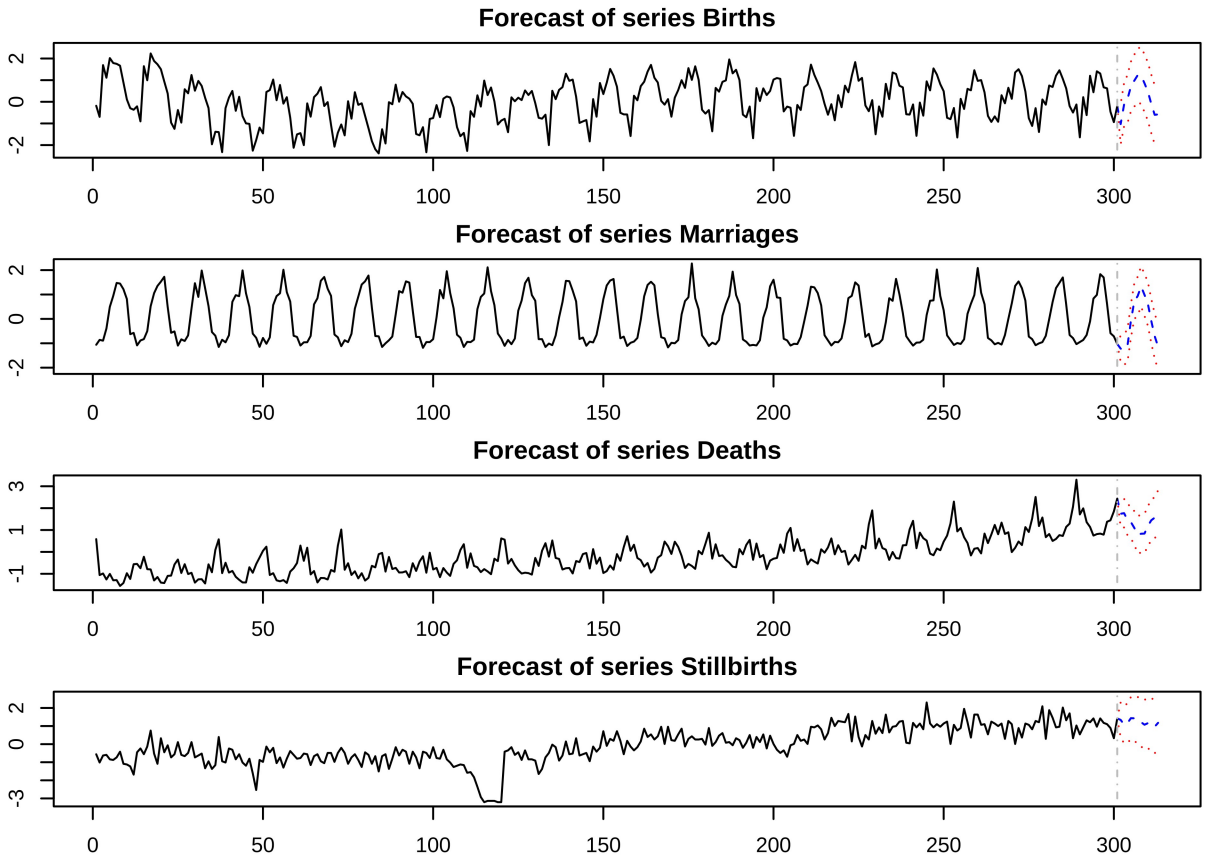
```
## [24,] -1.05591408 -2.21751515  0.1056870 1.1616011
##
## $Deaths
##            fcst       lower    upper        CI
##  [1,] 1.7437129  1.13478599 2.352640 0.6089269
##  [2,] 1.7711305  1.11680011 2.425461 0.6543304
##  [3,] 1.4618584  0.76909086 2.154626 0.6927676
##  [4,] 1.3646516  0.61819464 2.111109 0.7464570
##  [5,] 1.1006891  0.33805412 1.863324 0.7626350
##  [6,] 0.7859971 -0.06539757 1.637392 0.8513946
##  [7,] 0.8307953 -0.03275349 1.694344 0.8635488
##  [8,] 0.8381166 -0.05757421 1.733807 0.8956908
##  [9,] 1.1859087  0.27570012 2.096117 0.9102085
## [10,] 1.4467674  0.52415997 2.369375 0.9226075
## [11,] 1.5646945  0.61411646 2.515272 0.9505780
## [12,] 1.8482346  0.88429906 2.812170 0.9639356
## [13,] 1.6766831  0.67911253 2.674254 0.9975706
## [14,] 1.6359125  0.61889954 2.652926 1.0170130
## [15,] 1.3622976  0.32471179 2.399883 1.0375858
## [16,] 1.0842956  0.02312571 2.145466 1.0611699
## [17,] 0.8980867 -0.17612445 1.972298 1.0742111
## [18,] 0.6984174 -0.40235396 1.799189 1.1007713
## [19,] 0.7191444 -0.39549608 1.833785 1.1146405
## [20,] 0.8006820 -0.32953766 1.930902 1.1302197
## [21,] 1.0108751 -0.13248905 2.154239 1.1433642
## [22,] 1.2750193  0.12222789 2.427811 1.1527915
## [23,] 1.4431649  0.27410365 2.612226 1.1690612
## [24,] 1.6119158  0.42930902 2.794523 1.1826067
##
## $Stillbirths
##            fcst       lower    upper        CI
##  [1,] 1.3399049  0.37266756 2.307142 0.9672374
##  [2,] 1.0819892  0.04513851 2.118840 1.0368507
##  [3,] 1.1630142  0.07687611 2.249152 1.0861380
##  [4,] 1.4372873  0.26687255 2.607702 1.1704148
##  [5,] 1.4301592  0.19422768 2.666091 1.2359315
##  [6,] 1.3096296  0.01454858 2.604711 1.2950811
##  [7,] 1.2135121 -0.12634485 2.553369 1.3398569
##  [8,] 1.0736697 -0.29612109 2.443460 1.3697908
##  [9,] 1.1605838 -0.23944302 2.560611 1.4000269
## [10,] 1.1134717 -0.31962779 2.546571 1.4330994
## [11,] 0.9655475 -0.50018815 2.431283 1.4657356
## [12,] 1.1795841 -0.30052668 2.659695 1.4801108
## [13,] 1.1749637 -0.33884088 2.688768 1.5138045
## [14,] 1.2945185 -0.23911674 2.828154 1.5336352
## [15,] 1.3306540 -0.22574861 2.887057 1.5564026
## [16,] 1.3358799 -0.24355452 2.915314 1.5794344
## [17,] 1.3459530 -0.25047909 2.942385 1.5964320
## [18,] 1.2728585 -0.34405613 2.889773 1.6169147
## [19,] 1.2026380 -0.43041140 2.835687 1.6330494
## [20,] 1.1003348 -0.54755748 2.748227 1.6478923
## [21,] 1.0411433 -0.62175633 2.704043 1.6628996
## [22,] 1.0254704 -0.64960951 2.700550 1.6750800
## [23,] 0.9966088 -0.69316806 2.686386 1.6897769
```

```
## [24,] 1.0754872 -0.62521336 2.776188 1.7007006
```

```
fcast3 = predict(vital_ts_var, n.ahead = 12) # predicting the 12 months after the data ends
par(mar = c(2,2,2,2))
plot(fcast3)
```




```
fcast3
```

```
## $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
##
## $Marriages
##              fcst       lower      upper        CI
```

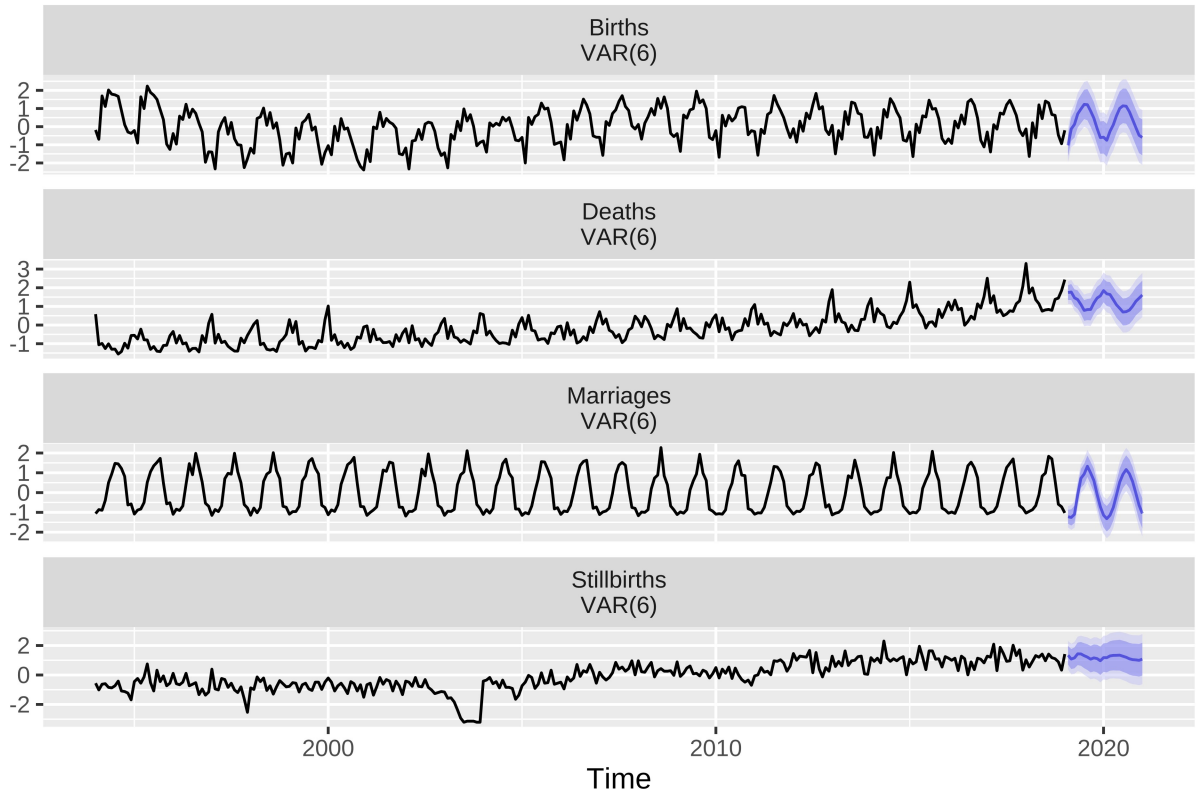
```
##  [1,] -1.21914841 -1.75831304 -0.6799838 0.5391646
##  [2,] -1.25448833 -1.88187077 -0.6271059 0.6273824
##  [3,] -1.09705777 -1.77091425 -0.4232013 0.6738565
##  [4,] -0.08663150 -0.77469471  0.6014317 0.6880632
##  [5,]  0.72055412 -0.01105549  1.4521637 0.7316096
##  [6,]  0.93995191  0.14982137  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
##
## $Deaths
##            fcst       lower    upper        CI
##  [1,] 1.7437129  1.13478599 2.352640 0.6089269
##  [2,] 1.7711305  1.11680011 2.425461 0.6543304
##  [3,] 1.4618584  0.76909086 2.154626 0.6927676
##  [4,] 1.3646516  0.61819464 2.111109 0.7464570
##  [5,] 1.1006891  0.33805412 1.863324 0.7626350
##  [6,] 0.7859971 -0.06539757 1.637392 0.8513946
##  [7,] 0.8307953 -0.03275349 1.694344 0.8635488
##  [8,] 0.8381166 -0.05757421 1.733807 0.8956908
##  [9,] 1.1859087  0.27570012 2.096117 0.9102085
## [10,] 1.4467674  0.52415997 2.369375 0.9226075
## [11,] 1.5646945  0.61411646 2.515272 0.9505780
## [12,] 1.8482346  0.88429906 2.812170 0.9639356
##
## $Stillbirths
##            fcst       lower    upper        CI
##  [1,] 1.3399049  0.37266756 2.307142 0.9672374
##  [2,] 1.0819892  0.04513851 2.118840 1.0368507
##  [3,] 1.1630142  0.07687611 2.249152 1.0861380
##  [4,] 1.4372873  0.26687255 2.607702 1.1704148
##  [5,] 1.4301592  0.19422768 2.666091 1.2359315
##  [6,] 1.3096296  0.01454858 2.604711 1.2950811
##  [7,] 1.2135121 -0.12634485 2.553369 1.3398569
##  [8,] 1.0736697 -0.29612109 2.443460 1.3697908
##  [9,] 1.1605838 -0.23944302 2.560611 1.4000269
## [10,] 1.1134717 -0.31962779 2.546571 1.4330994
## [11,] 0.9655475 -0.50018815 2.431283 1.4657356
## [12,] 1.1795841 -0.30052668 2.659695 1.4801108
```

```
head(Final_dataset)
```

```
##         Date Births Marriages Deaths Stillbirths Covid
## 1 1994-01-01  11631      2078   8094          75     0
## 2 1994-02-01  11254      2650   6428          62     0
## 3 1994-03-01  13003      2557   6503          73     0
## 4 1994-04-01  12576      3967   6224          74     0
## 5 1994-05-01  13240      6493   6483          67     0
## 6 1994-06-01  13072      7754   6187          66     0
```

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 acutal 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")

covid_stand <-  Covid_monthly %>% mutate_each_(list(~scale(.) %>% as.vector),
                                vars = c("Covid"))
covid_stand$Date <- as.Date(covid_stand$Date,"%Y-%m-%d")
summary(covid_stand)
```

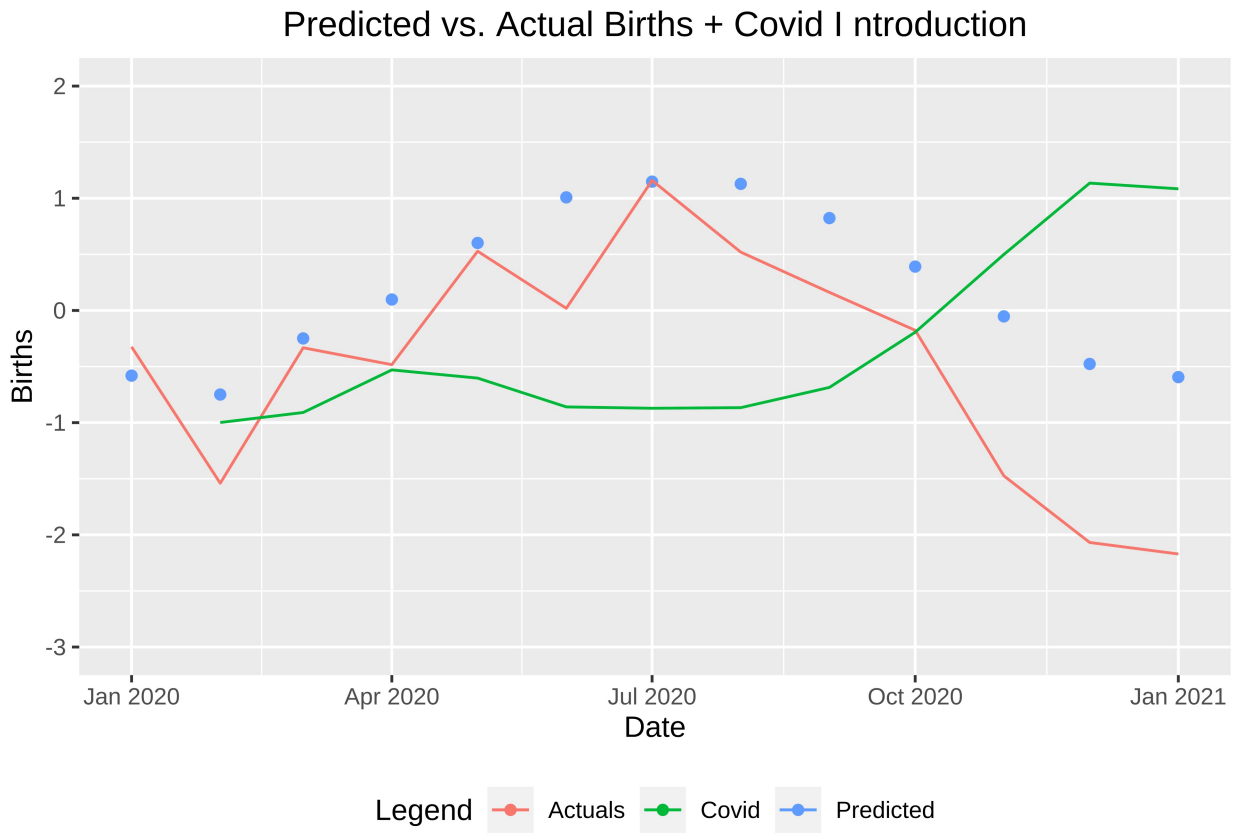
```
##       Date                Covid
##  Min.   :2020-02-01   Min.   :-0.9986
##  1st Qu.:2020-07-16   1st Qu.:-0.7585
##  Median :2021-01-01   Median :-0.2016
##  Mean   :2020-12-31   Mean   : 0.0000
##  3rd Qu.:2021-06-16   3rd Qu.: 0.4092
##  Max.   :2021-12-01   Max.   : 3.1562
```

Predicted vs Actuals Births

```
ggplot() +

      geom_point(data=predicted, aes(x=Date, y=Births, color="Predicted")) +
      geom_line(data=actuals, aes(x=Date, y=Births,color="Actuals"))  +
      geom_line(data=covid_stand, aes(x = Date, y=Covid,color="Covid"))  +
      ylim(-3,+2)+
      labs(color='Legend', title = "Predicted vs. Actual Births + Covid I ntroduction")+
      theme(legend.position = c("bottom"), plot.title = element_text(hjust = 0.5)) +
      scale_x_date(limits = as.Date(c("2020-01-01","2021-01-01")))
```

```
## Warning: Removed 11 row(s) containing missing values (geom_path).
```

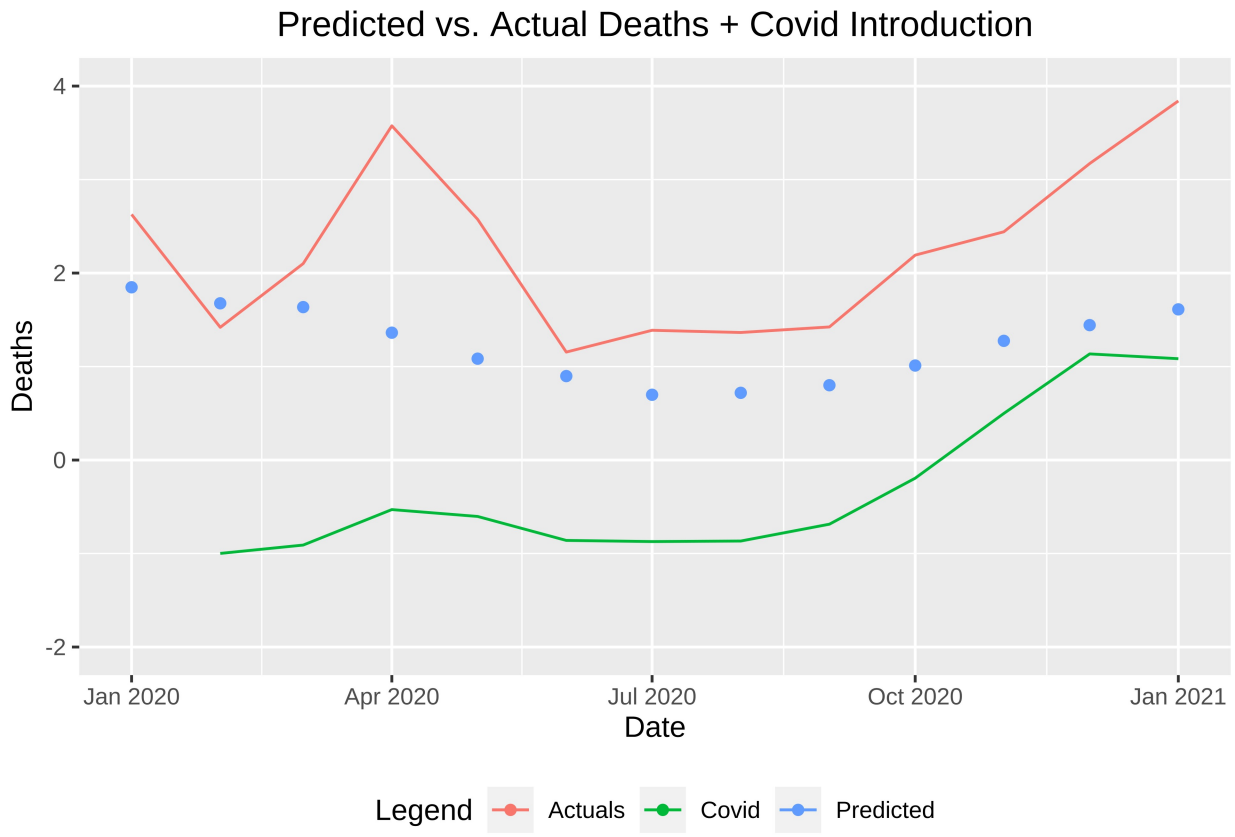


Predicted vs Actuals Deaths

```
ggplot() +

      geom_point(data=predicted, aes(x=Date, y=Deaths, color="Predicted")) +
      geom_line(data=actuals, aes(x=Date, y=Deaths,color="Actuals"))  +
      geom_line(data=covid_stand, aes(x = Date, y=Covid,color="Covid"))  +
      ylim(-2,+4)+
      labs(color='Legend', title = "Predicted vs. Actual Deaths + Covid Introduction")+ theme(legend.pos
      scale_x_date(limits = as.Date(c("2020-01-01","2021-01-01")))
```

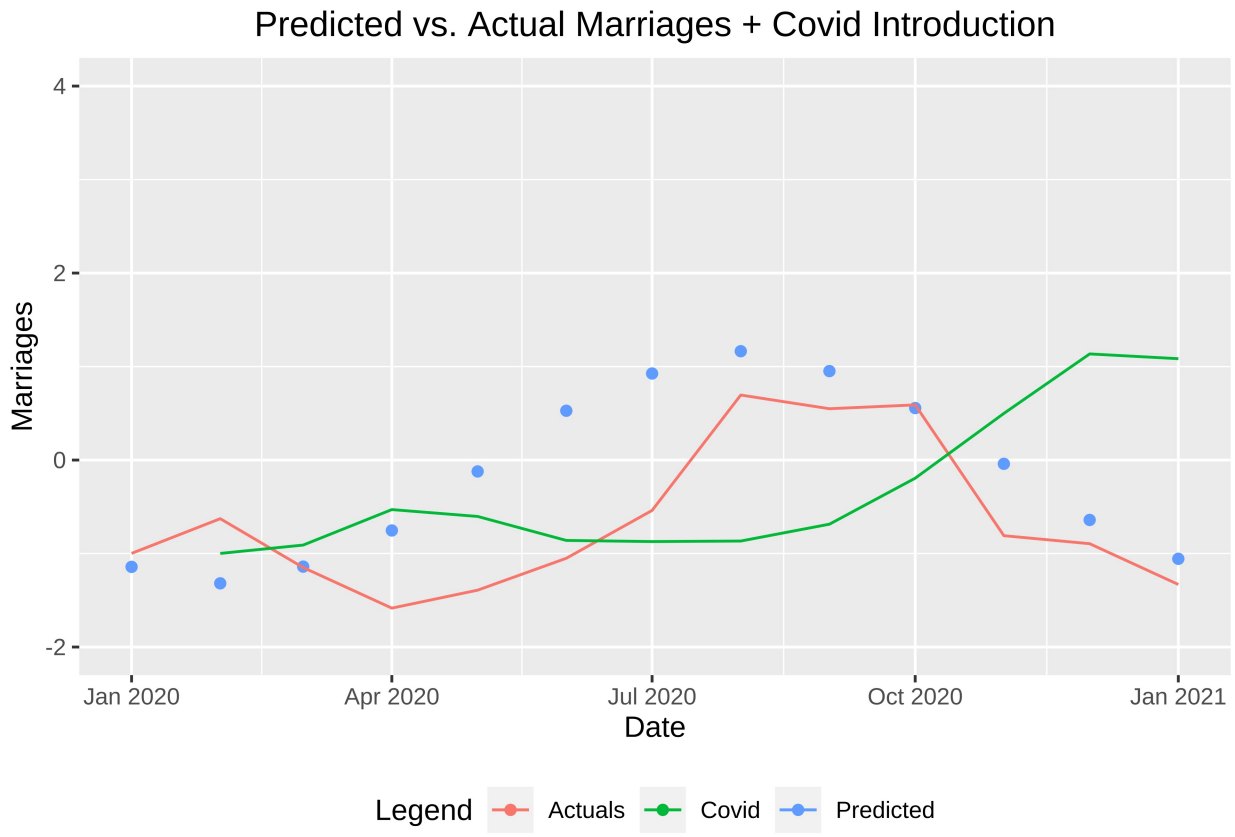
```
## Warning: Removed 11 row(s) containing missing values (geom_path).
```




```
ggplot() +

      geom_point(data=predicted, aes(x=Date, y=Marriages, color="Predicted")) +
      geom_line(data=actuals, aes(x=Date, y=Marriages,color="Actuals"))  +
      geom_line(data=covid_stand, aes(x = Date, y=Covid,color="Covid"))  +
      ylim(-2,+4)+
      labs(color='Legend', title = "Predicted vs. Actual Marriages + Covid Introduction")+ theme(legend
      scale_x_date(limits = as.Date(c("2020-01-01","2021-01-01")))
```

```
## Warning: Removed 11 row(s) containing missing values (geom_path).
```

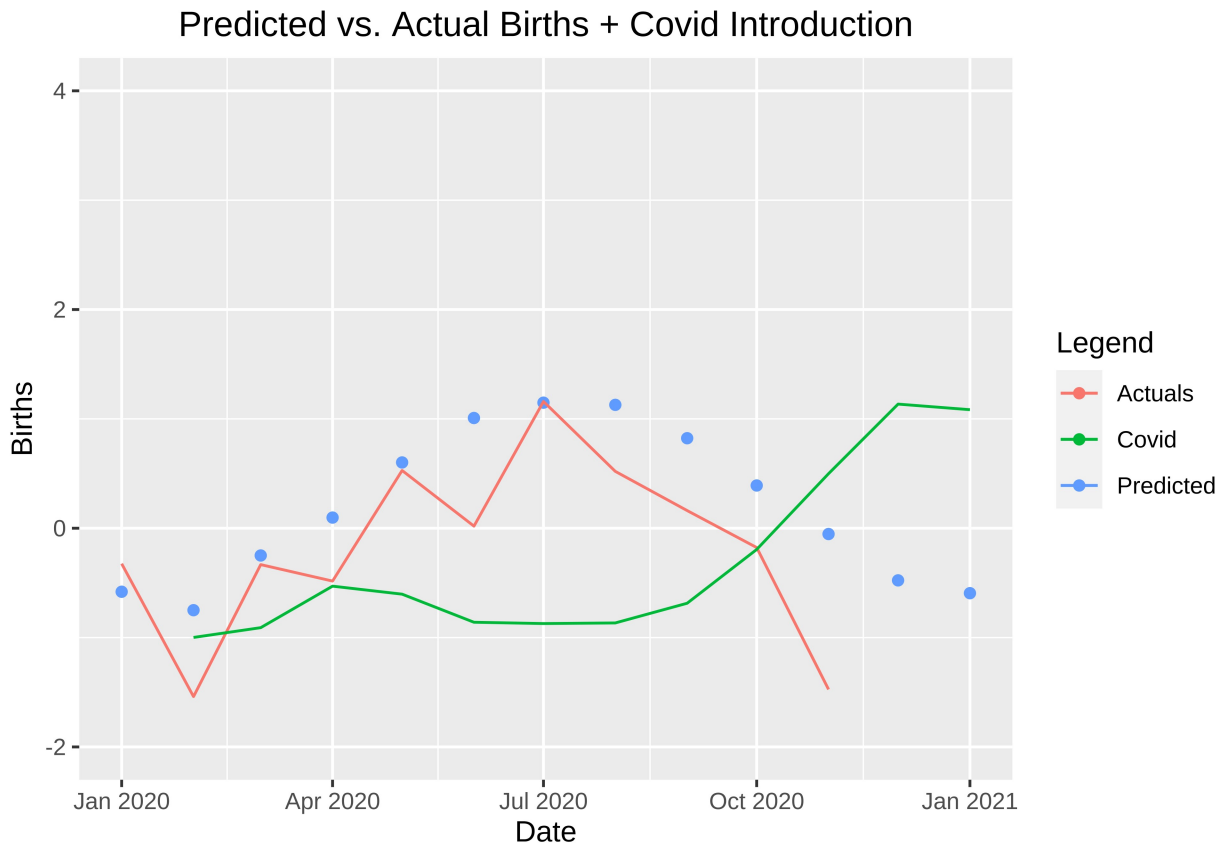



```
ggplot() +

      geom_point(data=predicted, aes(x=Date, y=Births, color="Predicted")) +
      geom_line(data=actuals, aes(x=Date, y=Births,color="Actuals"))  +
      geom_line(data=covid_stand, aes(x = Date, y=Covid,color="Covid"))  +
      ylim(-2,+4)+
      labs(color='Legend', title = "Predicted vs. Actual Births + Covid Introduction")+ theme(legend.po
      scale_x_date(limits = as.Date(c("2020-01-01","2021-01-01")))
```

```
## Warning: Removed 2 row(s) containing missing values (geom_path).
```

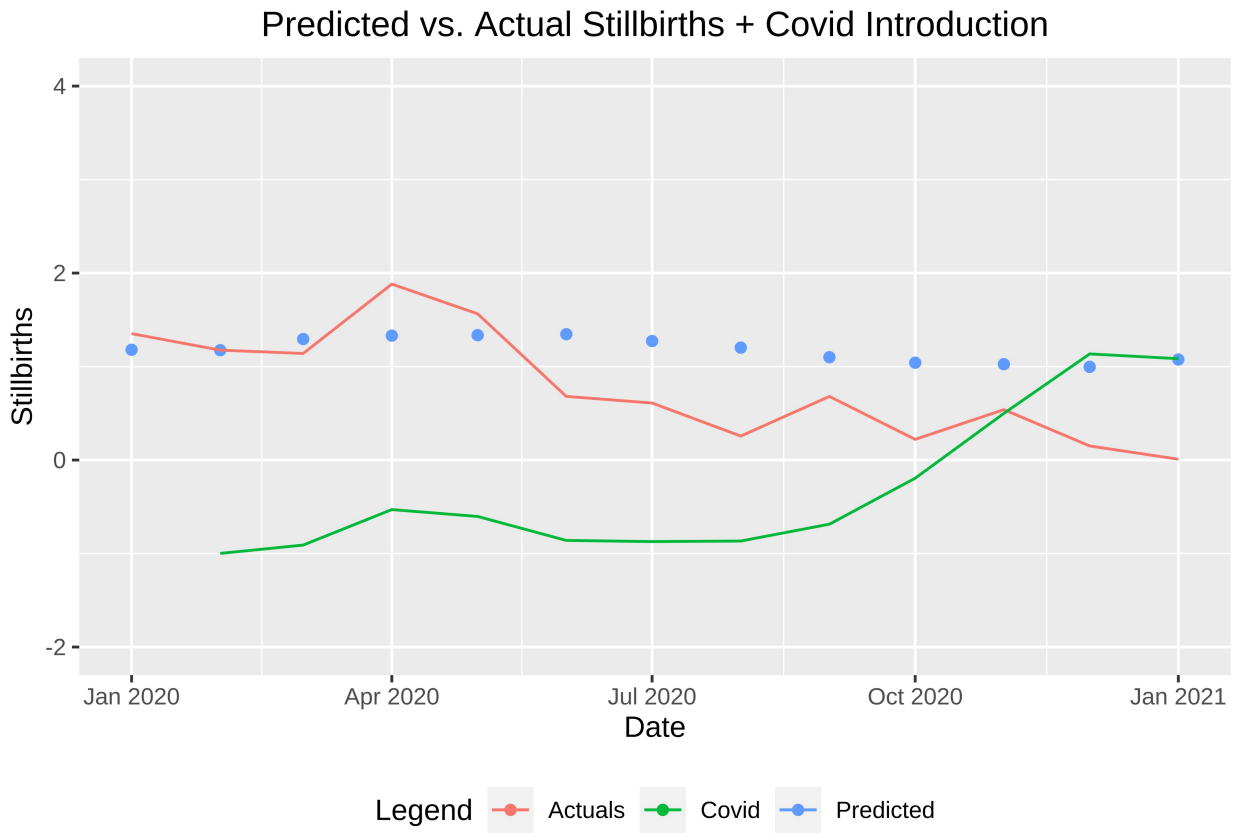
```
## Warning: Removed 11 row(s) containing missing values (geom_path).
```




```
ggplot() +

      geom_point(data=predicted, aes(x=Date, y=Stillbirths, color="Predicted")) +
      geom_line(data=actuals, aes(x=Date, y=Stillbirths,color="Actuals"))  +
      geom_line(data=covid_stand, aes(x = Date, y=Covid,color="Covid"))  +
      ylim(-2,+4)+
      labs(color='Legend', title = "Predicted vs. Actual Stillbirths + Covid Introduction")+ theme(lege
      scale_x_date(limits = as.Date(c("2020-01-01","2021-01-01")))
```

```
## Warning: Removed 11 row(s) containing missing values (geom_path).
```


Predicted vs. Actual Stillbirths + Covid Introduction
Stillbirths
4
2
0
-2
Jan 2020
Apr 2020
Jul 2020
Oct 2020
Jan 2021
Date
Legend
Actuals
Covid
Predicted