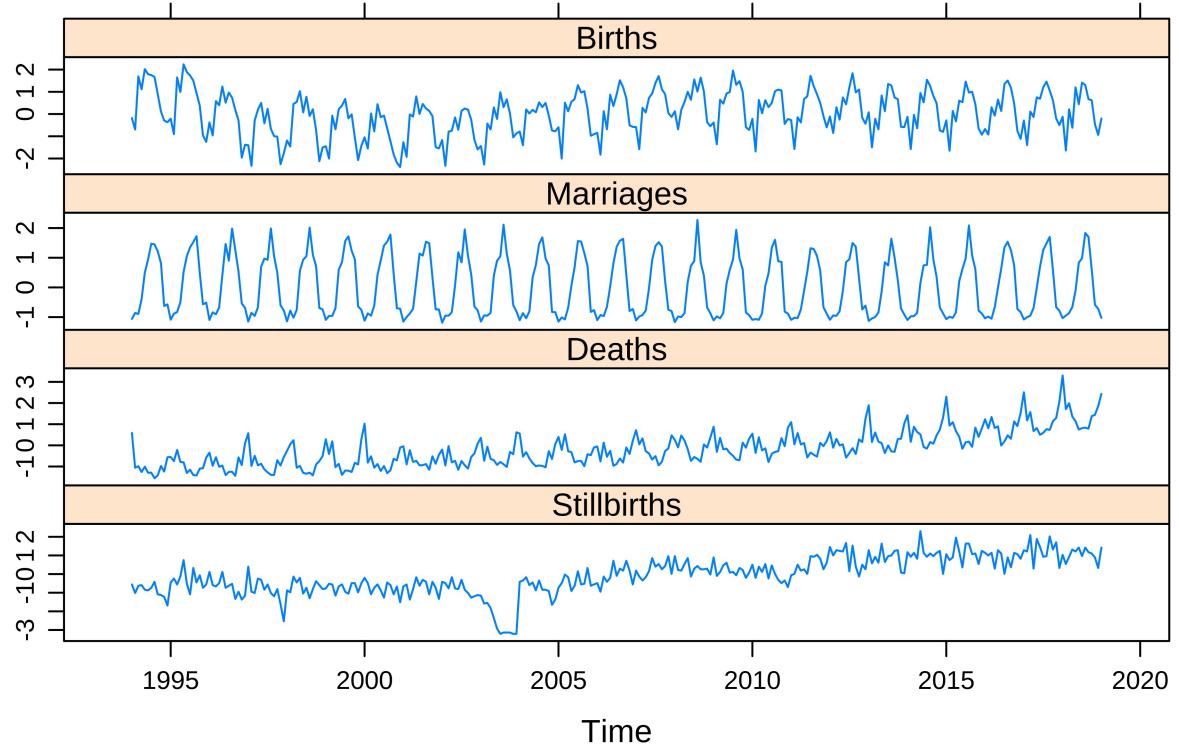
Convert data frame to a time series up to 2019, so that I can compare predictions for 2021-2021 to actual observed numbers

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

```
plot(vital_events_TS)
```

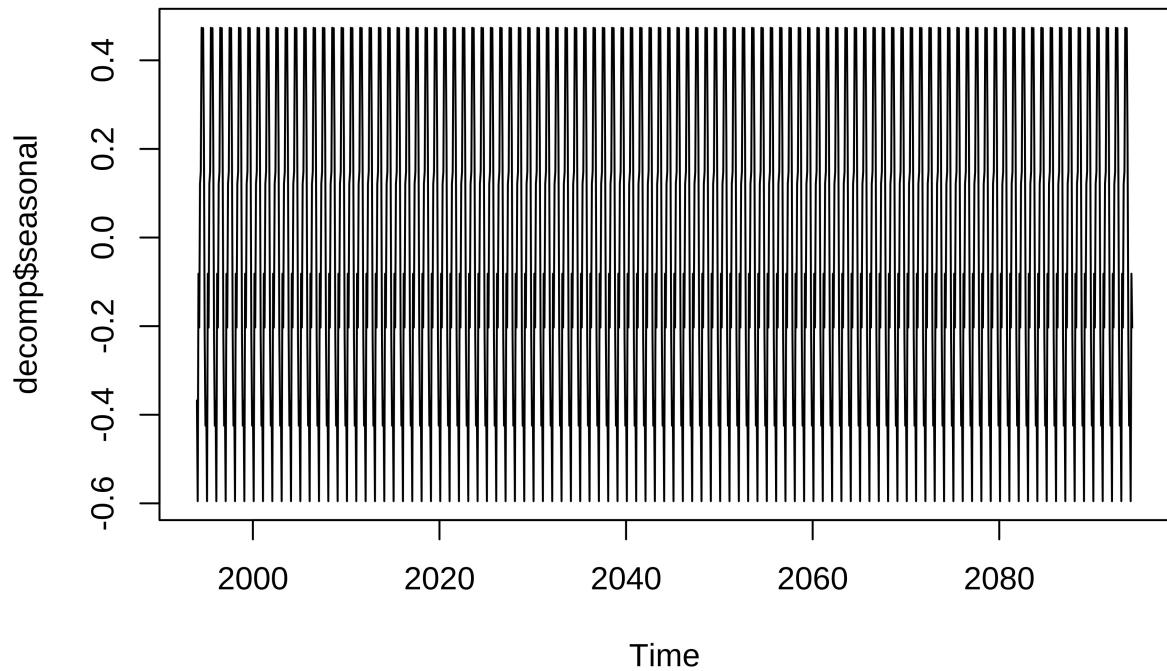


```
xyplot.ts(vital_events_TS)
```



decompose data and display results vital events without covid

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



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