FINAL PROJECT

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Executive Summary

Introduction

The problem I am studying for this project is how the yield spread of the 2-year and 10-year U.S. T-notes is affected by the U.S. economic performance indicators such as the unemployment rate, flexible CPI, and the federal fund effective rate.

Recently, the U.S. Treasury yield spread, the difference between the Fed's short-term borrowing rate and the rate on longer-term U.S. Treasury notes, dropped below zero, which wasn't a good sign for the U.S. economy. The yield spread shifts based on actions in the bond market, and it can be seen as an important predictor for the future of the U.S. economic.

Usually, people would earn interest when they buy any treasury note from the U.S. government since the treasury note acts like a loan that the U.S. government takes from them. The longer the loan, the higher the interest rate because the longer loan has a higher risk. For this reason, people would expect it to be cheaper to purchase short-term bonds than long-term bonds since the short-term bonds have lowers risk and the U.S. government would also pay lower interest rate for them.

The difference between the long-term bonds' yield and the short-term bonds' yields is called the yield spread. For example, according to "The U.S. Treasury Yield Spread" by Thomas Kenny (2022), one of the most common yield spreads is the one that presents the yield difference between the 2-year T-notes (Treasury Bonds) and 10-year T-notes. This yield spreads is calculated by using the 10-year T-notes' yield minus the 2-year T-notes' yield, and it rises as the difference increases and declines as the difference decreases. When it drops below zero, it means that the yield is inverted, which indicates that short-term bonds are yielding more than long-term bonds. According to the article (Kenny, 2022), The yield spread became inverted at three crucial moments in time: just prior to the recession of the early 1990s, before the bursting of the technology stock bubble in 2000-2001, and before the financial crisis of 2007-2008. In each case, the yield curve provided an advance warning of severe weakness in the stock market. From this perspective, the yield spread can be seen as a crucial predictor for the future U.S. economy, and it might have some lag effects associate with economic indicators such as the unemployment rate, flexible CPI, and the federal fund effective rate that reflect on the current U.S. economic performance.

The unemployment rate is the percentage of unemployed workers in the total labor force, and It is commonly recognized as a performance indicator of the labor market. In the article "How the Unemployment Rate Affects Everybody" by Elvis Picardo (2022), when workers are unemployed, their families lose wages, and the nation as a whole loses their contribution to the economy in terms of the goods or services that could have been produced. Unemployed workers also lose their purchasing power, which can lead to unemployment for other workers, creating a cascading effect that ripples through the economy. From this point of view, unemployment impacts everybody that is connected to the economy.

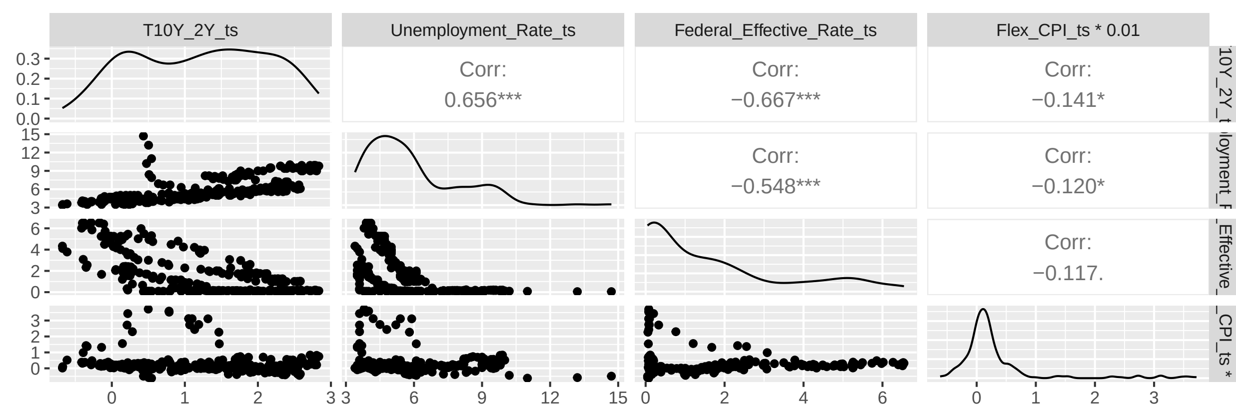
On the other hand, the Consumer Price Index (CPI) is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services. The flexible CPI is calculated from a subset of goods and services included in the CPI that change price relatively frequently. According to the article "Are Some Prices in the CPI More Forward Looking Than Others? We Think So" by Michael F. Bryan and Brent H. Meyer (2010), because these services and goods change their price quickly, it assumes that when their prices are settled, the flexible CPI don't closely relate to the inflation. Rather, it is more responsive to changes in the current economic environment since it is flexible to change.

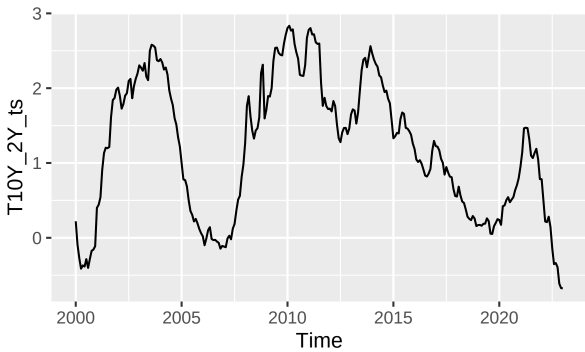
Lastly, the federal funds rate is the interest rate that depository banks trade federal funds (balances held at Federal Reserve Banks) with each other overnight. The federal funds effective rate is the weighted average rate for the federal funds rate amongst all depository banks, which is determined by the market and influenced by the Federal Reserve. The Federal Open Market Committee (FOMC) meets eight times a year to determine and set the federal funds target rate via buying or selling government bonds.

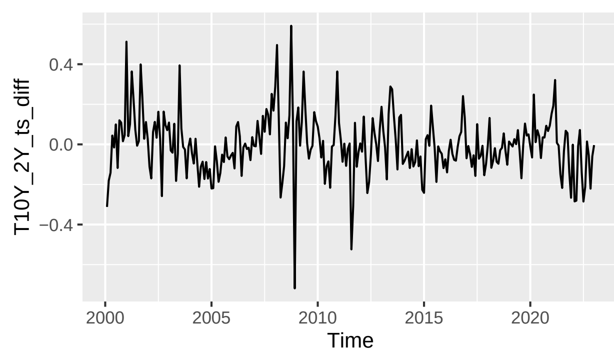
According to the "Monetary Policy" by the Board of Governors of the Federal Reserve System (2023), If the FOMC believes the economy is growing too fast and inflation pressures are inconsistent with the dual mandate of the Federal Reserve, the Committee may set a higher federal funds rate target to temper economic activity. In the opposing scenario, the FOMC may set a lower federal funds rate target to spur greater economic activity. Thus, the federal funds effective rate is closely related to the current performance of the U.S. economy and influences many other interest rates and financial products that involve interest rates.

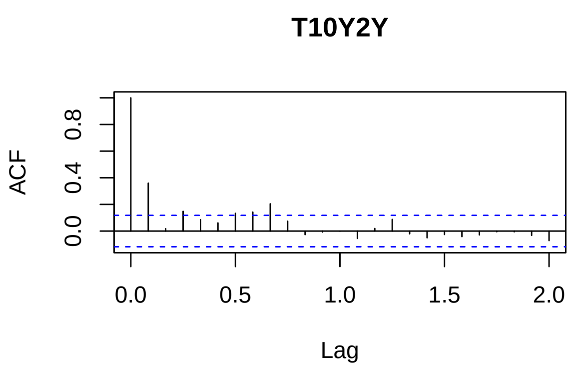
The four datasets, including the yield spread of the 2-year and 10-year U.S. T-notes, the unemployment rate, flexible CPI, and the federal fund effective rate are all from FRED or Federal Reserve Economic Data. FRED is created and maintained by the Research Department at the Federal Reserve Bank of St. Louis, which makes it a trusted source. Moreover, since I am studying U.S. economic performance, I believe it is better to collect data from the institution that direct response to the U.S. economy, which is the Federal Reserve Bank.

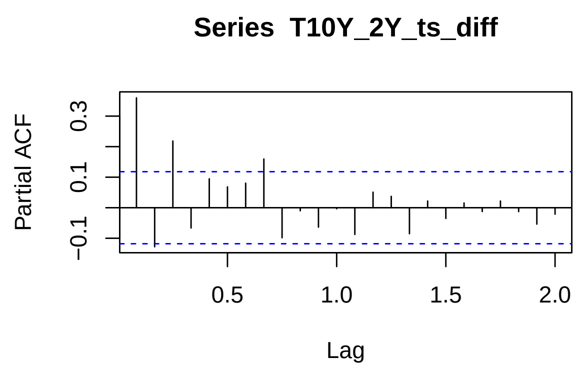
Data Analysis and Experimental Design





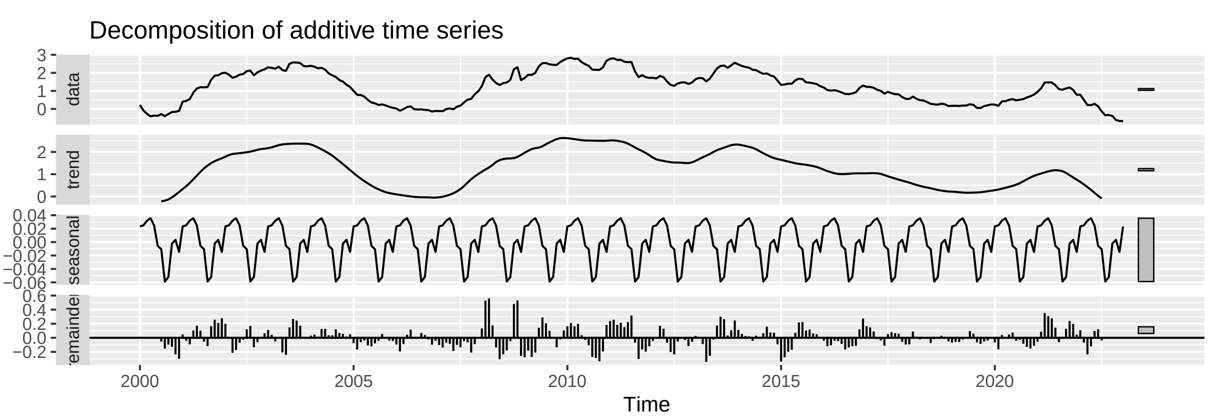


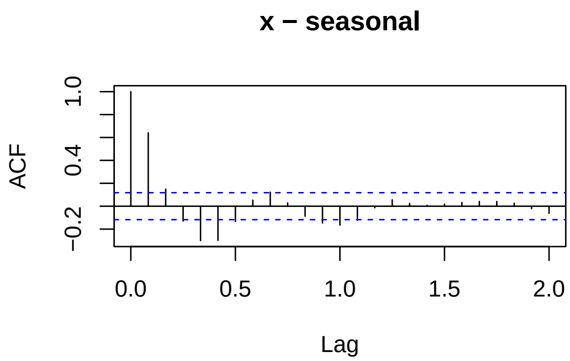


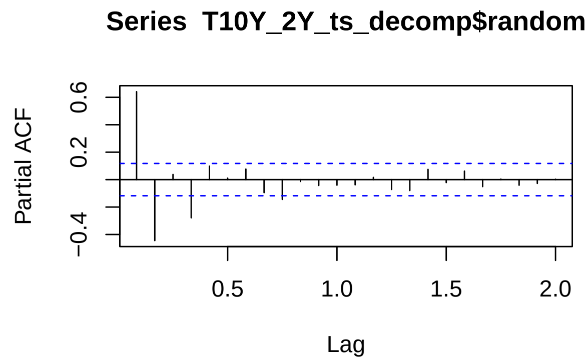



```
##
##  Box-Pierce test
##
## data:  T10Y_2Y_ts_diff
## X-squared = 35.732, df = 1, p-value = 2.264e-09
```

```
##
##  Box-Ljung test
##
## data:  T10Y_2Y_ts_diff
## X-squared = 36.122, df = 1, p-value = 1.854e-09
```

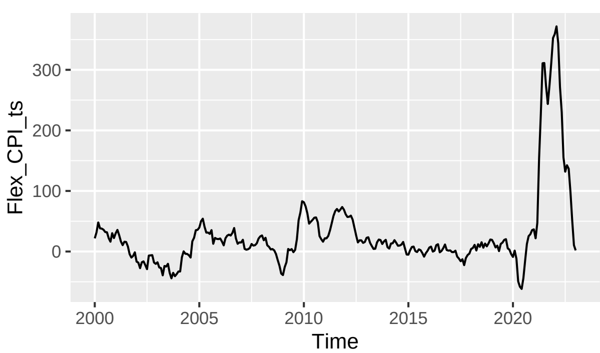


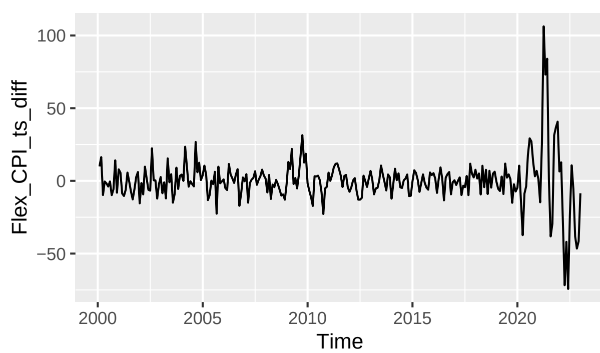


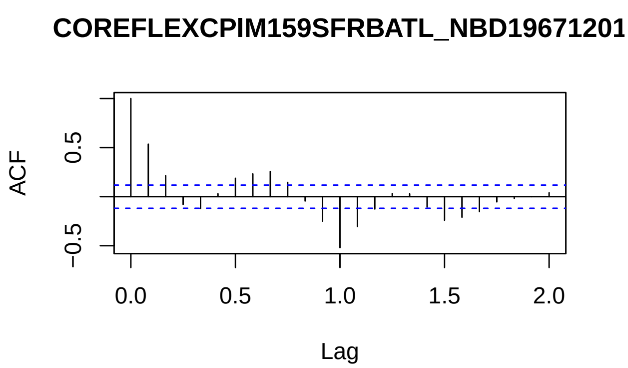


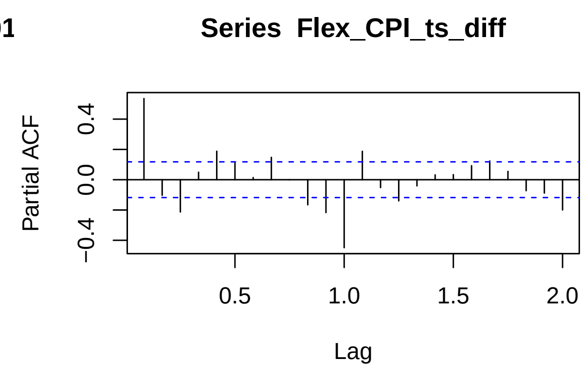

```
##
##  Box-Pierce test
##
## data:  T10Y_2Y_ts_decomp$random
## X-squared = 108.92, df = 1, p-value < 2.2e-16
```

```
##
##  Box-Ljung test
##
## data:  T10Y_2Y_ts_decomp$random
## X-squared = 110.16, df = 1, p-value < 2.2e-16
```





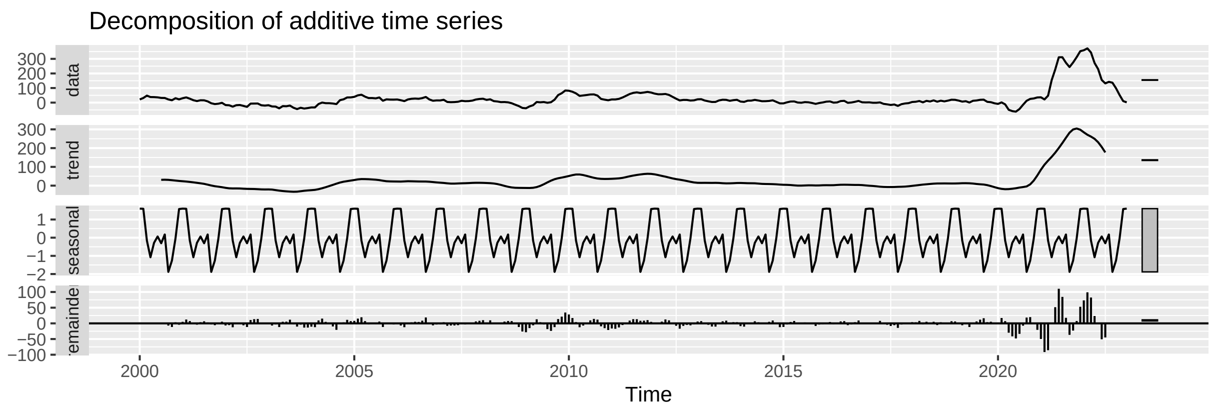


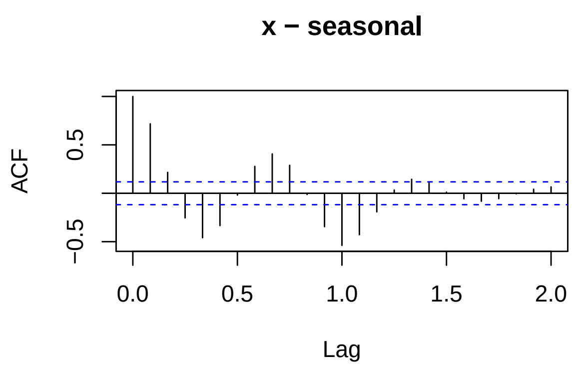


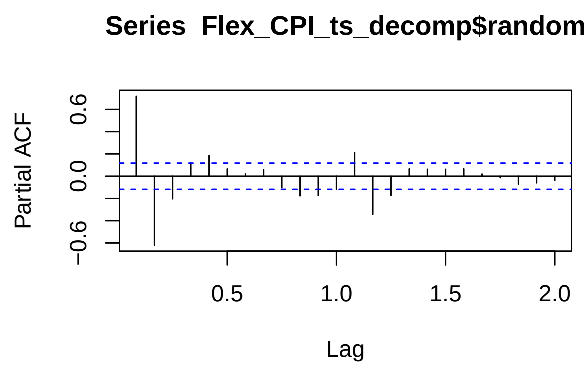

```
##
##  Box-Pierce test
```

```
##
## data:  Flex_CPI_ts_diff
## X-squared = 79.242, df = 1, p-value < 2.2e-16
```

```
##
##  Box-Ljung test
##
## data:  Flex_CPI_ts_diff
## X-squared = 80.107, df = 1, p-value < 2.2e-16
```

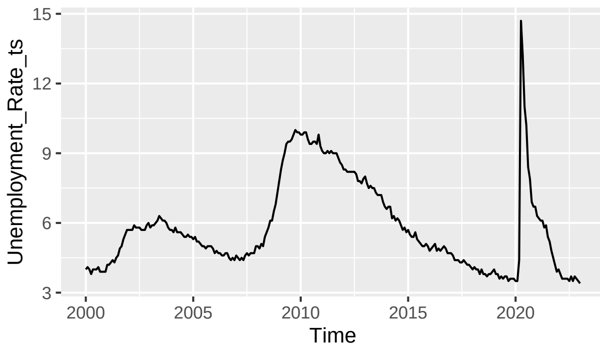


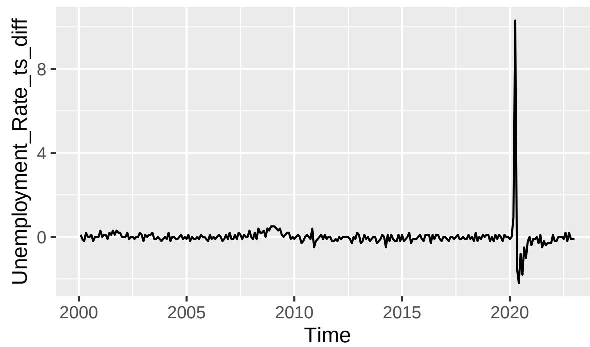





```
##
##  Box-Pierce test
##
## data:  Flex_CPI_ts_decomp$random
## X-squared = 136.67, df = 1, p-value < 2.2e-16
```

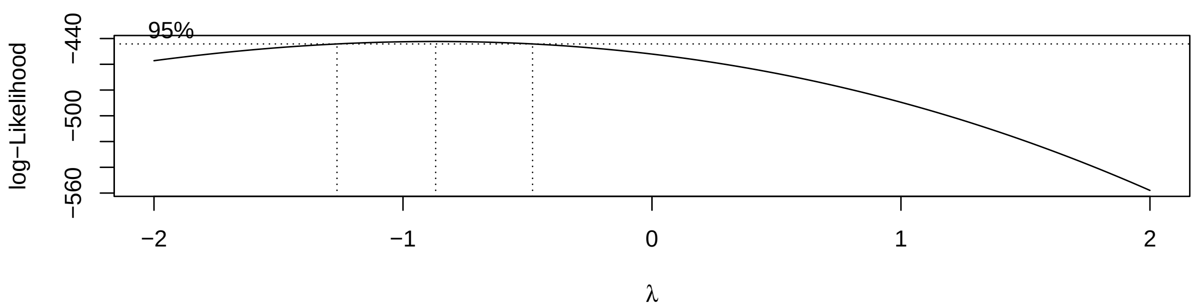
```
##
##  Box-Ljung test
##
## data:  Flex_CPI_ts_decomp$random
## X-squared = 138.23, df = 1, p-value < 2.2e-16
```

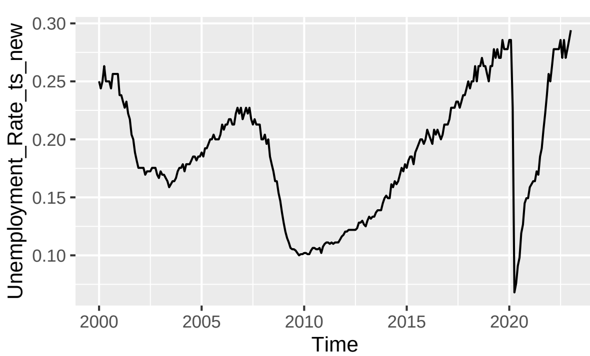


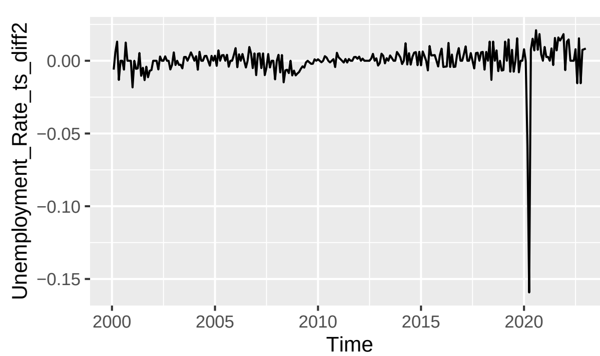


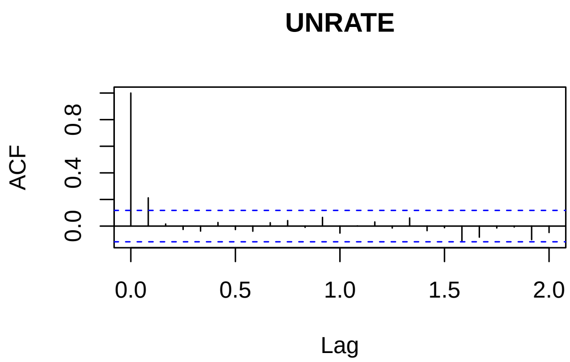

```
##
##  Box-Pierce test
##
## data:  Unemployment_Rate_ts_diff
## X-squared = 0.20376, df = 1, p-value = 0.6517
```

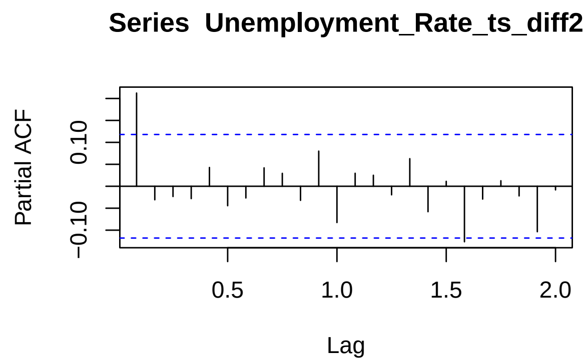
```
##
##  Box-Ljung test
##
## data:  Unemployment_Rate_ts_diff
## X-squared = 0.20598, df = 1, p-value = 0.6499
```





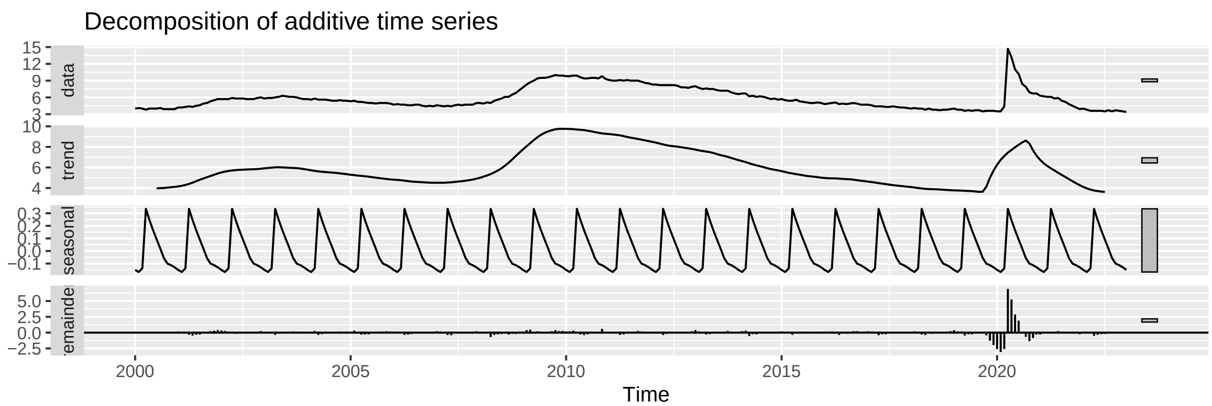


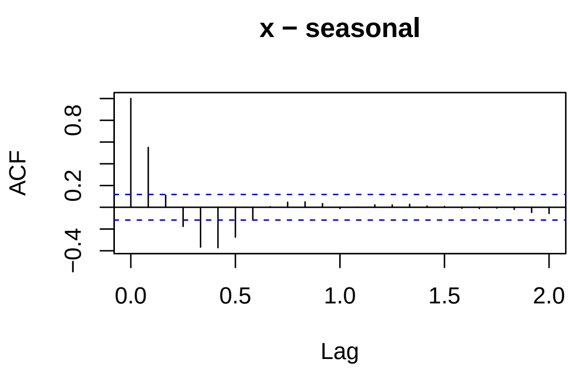





```
##
##  Box-Pierce test
##
## data:  Unemployment_Rate_ts_diff2
## X-squared = 12.45, df = 1, p-value = 0.0004181
```

```
##
##  Box-Ljung test
##
## data:  Unemployment_Rate_ts_diff2
## X-squared = 12.585, df = 1, p-value = 0.0003888
```

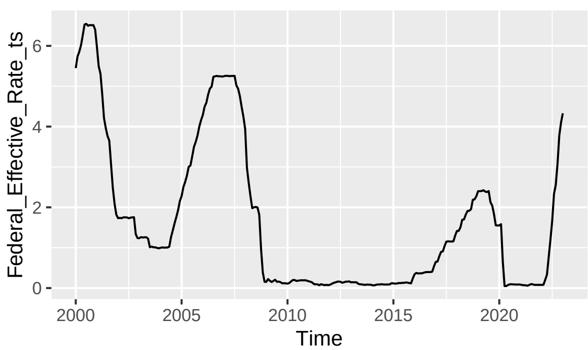


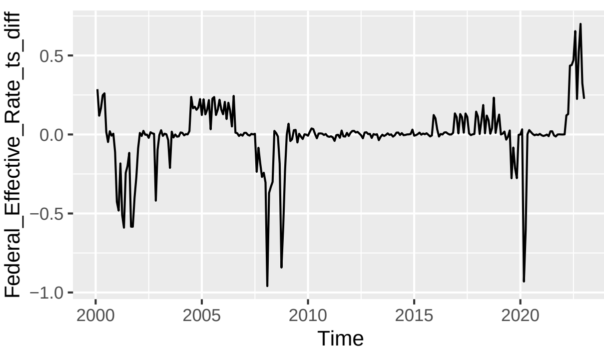


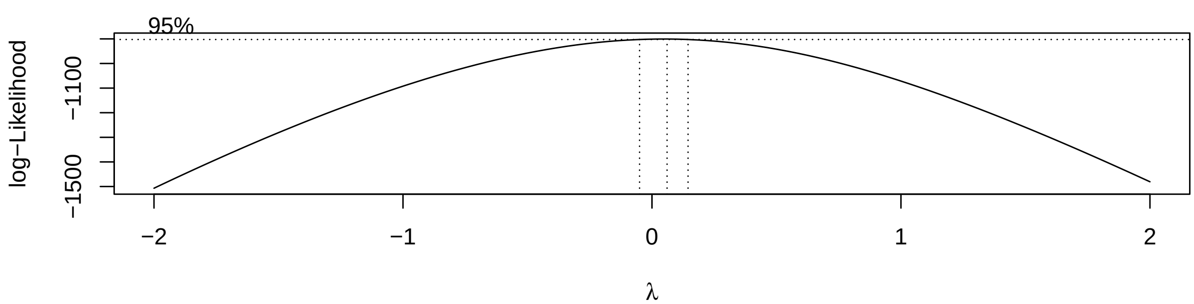

```
##
##  Box-Pierce test
```

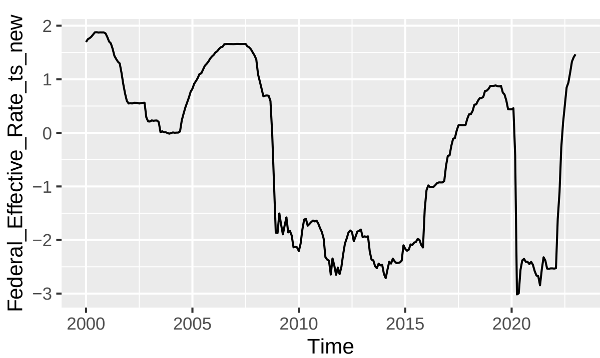
```
##
## data:  Unemployment_Rate_ts_decomp$random
## X-squared = 80.565, df = 1, p-value < 2.2e-16
```

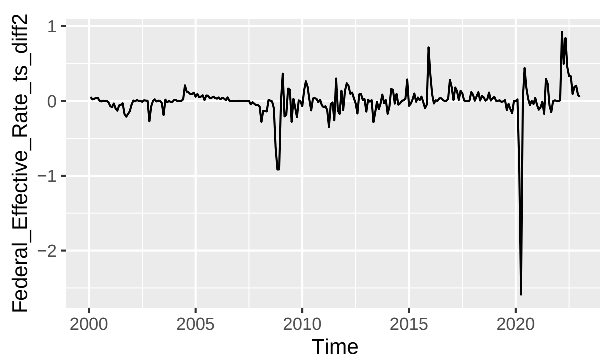
```
##
##  Box-Ljung test
##
## data:  Unemployment_Rate_ts_decomp$random
## X-squared = 81.481, df = 1, p-value < 2.2e-16
```

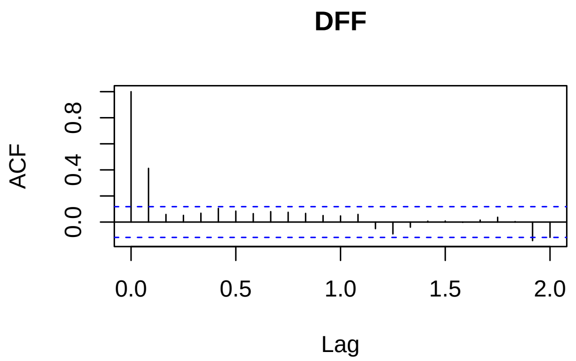


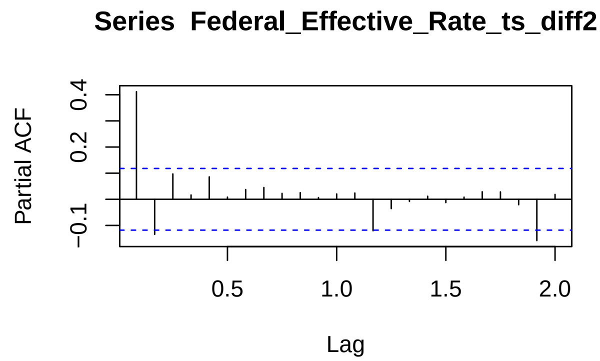






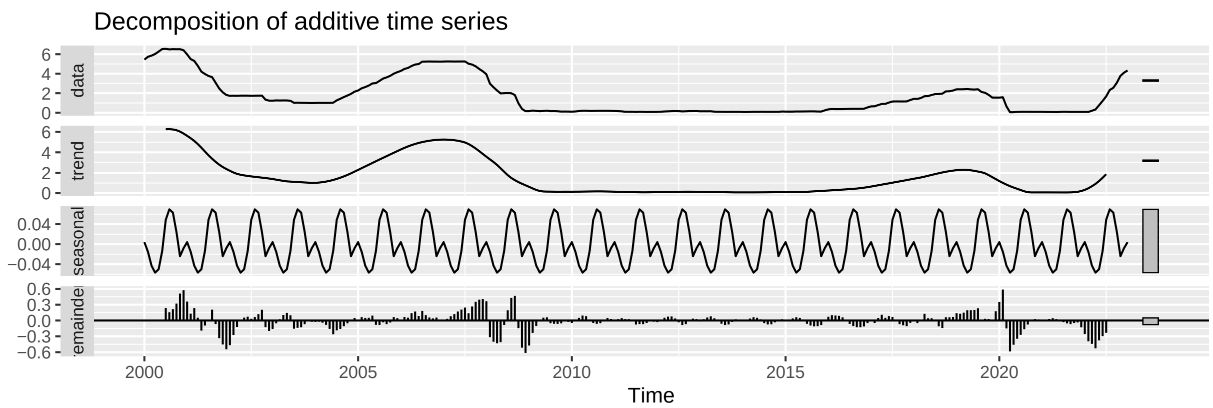


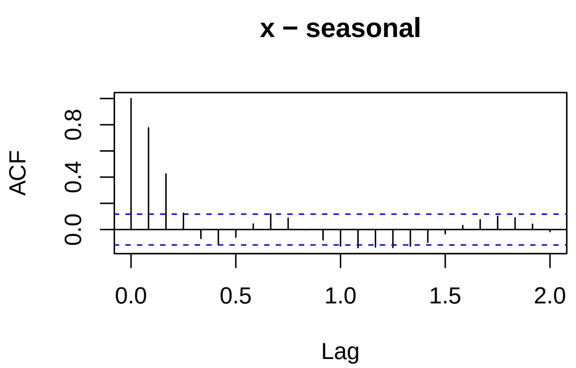


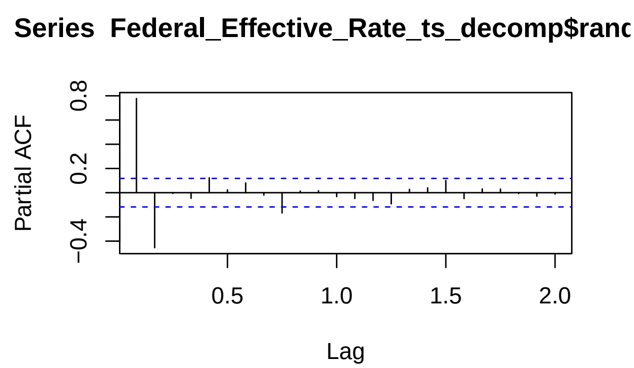



```
##
##  Box-Pierce test
##
## data:  Federal_Effective_Rate_ts_diff2
## X-squared = 46.817, df = 1, p-value = 7.795e-12
```

```
##
##  Box-Ljung test
##
## data:  Federal_Effective_Rate_ts_diff2
## X-squared = 47.327, df = 1, p-value = 6.007e-12
```







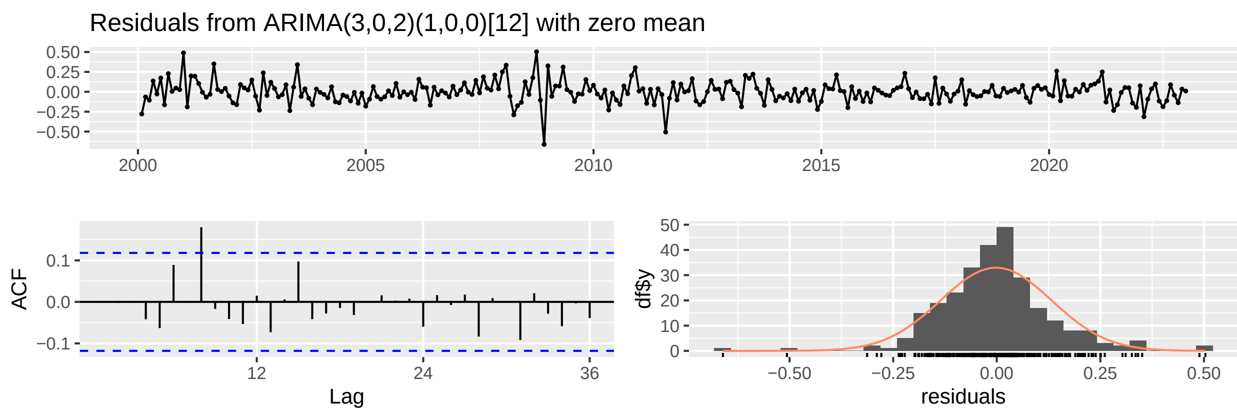

```
##
##  Box-Pierce test
```

```
##
## data:  Federal_Effective_Rate_ts_decomp$random
## X-squared = 160.12, df = 1, p-value < 2.2e-16
```

```
##
##  Box-Ljung test
##
## data:  Federal_Effective_Rate_ts_decomp$random
## X-squared = 161.94, df = 1, p-value < 2.2e-16
```

Time Series Modelling and Forecasting

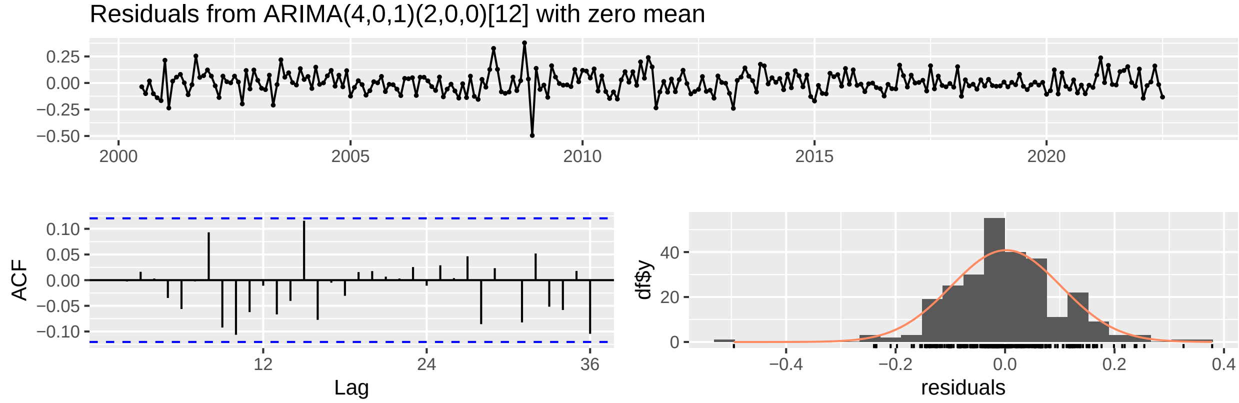
```
## Series: T10Y_2Y_ts_diff
## ARIMA(3,0,2)(1,0,0)[12] with zero mean
##
## Coefficients:
##          ar1     ar2     ar3      ma1      ma2     sar1
##       0.6373  0.0571  0.1256  -0.1939  -0.4004  -0.0235
## s.e.  0.1602  0.1583  0.0813   0.1556   0.1242   0.0648
##
## sigma^2 = 0.01834:  log likelihood = 163.01
## AIC=-312.02   AICc=-311.6   BIC=-286.68
##
## Training set error measures:
##                         ME      RMSE        MAE      MPE     MAPE      MASE
## Training set -0.001704798 0.1339487 0.09651123 25.54858 178.4432 0.6439242
##                      ACF1
## Training set -0.002275268
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(3,0,2)(1,0,0)[12] with zero mean
## Q* = 21.25, df = 18, p-value = 0.267
##
## Model df: 6.   Total lags used: 24
```

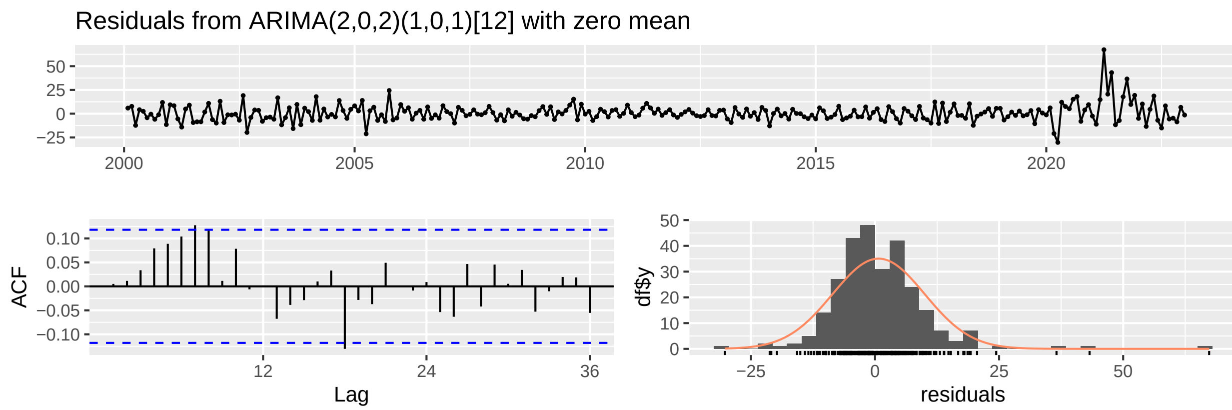
```
## Series: T10Y_2Y_ts_decomp$random
## ARIMA(4,0,1)(2,0,0)[12] with zero mean
##
## Coefficients:
##          ar1      ar2     ar3      ar4     ma1     sar1     sar2
##       0.5898  -0.2739  0.1352  -0.2683  0.3940  -0.0922  -0.1315
```

```
## s.e.   0.1810   0.1839  0.1236   0.0659  0.1887   0.0647   0.0651
##
## sigma^2 = 0.01036:  log likelihood = 232.1
## AIC=-448.21   AICc=-447.64   BIC=-419.57
##
## Training set error measures:
##                     ME      RMSE        MAE     MPE     MAPE      MASE
## Training set 0.0018942 0.1004278 0.07549709 -21.814 188.8122 0.4227866
##                       ACF1
## Training set -0.0004587772
```



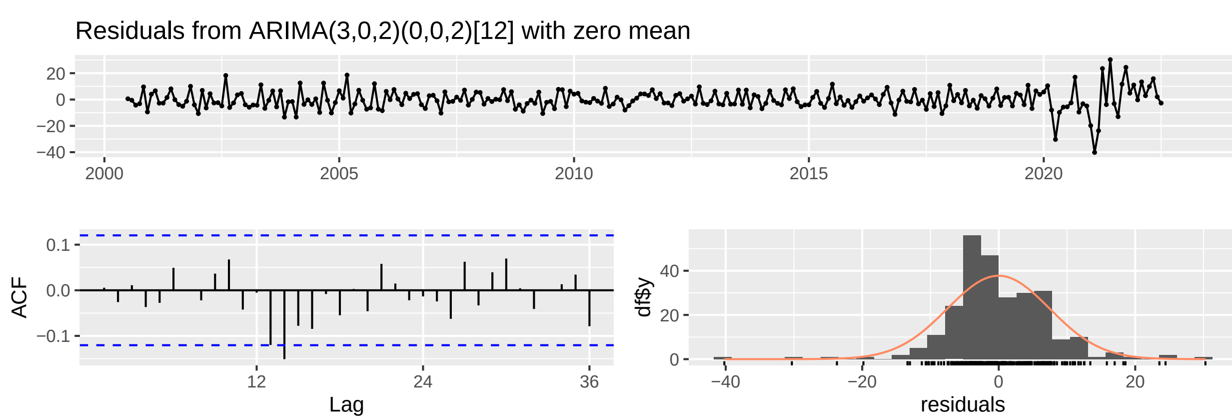

```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(4,0,1)(2,0,0)[12] with zero mean
## Q* = 18.135, df = 17, p-value = 0.3804
##
## Model df: 7.   Total lags used: 24
```

```
## Series: Flex_CPI_ts_diff
## ARIMA(2,0,2)(1,0,1)[12] with zero mean
##
## Coefficients:
##          ar1      ar2      ma1     ma2     sar1     sma1
##       0.5509  -0.4531  -0.0224  0.5743  -0.1392  -0.8131
## s.e.  0.1417   0.1204   0.1382  0.0784   0.0763   0.0597
##
## sigma^2 = 88.49:  log likelihood = -1015.55
## AIC=2045.1   AICc=2045.52   BIC=2070.44
##
## Training set error measures:
##                     ME     RMSE      MAE      MPE     MAPE      MASE
## Training set 0.7191948 9.304048 6.455373 170.9745 1067.009 0.4090378
##                     ACF1
## Training set 0.005022291
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(2,0,2)(1,0,1)[12] with zero mean
## Q* = 26.683, df = 18, p-value = 0.08513
##
## Model df: 6.   Total lags used: 24
```

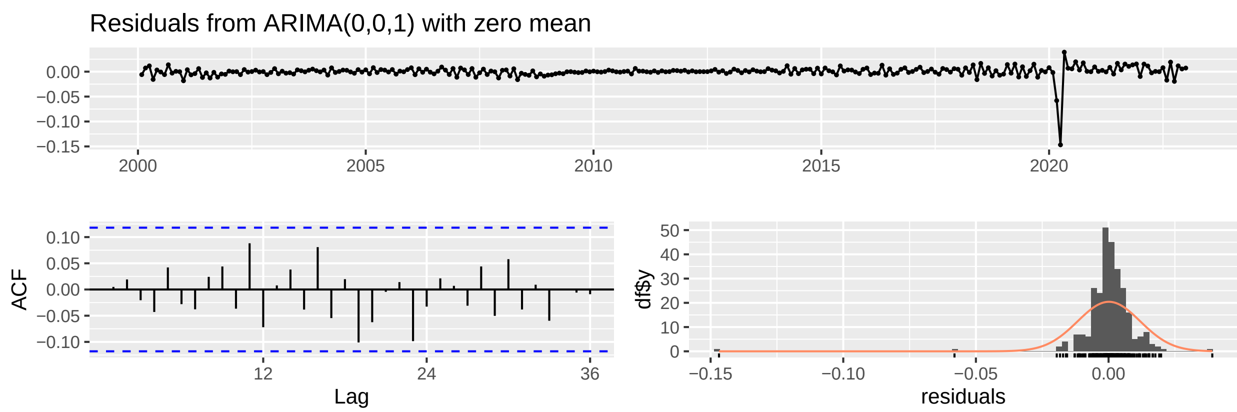
```
## Series: Flex_CPI_ts_decomp$random
## ARIMA(3,0,2)(0,0,2)[12] with zero mean
##
## Coefficients:
##          ar1      ar2     ar3      ma1     ma2     sma1    sma2
##       1.1393  -0.7809  0.0686  -0.1457  0.4421  -0.8995  0.2161
## s.e.  0.1493   0.2013  0.1268   0.1354  0.1085   0.0712  0.0699
##
## sigma^2 = 57.24:  log likelihood = -915.06
## AIC=1846.13   AICc=1846.69   BIC=1874.77
##
## Training set error measures:
##                       ME     RMSE      MAE      MPE    MAPE      MASE
## Training set -0.02652009 7.465442 5.402556 62.69182 301.447 0.2968822
##                     ACF1
## Training set 0.005659801
```




```
##
##  Ljung-Box test
##
```

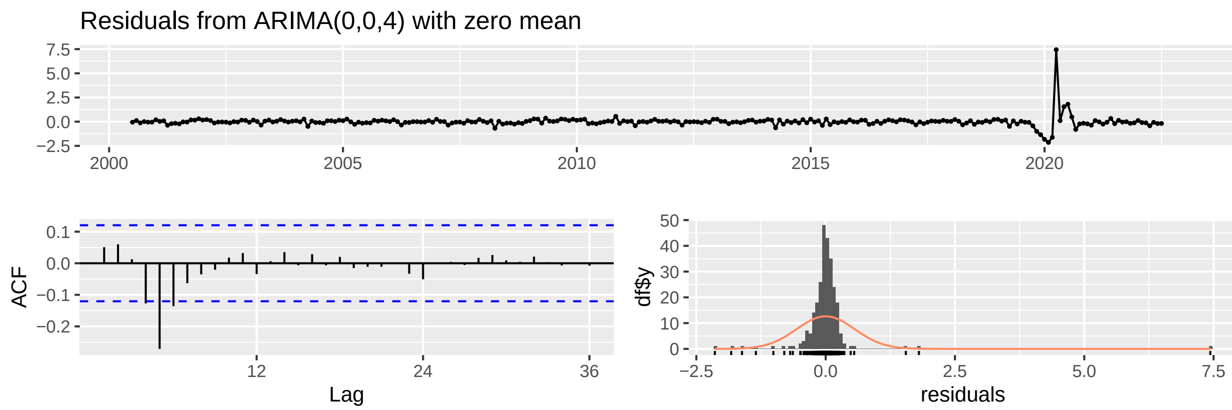
```
## data:  Residuals from ARIMA(3,0,2)(0,0,2)[12] with zero mean
## Q* = 20.658, df = 17, p-value = 0.242
##
## Model df: 7.   Total lags used: 24
```

```
## Series: Unemployment_Rate_ts_diff2
## ARIMA(0,0,1) with zero mean
##
## Coefficients:
##          ma1
##       0.2136
## s.e.  0.0577
##
## sigma^2 = 0.0001391:  log likelihood = 834.38
## AIC=-1664.76   AICc=-1664.72   BIC=-1657.52
##
## Training set error measures:
##                        ME       RMSE         MAE MPE MAPE     MASE        ACF1
## Training set 0.0001366312 0.01177064 0.005650135 NaN  Inf 0.692295 0.004955723
```



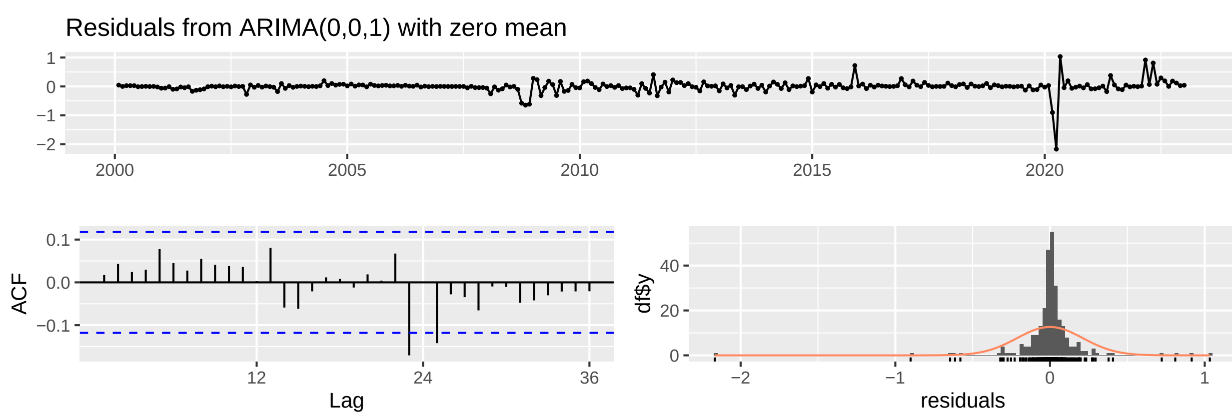

```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(0,0,1) with zero mean
## Q* = 18.104, df = 23, p-value = 0.7518
##
## Model df: 1.   Total lags used: 24
```

```
## Series: Unemployment_Rate_ts_decomp$random
## ARIMA(0,0,4) with zero mean
##
## Coefficients:
##          ma1     ma2      ma3      ma4
##       0.6030  0.0673  -0.1638  -0.2307
## s.e.  0.1092  0.2241   0.2716   0.1696
##
## sigma^2 = 0.3184:  log likelihood = -222.68
## AIC=455.36   AICc=455.59   BIC=473.26
##
## Training set error measures:
##                         ME     RMSE       MAE      MPE     MAPE     MASE
## Training set -1.459378e-05 0.560036 0.2035822 189.3545 516.3343 0.513928
##                    ACF1
## Training set 0.05092309
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(0,0,4) with zero mean
## Q* = 35.335, df = 20, p-value = 0.01839
##
## Model df: 4.   Total lags used: 24
```

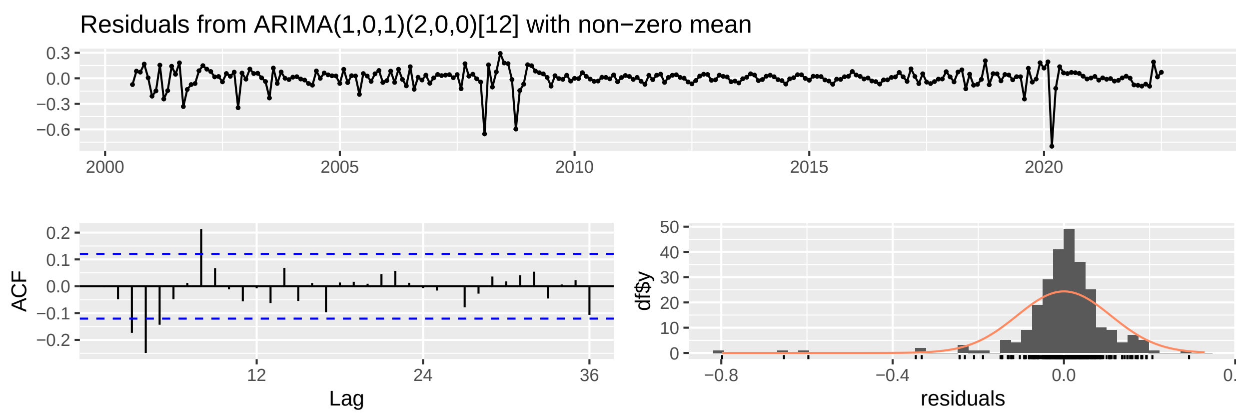
```
## Series: Federal_Effective_Rate_ts_diff2
## ARIMA(0,0,1) with zero mean
##
## Coefficients:
##          ma1
##       0.4673
## s.e.  0.0524
##
## sigma^2 = 0.04531:  log likelihood = 35.74
## AIC=-67.49   AICc=-67.44   BIC=-60.24
##
## Training set error measures:
##                         ME      RMSE        MAE MPE MAPE      MASE       ACF1
## Training set -0.000527206 0.2124842 0.09451561 NaN  Inf 0.5997379 0.01721703
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(0,0,1) with zero mean
## Q* = 20.24, df = 23, p-value = 0.6274
```

```
##
## Model df: 1.   Total lags used: 24
```

```
## Series: diff(Federal_Effective_Rate_ts_decomp$random)
## ARIMA(1,0,1)(2,0,0)[12] with non-zero mean
##
## Coefficients:
##           ar1     ma1     sar1     sar2     mean
##       -0.1025  0.4739  -0.0532  -0.0749  -0.0017
## s.e.   0.1507  0.1331   0.0641   0.0643   0.0080
##
## sigma^2 = 0.01218:  log likelihood = 209.56
## AIC=-407.11   AICc=-406.79   BIC=-385.66
##
## Training set error measures:
##                        ME      RMSE        MAE      MPE     MAPE      MASE
## Training set 3.817702e-06 0.1093347 0.06486701 9.664782 330.5475 0.6598089
##                      ACF1
## Training set -0.002862292
```




```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(1,0,1)(2,0,0)[12] with non-zero mean
## Q* = 54.062, df = 20, p-value = 5.664e-05
##
## Model df: 4.   Total lags used: 24
```

Discussion and Conclusions

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