Timeseries

Clear all variables in work space and install packages

```
rm(list=ls())

requiredPackages = c('quantmod','TTR','aTSA','scales')
for(p in requiredPackages){
  if(!require(p,character.only = TRUE)) install.packages(p) #install package if it does not exist
  library(p,character.only = TRUE)
}

#suppress `getSymbols` message
options("getSymbols.warning4.0"=FALSE)
```

Load the forecasting packages

```
## -- Attaching packages ---------------------------------------------- fpp2 2.4 --

## v ggplot2   3.3.5     v fma       2.4
## v forecast  8.15      v expsmooth 2.3

## -- Conflicts ------------------------------------------------ fpp2_conflicts --
## x forecast::forecast() masks aTSA::forecast()
```

Get to Know Time-Series Data

Load Dataset

Data is collected from Yahoo Finance using the Quantitative Financial Modeling Framework (Quantmod). Data obtained in eXtensible-Time-Series format is being used for data exploration.

```
#Download data from yahoo finance
df_tsm <- getSymbols('TSM',src='yahoo',auto.assign=FALSE,from="2011-01-01")

#Check the contents of the data
class(df_tsm)
```

```
## [1] "xts" "zoo"
```

```
#List the number of rows in the data
nrow(df_tsm)
```

```
## [1] 2775
```

```
#Print the last 6 rows of the data
tail(df_tsm)
```

```
##            TSM.Open TSM.High TSM.Low TSM.Close TSM.Volume TSM.Adjusted
## 2022-01-03   124.13   129.59  124.00     128.80   18592000        128.80
## 2022-01-04   130.87   135.50  130.30     133.40   25554900        133.40
## 2022-01-05   130.71   130.88  126.88     127.06   17891200        127.06
## 2022-01-06   127.00   129.00  124.81     128.47   16249000        128.47
## 2022-01-07   126.55   127.14  123.31     123.50   21239000        123.50
## 2022-01-10   125.11   125.87  123.26     125.01   11823100        125.01
```

Stock price visualization

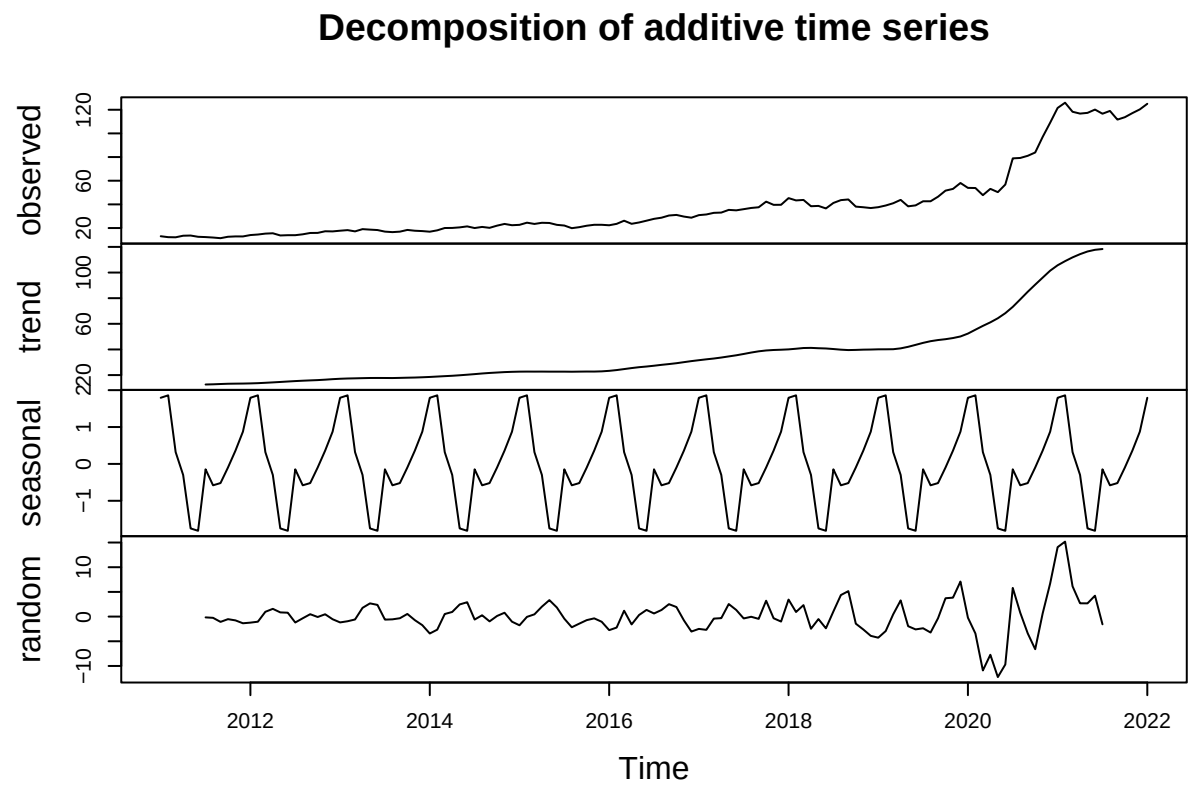
This show show the patterns of the data.

```
tsm_title = "Taiwan Semiconductor Manufacturing Company Limited Stock Price (TSM) (2011-2022)"


chartSeries(df_tsm , name="TSM price 2011-2022")
```

TSM has grown upwards from 2011 to 2022 shown by the upward trends

Time plot of the data

```
#returns the closing price
tsm_close = Cl(to.monthly(df_tsm))

#decompose the data
dc <- decompose(as.ts(tsm_close, start=c(2011,1)))
plot(dc)
```



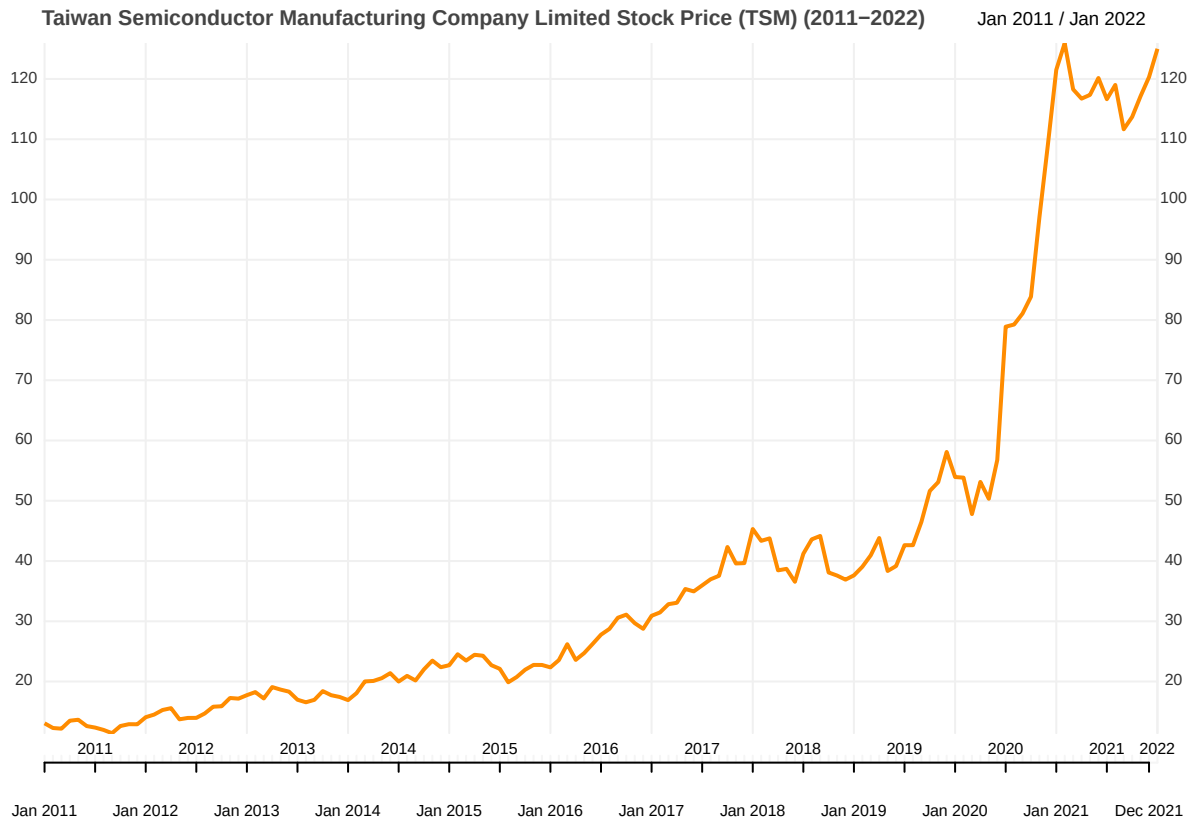

```
dc$seasonal
```

```
##             Jan         Feb         Mar         Apr         May         Jun
## 2011  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2012  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2013  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2014  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2015  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2016  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2017  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2018  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2019  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2020  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2021  1.79336858  1.85986888  0.31928563 -0.29946417 -1.74992240 -1.81371426
## 2022  1.79336858
```

```
##              Jul         Aug         Sep         Oct         Nov         Dec
## 2011 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2012 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2013 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2014 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2015 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2016 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2017 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2018 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2019 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2020 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2021 -0.14710072 -0.57967266 -0.52029777 -0.09754725  0.36020195  0.87499420
## 2022
```

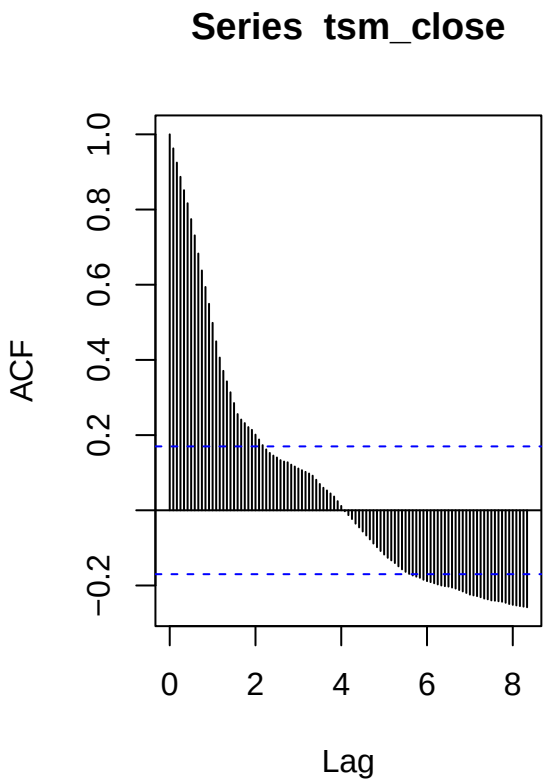
The output shows for plots of TSM closing price which are:
- **Observed**: Original plot of the data. - **Trend** : There is an upward trend that is significant from 2018.
- **Seasonal** There is repetitive seasonal fluctuation of data.

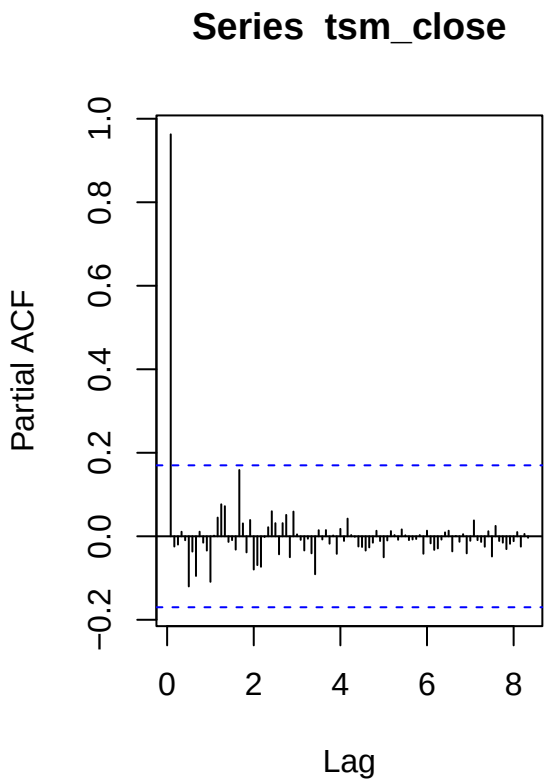
```
#plot(df_tsm$TSM.Close,main = tsm_title)
chart_Series(tsm_close,name=tsm_title)
```



From the figure above TSM stock price has a `strong positive trend`.This shows that it is `non-stationary`

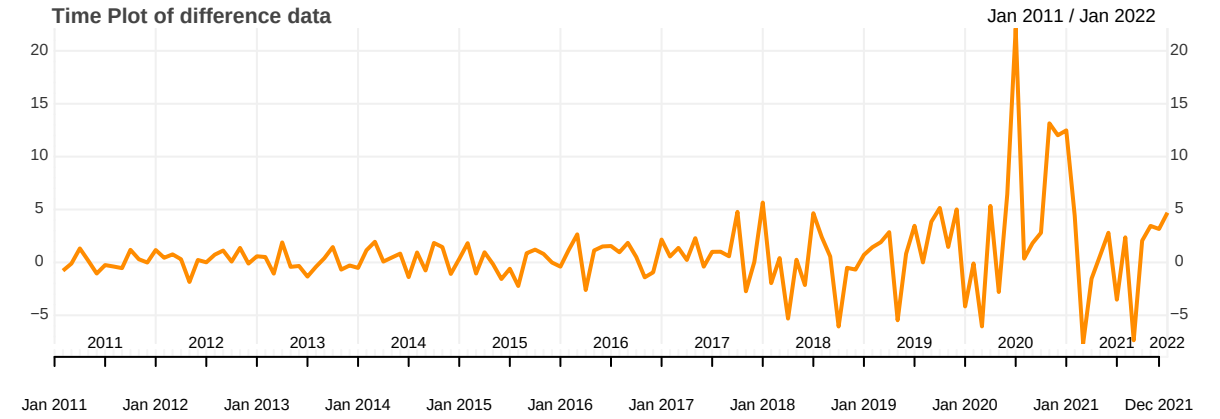
```
par(mfrow=c(1,2))
acf(tsm_close, lag=100)
pacf(tsm_close ,lag=100)
```

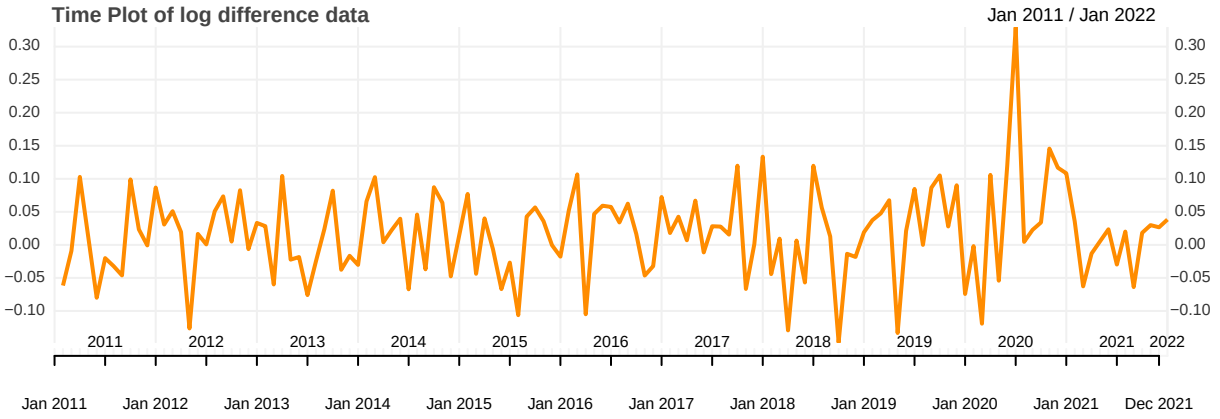




The trend can be removed by `differensing` the data to removes the trend

```
par(mfrow=c(2,1))

dy = diff(tsm_close,lag = 1)
chart_Series(dy,name="Time Plot of difference data")

wld = diff(log(tsm_close))
chart_Series(wld,name="Time Plot of log difference data")
```





Test Stationarity

```
adf.test(tsm_close)
```

```
## Augmented Dickey-Fuller Test
## alternative: stationary
##
## Type 1: no drift no trend
##      lag  ADF p.value
## [1,]   0 4.40    0.99
## [2,]   1 3.53    0.99
## [3,]   2 3.29    0.99
## [4,]   3 3.53    0.99
## [5,]   4 3.51    0.99
## Type 2: with drift no trend
##      lag  ADF p.value
## [1,]   0 3.43    0.99
## [2,]   1 2.79    0.99
## [3,]   2 2.64    0.99
## [4,]   3 2.91    0.99
## [5,]   4 2.93    0.99
## Type 3: with drift and trend
##      lag  ADF p.value
## [1,]   0 2.16    0.99
## [2,]   1 1.80    0.99
## [3,]   2 1.72    0.99
```

```
## [4,]   3 1.89    0.99
## [5,]   4 1.95    0.99
## ----
## Note: in fact, p.value = 0.01 means p.value <= 0.01
```

Fit arima

```
# differencing is set to 1 d=1
# TRACE prints out all models that have been tried
fit_arima = auto.arima(tsm_close,d=1,stepwise = FALSE,approximation = FALSE,trace = TRUE)
```

```
##
##  ARIMA(0,1,0)                            : 714.4123
##  ARIMA(0,1,0)            with drift      : 708.9161
##  ARIMA(0,1,0)(0,0,1)[12]                 : 714.1471
##  ARIMA(0,1,0)(0,0,1)[12] with drift      : 710.1593
##  ARIMA(0,1,0)(0,0,2)[12]                 : 716.1574
##  ARIMA(0,1,0)(0,0,2)[12] with drift      : 712.2682
##  ARIMA(0,1,0)(1,0,0)[12]                 : 714.09
##  ARIMA(0,1,0)(1,0,0)[12] with drift      : 710.1805
##  ARIMA(0,1,0)(1,0,1)[12]                 : 716.1748
##  ARIMA(0,1,0)(1,0,1)[12] with drift      : Inf
##  ARIMA(0,1,0)(1,0,2)[12]                 : Inf
##  ARIMA(0,1,0)(1,0,2)[12] with drift      : Inf
##  ARIMA(0,1,0)(2,0,0)[12]                 : 716.1717
##  ARIMA(0,1,0)(2,0,0)[12] with drift      : 712.2291
##  ARIMA(0,1,0)(2,0,1)[12]                 : Inf
##  ARIMA(0,1,0)(2,0,1)[12] with drift      : Inf
##  ARIMA(0,1,0)(2,0,2)[12]                 : 720.0767
##  ARIMA(0,1,0)(2,0,2)[12] with drift      : 715.0275
##  ARIMA(0,1,1)                            : 709.4551
##  ARIMA(0,1,1)            with drift      : 705.9142
##  ARIMA(0,1,1)(0,0,1)[12]                 : 710.3168
##  ARIMA(0,1,1)(0,0,1)[12] with drift      : 707.5841
##  ARIMA(0,1,1)(0,0,2)[12]                 : 712.3888
##  ARIMA(0,1,1)(0,0,2)[12] with drift      : 709.7266
##  ARIMA(0,1,1)(1,0,0)[12]                 : 710.2968
##  ARIMA(0,1,1)(1,0,0)[12] with drift      : 707.5961
##  ARIMA(0,1,1)(1,0,1)[12]                 : 712.4243
##  ARIMA(0,1,1)(1,0,1)[12] with drift      : Inf
##  ARIMA(0,1,1)(1,0,2)[12]                 : 714.096
##  ARIMA(0,1,1)(1,0,2)[12] with drift      : Inf
##  ARIMA(0,1,1)(2,0,0)[12]                 : 712.424
##  ARIMA(0,1,1)(2,0,0)[12] with drift      : 709.6759
##  ARIMA(0,1,1)(2,0,1)[12]                 : 714.2089
##  ARIMA(0,1,1)(2,0,1)[12] with drift      : 710.0525
##  ARIMA(0,1,1)(2,0,2)[12]                 : 716.1673
##  ARIMA(0,1,1)(2,0,2)[12] with drift      : 712.1852
##  ARIMA(0,1,2)                            : 707.798
##  ARIMA(0,1,2)            with drift      : 705.6063
##  ARIMA(0,1,2)(0,0,1)[12]                 : 708.5098
##  ARIMA(0,1,2)(0,0,1)[12] with drift      : 707.0786
```

```
##  ARIMA(0,1,2)(0,0,2)[12]                    : 710.6706
##  ARIMA(0,1,2)(0,0,2)[12] with drift         : 709.228
##  ARIMA(0,1,2)(1,0,0)[12]                    : 708.5266
##  ARIMA(0,1,2)(1,0,0)[12] with drift         : 707.1048
##  ARIMA(0,1,2)(1,0,1)[12]                    : 710.6708
##  ARIMA(0,1,2)(1,0,1)[12] with drift         : 709.2626
##  ARIMA(0,1,2)(1,0,2)[12]                    : Inf
##  ARIMA(0,1,2)(1,0,2)[12] with drift         : Inf
##  ARIMA(0,1,2)(2,0,0)[12]                    : 710.6448
##  ARIMA(0,1,2)(2,0,0)[12] with drift         : 709.1523
##  ARIMA(0,1,2)(2,0,1)[12]                    : Inf
##  ARIMA(0,1,2)(2,0,1)[12] with drift         : 709.8669
##  ARIMA(0,1,3)                               : 709.9144
##  ARIMA(0,1,3)             with drift        : 707.6851
##  ARIMA(0,1,3)(0,0,1)[12]                    : 710.6707
##  ARIMA(0,1,3)(0,0,1)[12] with drift         : 709.1851
##  ARIMA(0,1,3)(0,0,2)[12]                    : 712.8659
##  ARIMA(0,1,3)(0,0,2)[12] with drift         : 711.3286
##  ARIMA(0,1,3)(1,0,0)[12]                    : 710.6866
##  ARIMA(0,1,3)(1,0,0)[12] with drift         : 709.2173
##  ARIMA(0,1,3)(1,0,1)[12]                    : 712.8662
##  ARIMA(0,1,3)(1,0,1)[12] with drift         : 711.3936
##  ARIMA(0,1,3)(2,0,0)[12]                    : 712.8406
##  ARIMA(0,1,3)(2,0,0)[12] with drift         : 711.241
##  ARIMA(0,1,4)                               : 711.8624
##  ARIMA(0,1,4)             with drift        : 709.4918
##  ARIMA(0,1,4)(0,0,1)[12]                    : 712.7457
##  ARIMA(0,1,4)(0,0,1)[12] with drift         : 711.1309
##  ARIMA(0,1,4)(1,0,0)[12]                    : 712.7562
##  ARIMA(0,1,4)(1,0,0)[12] with drift         : 711.1566
##  ARIMA(0,1,5)                               : 713.873
##  ARIMA(0,1,5)             with drift        : 711.6755
##  ARIMA(1,1,0)                               : 707.55
##  ARIMA(1,1,0)             with drift        : 704.8818
##  ARIMA(1,1,0)(0,0,1)[12]                    : 708.59
##  ARIMA(1,1,0)(0,0,1)[12] with drift         : 706.5536
##  ARIMA(1,1,0)(0,0,2)[12]                    : 710.6829
##  ARIMA(1,1,0)(0,0,2)[12] with drift         : 708.6977
##  ARIMA(1,1,0)(1,0,0)[12]                    : 708.5799
##  ARIMA(1,1,0)(1,0,0)[12] with drift         : 706.5654
##  ARIMA(1,1,0)(1,0,1)[12]                    : 710.7069
##  ARIMA(1,1,0)(1,0,1)[12] with drift         : Inf
##  ARIMA(1,1,0)(1,0,2)[12]                    : 712.3698
##  ARIMA(1,1,0)(1,0,2)[12] with drift         : Inf
##  ARIMA(1,1,0)(2,0,0)[12]                    : 710.7057
##  ARIMA(1,1,0)(2,0,0)[12] with drift         : 708.6454
##  ARIMA(1,1,0)(2,0,1)[12]                    : Inf
##  ARIMA(1,1,0)(2,0,1)[12] with drift         : 709.0262
##  ARIMA(1,1,0)(2,0,2)[12]                    : 714.3977
##  ARIMA(1,1,0)(2,0,2)[12] with drift         : Inf
##  ARIMA(1,1,1)                               : 708.41
##  ARIMA(1,1,1)             with drift        : 706.6032
##  ARIMA(1,1,1)(0,0,1)[12]                    : 709.408
##  ARIMA(1,1,1)(0,0,1)[12] with drift         : 708.2124
```

```
##  ARIMA(1,1,1)(0,0,2)[12]                    : 711.4855
##  ARIMA(1,1,1)(0,0,2)[12] with drift         : 710.4051
##  ARIMA(1,1,1)(1,0,0)[12]                    : 709.3824
##  ARIMA(1,1,1)(1,0,0)[12] with drift         : 708.2221
##  ARIMA(1,1,1)(1,0,1)[12]                    : 711.5427
##  ARIMA(1,1,1)(1,0,1)[12] with drift         : 710.4078
##  ARIMA(1,1,1)(1,0,2)[12]                    : 713.1825
##  ARIMA(1,1,1)(1,0,2)[12] with drift         : Inf
##  ARIMA(1,1,1)(2,0,0)[12]                    : 711.5401
##  ARIMA(1,1,1)(2,0,0)[12] with drift         : 710.3668
##  ARIMA(1,1,1)(2,0,1)[12]                    : Inf
##  ARIMA(1,1,1)(2,0,1)[12] with drift         : 710.9011
##  ARIMA(1,1,2)                               : 709.917
##  ARIMA(1,1,2)             with drift        : 707.7162
##  ARIMA(1,1,2)(0,0,1)[12]                    : 710.6707
##  ARIMA(1,1,2)(0,0,1)[12] with drift         : 709.2141
##  ARIMA(1,1,2)(0,0,2)[12]                    : 712.866
##  ARIMA(1,1,2)(0,0,2)[12] with drift         : 711.3721
##  ARIMA(1,1,2)(1,0,0)[12]                    : 710.6868
##  ARIMA(1,1,2)(1,0,0)[12] with drift         : 709.2447
##  ARIMA(1,1,2)(1,0,1)[12]                    : Inf
##  ARIMA(1,1,2)(1,0,1)[12] with drift         : Inf
##  ARIMA(1,1,2)(2,0,0)[12]                    : Inf
##  ARIMA(1,1,2)(2,0,0)[12] with drift         : 711.2873
##  ARIMA(1,1,3)                               : Inf
##  ARIMA(1,1,3)             with drift        : 709.8411
##  ARIMA(1,1,3)(0,0,1)[12]                    : Inf
##  ARIMA(1,1,3)(0,0,1)[12] with drift         : 711.3804
##  ARIMA(1,1,3)(1,0,0)[12]                    : Inf
##  ARIMA(1,1,3)(1,0,0)[12] with drift         : 711.4136
##  ARIMA(1,1,4)                               : Inf
##  ARIMA(1,1,4)             with drift        : 711.7149
##  ARIMA(2,1,0)                               : 708.2743
##  ARIMA(2,1,0)             with drift        : 706.3512
##  ARIMA(2,1,0)(0,0,1)[12]                    : 709.1061
##  ARIMA(2,1,0)(0,0,1)[12] with drift         : 707.8733
##  ARIMA(2,1,0)(0,0,2)[12]                    : 711.2245
##  ARIMA(2,1,0)(0,0,2)[12] with drift         : 710.0653
##  ARIMA(2,1,0)(1,0,0)[12]                    : 709.0911
##  ARIMA(2,1,0)(1,0,0)[12] with drift         : 707.8857
##  ARIMA(2,1,0)(1,0,1)[12]                    : 711.252
##  ARIMA(2,1,0)(1,0,1)[12] with drift         : 710.0683
##  ARIMA(2,1,0)(1,0,2)[12]                    : 712.959
##  ARIMA(2,1,0)(1,0,2)[12] with drift         : Inf
##  ARIMA(2,1,0)(2,0,0)[12]                    : 711.2512
##  ARIMA(2,1,0)(2,0,0)[12] with drift         : 710.0238
##  ARIMA(2,1,0)(2,0,1)[12]                    : Inf
##  ARIMA(2,1,0)(2,0,1)[12] with drift         : 710.6408
##  ARIMA(2,1,1)                               : 710.202
##  ARIMA(2,1,1)             with drift        : 708.2022
##  ARIMA(2,1,1)(0,0,1)[12]                    : 710.9826
##  ARIMA(2,1,1)(0,0,1)[12] with drift         : 709.6998
##  ARIMA(2,1,1)(0,0,2)[12]                    : 713.1676
##  ARIMA(2,1,1)(0,0,2)[12] with drift         : 711.9033
```

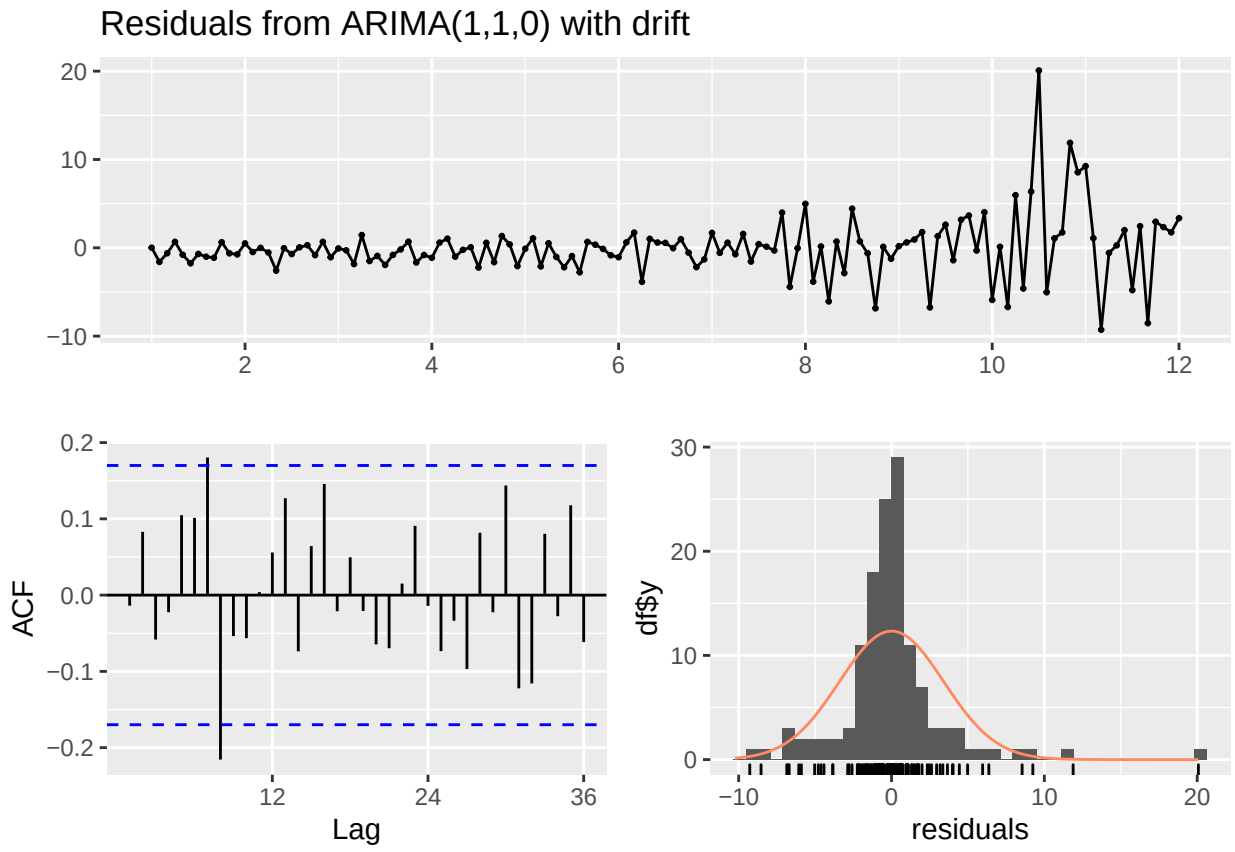
```
##  ARIMA(2,1,1)(1,0,0)[12]                    : 710.9853
##  ARIMA(2,1,1)(1,0,0)[12] with drift         : 709.7224
##  ARIMA(2,1,1)(1,0,1)[12]                    : 713.1743
##  ARIMA(2,1,1)(1,0,1)[12] with drift         : 711.9242
##  ARIMA(2,1,1)(2,0,0)[12]                    : 713.1625
##  ARIMA(2,1,1)(2,0,0)[12] with drift         : 711.8348
##  ARIMA(2,1,2)                               : Inf
##  ARIMA(2,1,2)            with drift         : Inf
##  ARIMA(2,1,2)(0,0,1)[12]                    : Inf
##  ARIMA(2,1,2)(0,0,1)[12] with drift         : Inf
##  ARIMA(2,1,2)(1,0,0)[12]                    : Inf
##  ARIMA(2,1,2)(1,0,0)[12] with drift         : Inf
##  ARIMA(2,1,3)                               : Inf
##  ARIMA(2,1,3)            with drift         : Inf
##  ARIMA(3,1,0)                               : 710.1714
##  ARIMA(3,1,0)            with drift         : 707.8465
##  ARIMA(3,1,0)(0,0,1)[12]                    : 710.9197
##  ARIMA(3,1,0)(0,0,1)[12] with drift         : 709.3453
##  ARIMA(3,1,0)(0,0,2)[12]                    : 713.1109
##  ARIMA(3,1,0)(0,0,2)[12] with drift         : 711.4793
##  ARIMA(3,1,0)(1,0,0)[12]                    : 710.9287
##  ARIMA(3,1,0)(1,0,0)[12] with drift         : 709.3791
##  ARIMA(3,1,0)(1,0,1)[12]                    : 713.1137
##  ARIMA(3,1,0)(1,0,1)[12] with drift         : 711.5527
##  ARIMA(3,1,0)(2,0,0)[12]                    : 713.0954
##  ARIMA(3,1,0)(2,0,0)[12] with drift         : 711.3791
##  ARIMA(3,1,1)                               : 712.3052
##  ARIMA(3,1,1)            with drift         : 710.0387
##  ARIMA(3,1,1)(0,0,1)[12]                    : 713.0881
##  ARIMA(3,1,1)(0,0,1)[12] with drift         : 711.5728
##  ARIMA(3,1,1)(1,0,0)[12]                    : 713.0995
##  ARIMA(3,1,1)(1,0,0)[12] with drift         : 711.6069
##  ARIMA(3,1,2)                               : Inf
##  ARIMA(3,1,2)            with drift         : Inf
##  ARIMA(4,1,0)                               : 712.1028
##  ARIMA(4,1,0)            with drift         : 710.0243
##  ARIMA(4,1,0)(0,0,1)[12]                    : 712.9446
##  ARIMA(4,1,0)(0,0,1)[12] with drift         : 711.5604
##  ARIMA(4,1,0)(1,0,0)[12]                    : 712.9628
##  ARIMA(4,1,0)(1,0,0)[12] with drift         : 711.5951
##  ARIMA(4,1,1)                               : 711.1045
##  ARIMA(4,1,1)            with drift         : 711.0768
##  ARIMA(5,1,0)                               : 710.3189
##  ARIMA(5,1,0)            with drift         : 709.4339
##
##
##
##  Best model: ARIMA(1,1,0)            with drift
```

```
print(summary(fit_arima))
```

```
## Series: tsm_close
## ARIMA(1,1,0) with drift
##
```

```
## Coefficients:
##          ar1   drift
##       0.2133  0.8526
## s.e.  0.0851  0.3768
##
## sigma^2 estimated as 11.82:  log likelihood=-349.35
## AIC=704.69   AICc=704.88   BIC=713.34
##
## Training set error measures:
##                       ME     RMSE      MAE       MPE     MAPE      MASE
## Training set 0.003007824 3.399679 2.04327 -1.423544 5.370052 0.1858007
##                      ACF1
## Training set -0.01380116
```

```
checkresiduals(fit_arima,plot=TRUE)
```

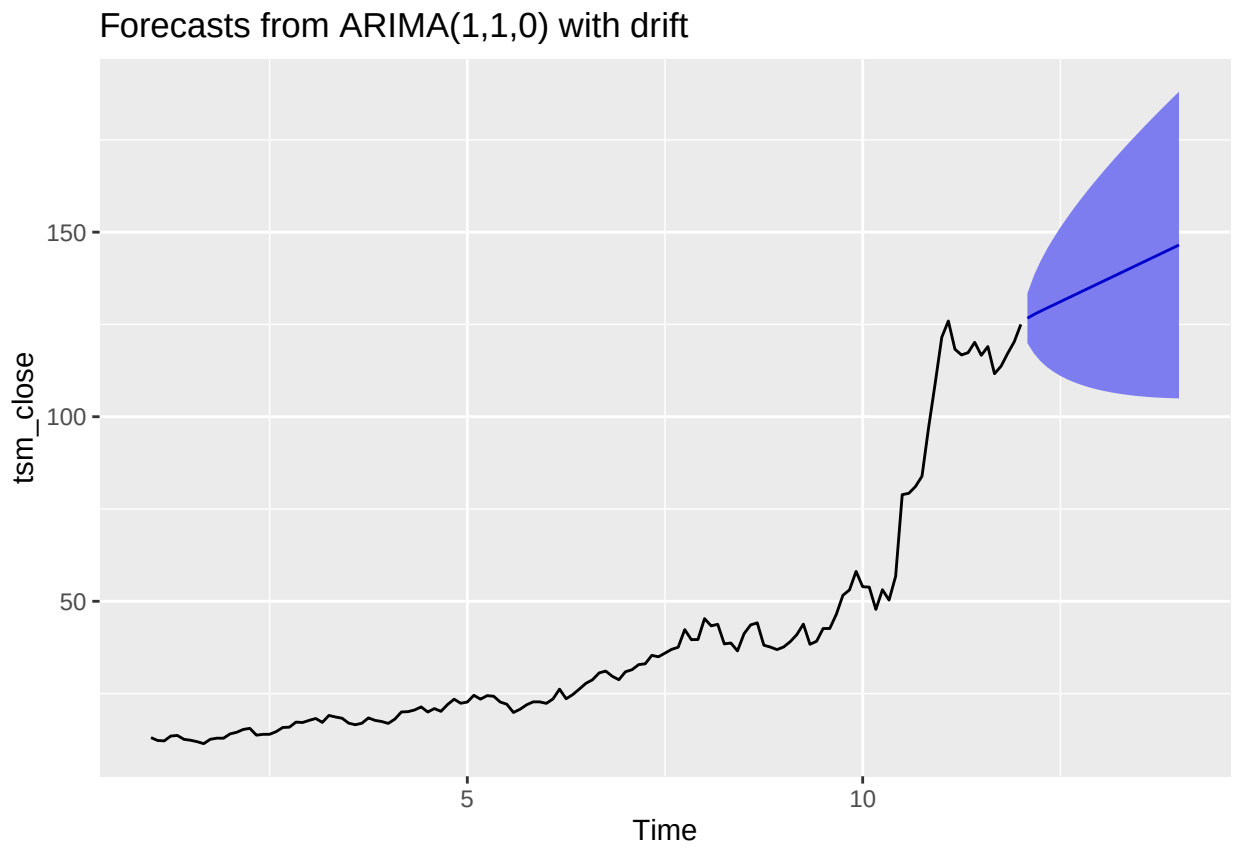



```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(1,1,0) with drift
## Q* = 27.668, df = 22, p-value = 0.1869
##
## Model df: 2.   Total lags used: 24
```

Forcast 24 month

```
fcst =  forecast(fit_arima, level=c(95),h=24)
autoplot(fcst) +   scale_x_continuous()
```

```
## Scale for 'x' is already present. Adding another scale for 'x', which will
## replace the existing scale.
```




```
#plot.fo
```