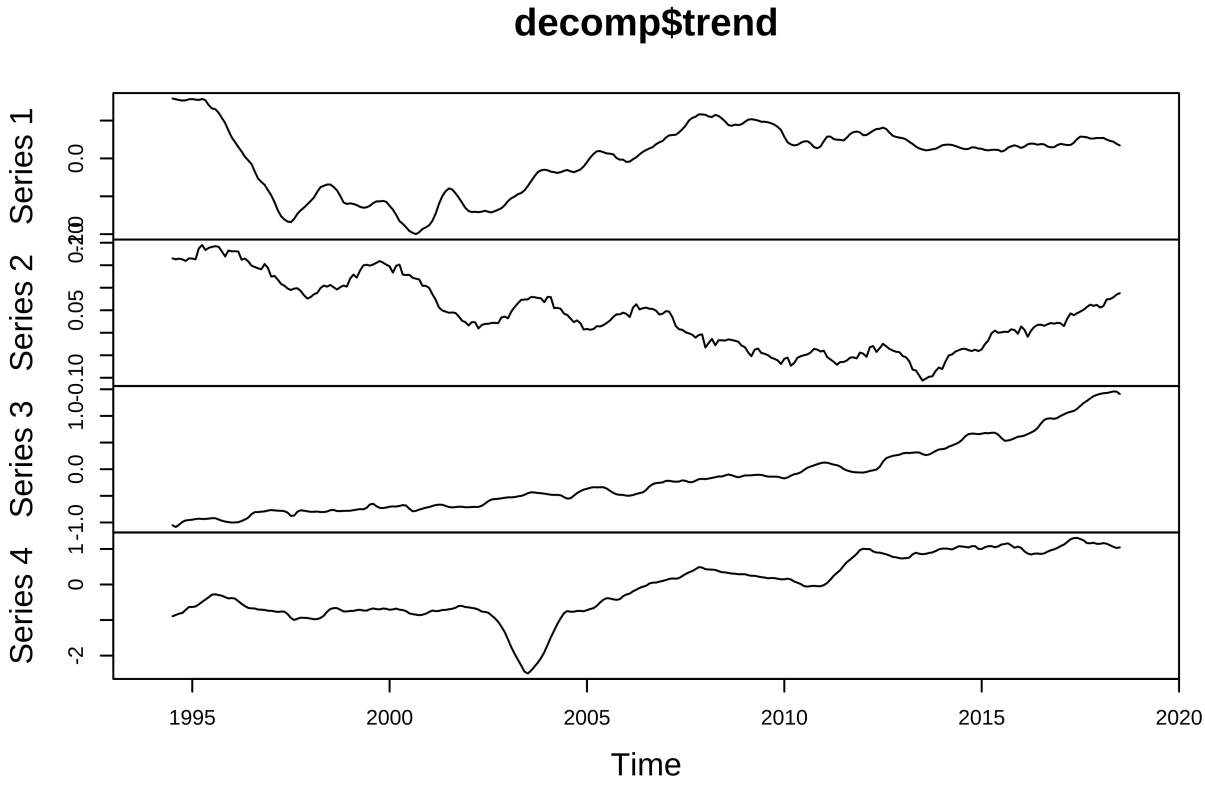
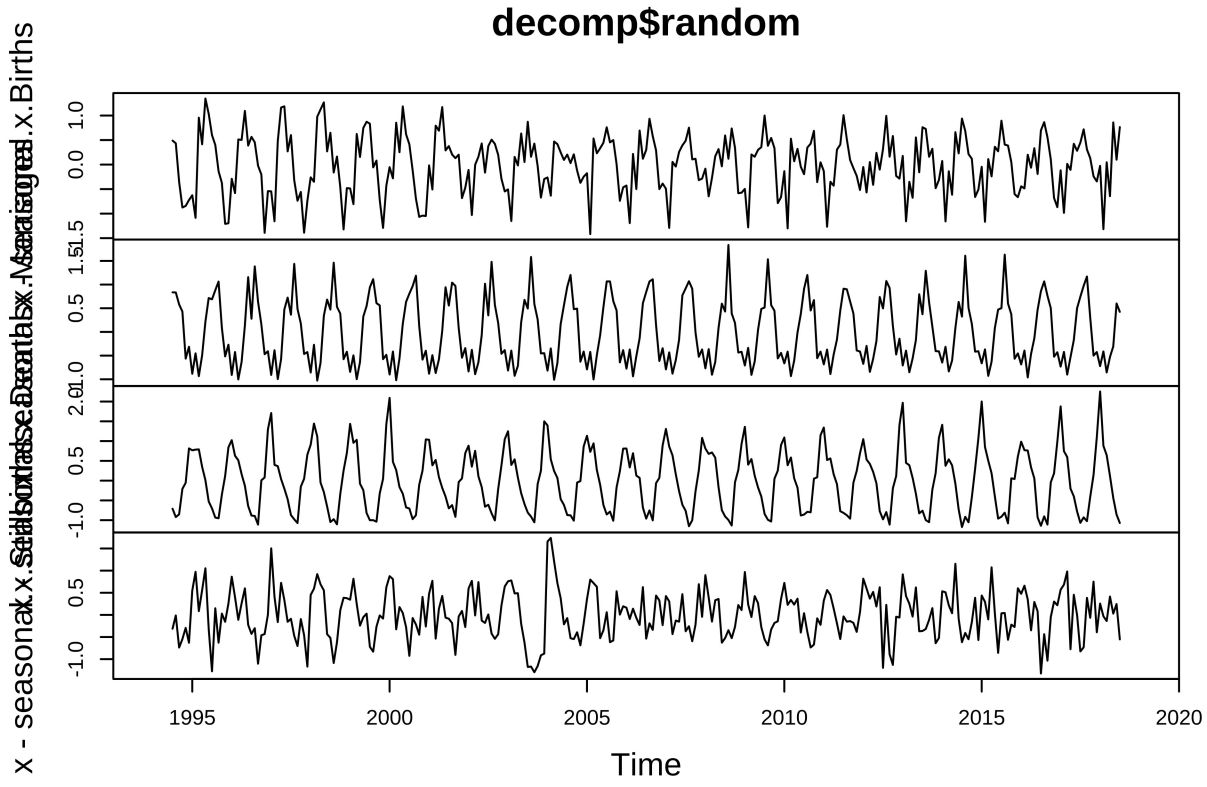



```
plot(decomp$random)
```



Dicky-Fuller test

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

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

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## 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]
```
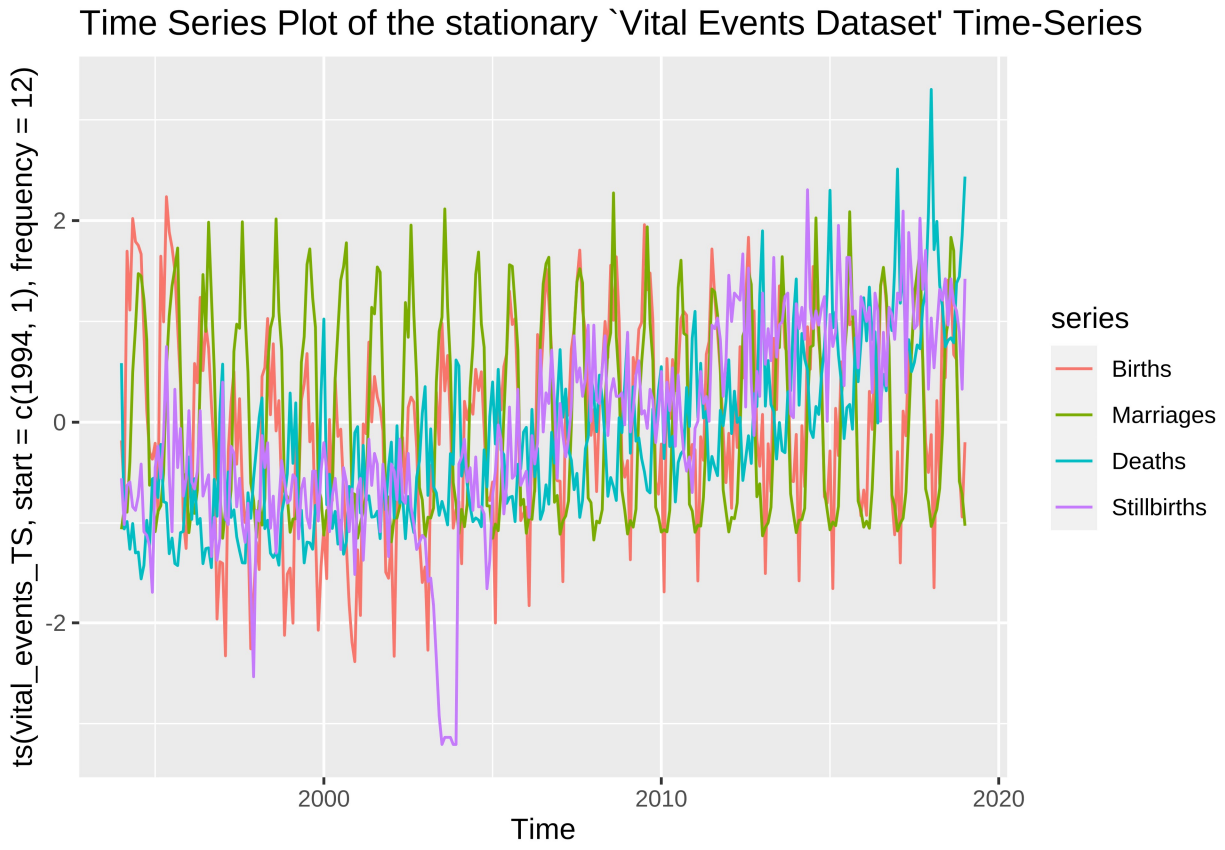

```
## Dickey-Fuller = -17.897, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
##
##
## $Deaths
##
##  Augmented Dickey-Fuller Test
##
## data:  newX[, i]
## Dickey-Fuller = -7.4351, Lag order = 6, p-value = 0.01
## alternative hypothesis: stationary
##
##
## $Stillbirths
##
##  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 0.64
## 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.l1
##
##                 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.l2  0.274422   0.066447   4.130 4.84e-05 ***
## Births.l3       0.056977   0.088660   0.643  0.52100
## Marriages.l3   -0.083387   0.096414  -0.865  0.38786
## Deaths.l3       0.076731   0.127968   0.600  0.54927
## Stillbirths.l3  0.030466   0.070685   0.431  0.66681
## Births.l4       0.027638   0.088342   0.313  0.75463
## Marriages.l4   -0.264438   0.095557  -2.767  0.00604 **
## Deaths.l4      -0.013943   0.130771  -0.107  0.91517
## Stillbirths.l4 -0.043111   0.070653  -0.610  0.54226
## Births.l5      -0.064941   0.080277  -0.809  0.41925
## Marriages.l5    0.115026   0.092278   1.247  0.21365
## Deaths.l5       0.139710   0.130846   1.068  0.28659
## Stillbirths.l5 -0.001272   0.070875  -0.018  0.98570
## Births.l6       0.089896   0.058505   1.537  0.12557
## Marriages.l6   -0.223793   0.093468  -2.394  0.01733 *
## Deaths.l6      -0.166313   0.105895  -1.571  0.11746
## Stillbirths.l6  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.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Births.l2 + Marriages.l2 + Deaths
##
##                 Estimate Std. Error t value Pr(>|t|)
## Births.l1       0.169253   0.042127   4.018 7.62e-05 ***
## Marriages.l1    0.489528   0.051388   9.526  < 2e-16 ***
## Deaths.l1      -0.328043   0.063256  -5.186 4.21e-07 ***
## Stillbirths.l1  0.009327   0.034858   0.268 0.789228
## Births.l2      -0.303776   0.048588  -6.252 1.57e-09 ***
## Marriages.l2    0.023323   0.056722   0.411 0.681264
## Deaths.l2       0.391482   0.070103   5.584 5.70e-08 ***
## Stillbirths.l2 -0.155644   0.038302  -4.064 6.33e-05 ***
## Births.l3       0.089269   0.051106   1.747 0.081815 .
## Marriages.l3   -0.160989   0.055576  -2.897 0.004078 **
## Deaths.l3      -0.285342   0.073764  -3.868 0.000137 ***
## Stillbirths.l3  0.080485   0.040745   1.975 0.049244 *
## Births.l4       0.217961   0.050923   4.280 2.59e-05 ***
## Marriages.l4   -0.221063   0.055082  -4.013 7.75e-05 ***
## Deaths.l4      -0.084982   0.075380  -1.127 0.260577
## Stillbirths.l4  0.155205   0.040726   3.811 0.000171 ***
## Births.l5       0.131916   0.046274   2.851 0.004697 **
## Marriages.l5   -0.062135   0.053191  -1.168 0.243777
## Deaths.l5       0.074042   0.075423   0.982 0.327130
## Stillbirths.l5 -0.023608   0.040854  -0.578 0.563837
## Births.l6      -0.320439   0.033724  -9.502  < 2e-16 ***
## Marriages.l6   -0.128101   0.053877  -2.378 0.018117 *
## Deaths.l6       0.174122   0.061041   2.853 0.004671 **
```

```
## Stillbirths.l6 -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.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Births.l2 + Marriages.l2 + Deaths.l
##
##                 Estimate Std. Error t value Pr(>|t|)
## Births.l1      -0.166115   0.047578  -3.491 0.000561 ***
## Marriages.l1   -0.128792   0.058037  -2.219 0.027307 *
## Deaths.l1       0.338831   0.071440   4.743 3.41e-06 ***
## Stillbirths.l1 -0.144012   0.039368  -3.658 0.000305 ***
## Births.l2       0.045533   0.054874   0.830 0.407395
## Marriages.l2    0.011435   0.064062   0.178 0.858465
## Deaths.l2       0.203972   0.079174   2.576 0.010517 *
## Stillbirths.l2  0.113077   0.043258   2.614 0.009448 **
## Births.l3       0.055496   0.057719   0.961 0.337164
## Marriages.l3    0.144884   0.062767   2.308 0.021736 *
## Deaths.l3       0.299109   0.083308   3.590 0.000392 ***
## Stillbirths.l3 -0.004528   0.046016  -0.098 0.921692
## Births.l4       0.110414   0.057512   1.920 0.055927 .
## Marriages.l4    0.046564   0.062209   0.749 0.454800
## Deaths.l4      -0.079049   0.085133  -0.929 0.353955
## Stillbirths.l4  0.029107   0.045996   0.633 0.527387
## Births.l5      -0.070343   0.052261  -1.346 0.179430
## Marriages.l5    0.243496   0.060074   4.053 6.60e-05 ***
## Deaths.l5       0.241997   0.085182   2.841 0.004840 **
## Stillbirths.l5  0.046596   0.046141   1.010 0.313460
## Births.l6      -0.042412   0.038088  -1.114 0.266466
## Marriages.l6   -0.150996   0.060849  -2.481 0.013690 *
## Deaths.l6      -0.060801   0.068939  -0.882 0.378580
## Stillbirths.l6  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.l1 + Marriages.l1 + Deaths.l1 + Stillbirths.l1 + Births.l2 + Marriages.l2 + Dea
##
##                 Estimate Std. Error t value Pr(>|t|)
## Births.l1       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"))
```

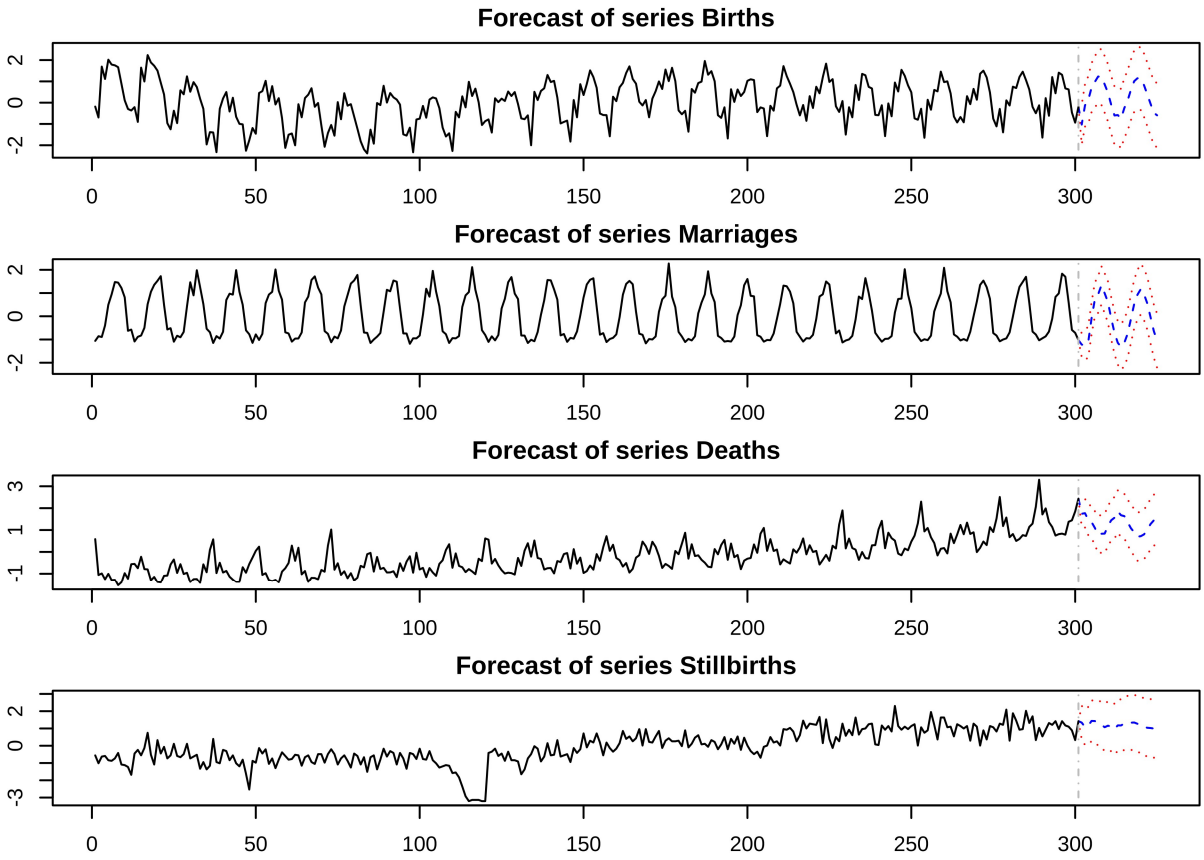
```
## $Granger
##
##  Granger causality H0: Marriages do not Granger-cause Births Deaths
##  Stillbirths
##
## data:  VAR object vital_ts_var
## F-Test = 14.545, df1 = 18, df2 = 1084, p-value < 2.2e-16
##
##
## $Instant
##
##  H0: No instantaneous causality between: Marriages and Births Deaths
##  Stillbirths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



```
fcast2
```

```
## $Births
##              fcst        lower       upper        CI
##  [1,] -1.02944692 -1.964801461 -0.09409238 0.9353545
##  [2,] -0.12514608 -1.123965327  0.87367317 0.9988192
##  [3,]  0.12685142 -0.989391468  1.24309432 1.1162429
##  [4,]  0.70567024 -0.443431797  1.85477227 1.1491020
##  [5,]  0.97606353 -0.224253274  2.17638032 1.2003168
##  [6,]  1.22865077 -0.008980785  2.46628232 1.2376316
##  [7,]  1.21119234 -0.102160929  2.52454562 1.3133533
##  [8,]  0.85971572 -0.472122197  2.19155365 1.3318379
##  [9,]  0.46841537 -0.879018748  1.81584949 1.3474341
## [10,] -0.09774769 -1.449323095  1.25382771 1.3515754
## [11,] -0.60179276 -1.966754695  0.76316918 1.3649619
## [12,] -0.58074382 -1.951569281  0.79008164 1.3708255
## [13,] -0.74929556 -2.140829277  0.64223816 1.3915337
## [14,] -0.24910636 -1.647947470  1.14973475 1.3988411
## [15,]  0.09757544 -1.317529429  1.51268030 1.4151049
## [16,]  0.60177198 -0.820840800  2.02438477 1.4226128
## [17,]  1.00804805 -0.432938398  2.44903450 1.4409864
## [18,]  1.14826532 -0.309834727  2.60636537 1.4581000
## [19,]  1.12838800 -0.348627941  2.60540395 1.4770159
## [20,]  0.82325339 -0.663879292  2.31038608 1.4871327
## [21,]  0.39088327 -1.100795523  1.88256207 1.4916788
## [22,] -0.05288043 -1.547352479  1.44159163 1.4944721
## [23,] -0.47673406 -1.978670458  1.02520234 1.5019364
## [24,] -0.59395428 -2.103924022  0.91601546 1.5099697
##
## $Marriages
##              fcst       lower      upper        CI
##  [1,] -1.21914841 -1.75831304 -0.6799838 0.5391646
##  [2,] -1.25448833 -1.88187077 -0.6271059 0.6273824
##  [3,] -1.09705777 -1.77091425 -0.4232013 0.6738565
##  [4,] -0.08663150 -0.77469471  0.6014317 0.6880632
##  [5,]  0.72055412 -0.01105549  1.4521637 0.7316096
##  [6,]  0.93995191  0.14982137  1.7300824 0.7901305
##  [7,]  1.33092738  0.50616252  2.1556922 0.8247649
##  [8,]  0.98895941  0.12597109  1.8519477 0.8629883
##  [9,]  0.61311822 -0.28091492  1.5071514 0.8940331
## [10,] -0.08488078 -0.98951950  0.8197579 0.9046387
## [11,] -0.71051448 -1.63010905  0.2090801 0.9195946
## [12,] -1.14226932 -2.08162618 -0.2029125 0.9393569
## [13,] -1.31835487 -2.30058180 -0.3361279 0.9822269
## [14,] -1.13977848 -2.15033320 -0.1292238 1.0105547
## [15,] -0.75309411 -1.77999124  0.2738030 1.0268971
## [16,] -0.12173567 -1.15544986  0.9119785 1.0337142
## [17,]  0.52758431 -0.51765816  1.5728268 1.0452425
## [18,]  0.92558012 -0.14030266  1.9914629 1.0658828
## [19,]  1.16438822  0.07170304  2.2570734 1.0926852
## [20,]  0.95164654 -0.16389256  2.0671856 1.1155391
## [21,]  0.55617847 -0.57228062  1.6846376 1.1284591
## [22,] -0.04014628 -1.17467309  1.0943805 1.1345268
## [23,] -0.64050299 -1.78527860  0.5042726 1.1447756
```