



MONASH
University

MONASH
BUSINESS
SCHOOL

ETW3420:

Assignment Project Exam Help

Principles of

Forecasting and

Applications

Add WeChat powcoder

Topic 2: Time Series Graphics

Dr. Jason Ng

1 Time series in R

2 Time plots

3 Seasonal plots

4 Seasonal or cyclic?

5 Lag plots and autocorrelation

6 White noise

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

A time series is stored in a ts object in R:

- a list of numbers
- information about times those numbers were recorded

Example

```
##      Year Observation
## 1 2012             123
## 2 2013              39
## 3 2014              78
## 4 2015              52
## 5 2016             110
```

```
y <- ts(c(123,39,78,52,110), start=2012)
```

Assignment Project Exam Help

For observations that are more frequent than once per year, add a frequency argument.

E.g., monthly data stored as a numerical vector z:

```
y <- ts(z, frequency=12, start=c(2003, 1))
```

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

Quarterly

Monthly

Daily

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

Quarterly

Monthly

Daily

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

ts(data, frequency, start)

Type of data

frequency

start example

Annual

1 1995

Quarterly

Monthly

Daily

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

Monthly

Daily

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1 1995

Quarterly

4 c('1995,2')

Monthly

Daily

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

c(1995,2)

Monthly

12

Daily

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

c(1995,2)

Monthly

12

c(1995,9)

Daily

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual 1 1995

Quarterly 4 c(1995,2)

Monthly 12 c(1995,9)

Daily 7 or 365.25

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

c(1995,2)

Monthly

12

c(1995,9)

Daily

7 or 365.25

1 or c(1995,234)

Weekly

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

c(1995,2)

Monthly

12

c(1995,9)

Daily

7 or 365.25

1 or c(1995,234)

Weekly

52 or 18

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

c(1995,2)

Monthly

12

c(1995,9)

Daily

7 or 365.25

1 or c(1995,234)

Weekly

52 or 182.5

c(1995,23)

Hourly

Half-hourly

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

c(1995,2)

Monthly

12

c(1995,9)

Daily

7 or 365.25

1 or c(1995,234)

Weekly

52 or 182

c(1995,23)

Hourly

24 or 168 or 8,766

Half-hourly

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual

1

1995

Quarterly

4

c(1995,2)

Monthly

12

c(1995,9)

Daily

7 or 365.25

1 or c(1995,234)

Weekly

52 or 182

c(1995,23)

Hourly

24 or 168 or 8,766

1

Half-hourly

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 or 365.25	1 or c(1995,234)
Weekly	52 or 182.6	c(1995,23)
Hourly	24 or 168 or 8,766	1
Half-hourly	48 or 336 or 17,532	

ts objects and ts function

`ts(data, frequency, start)`

Type of data

frequency

start example

Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 or 365.25	1 or c(1995,234)
Weekly	52 or 182.6	c(1995,23)
Hourly	24 or 168 or 8,766	1
Half-hourly	48 or 336 or 17,532	1

```
ausgdp <- ts(x, frequency=4, start=c(1971,3))
```

Class: "ts"

Print and plotting methods available.

```
ausgdp
```

```
##           Qtr1 Qtr2 Qtr3 Qtr4
```

```
## 1971                4612 4651
```

```
## 1972 4645 4615 4545 4722
```

```
## 1973 4780 4830 4887 4933
```

```
## 1974 4921 4875 4867 4905
```

```
## 1975 4938 4934 4942 4979
```

```
## 1976 5028 5079 5112 5127
```

```
## 1977 5130 5101 5072 5069
```

```
## 1978 5100 5166 5244 5313
```

<https://powcoder.com>

Add WeChat powcoder

Australian GDP

```
autoplot(ausgdp)
```

ausgdp

7000

6000

5000

1975

1980

1985

1990

1995

Time

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Assignment Project Exam Help

```
## Time Series:
```

```
## Start = 1989
```

```
## End = 2008
```

```
## Frequency = 1
```

```
## [1] 2354.34 2379.71 2318.52 2468.99 2386.09 2569.47
```

```
## [9] 2844.50 3000.70 3108.10 3357.50 3075.70 3180.60
```

```
## [17] 3430.60 3527.48 3637.89 3655.00
```

Assignment Project Exam Help

> library(fpp2)

<https://powcoder.com>

Add WeChat powcoder

Assignment Project Exam Help

```
> library(fpp2)
```

This loads:

<https://powcoder.com>

■ some data for use in examples and exercises

Add WeChat powcoder

Assignment Project Exam Help

```
> library(fpp2)
```

This loads:

- some data for use in examples and exercises
- **forecast** package (for forecasting functions)
- **ggplot2** package (for graphics functions)
- **fma** package (for lots of time series data)
- **expsmooth** package (for more time series data)

<https://powcoder.com>

Add WeChat powcoder

1 Time series in R

2 Time plots

3 Seasonal plots

4 Seasonal or cyclic?

5 Lag plots and autocorrelation

6 White noise

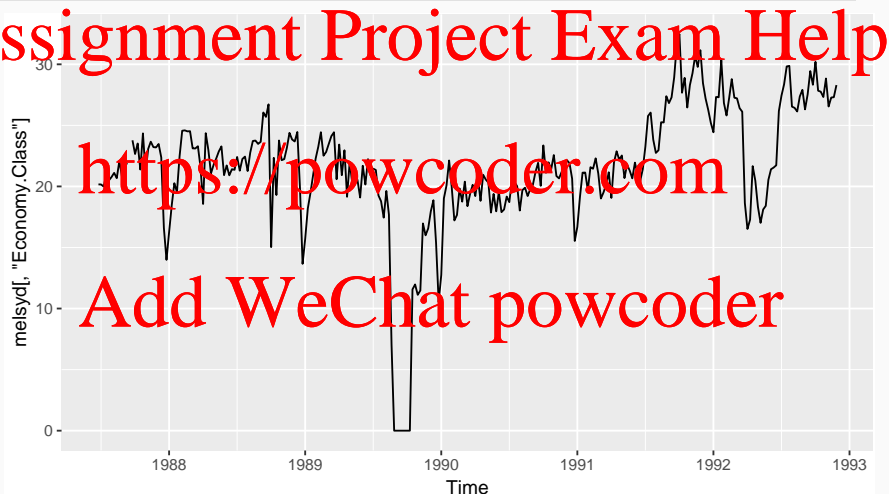
Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Time plots

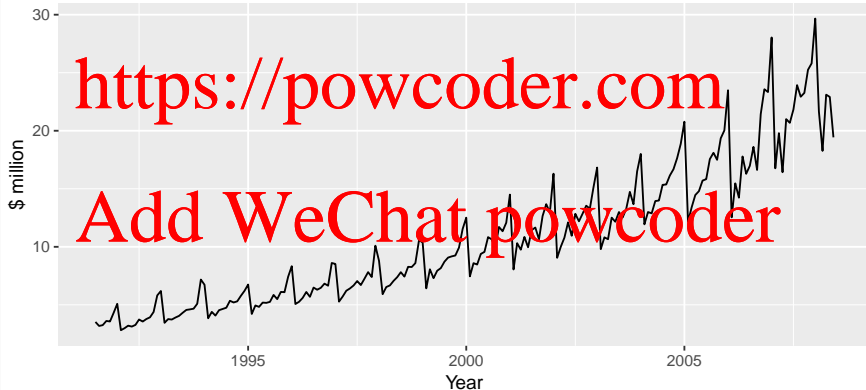
```
autoplot(melsyd[, "Economy.Class"])
```



Time plots

```
autoplot(a10) + ylab("$ million") + xlab("Year") +  
ggtitle("Antidiabetic drug sales")
```

Antidiabetic drug sales



<https://powcoder.com>

Add WeChat powcoder

Time plots

```
autoplot(elecdaily[, "Temperature"]) +  
  xlab("Week") + ylab("Max temperature")
```



Assignment Project Exam Help

- Create plots of the following time series: `dole`, `bricksq`, `lynx`, `goog`
- Use `help()` to find out about the data in each series.

Add WeChat powcoder

1 Time series in R

2 Time plots

3 Seasonal plots

4 Seasonal or cyclic?

5 Lag plots and autocorrelation

6 White noise

Assignment Project Exam Help

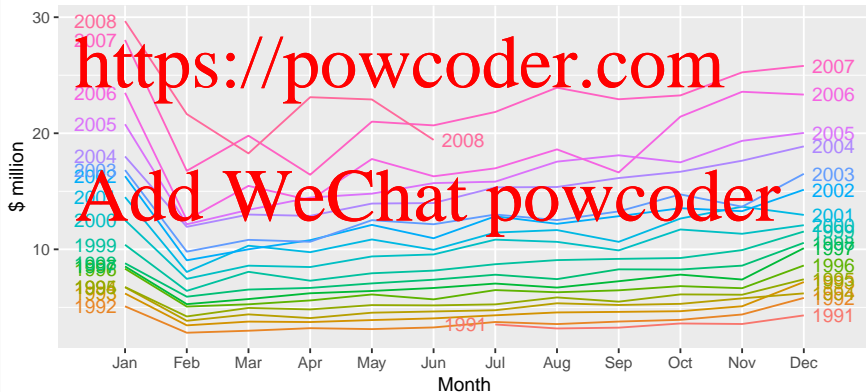
<https://powcoder.com>

Add WeChat powcoder

Seasonal plots

```
ggseasonplot(a10, year.labels=TRUE, year.labels.left=TRUE) +  
  ylab("$ million") +  
  ggtitle('Seasonal plot: antidiabetic drug sales')
```

Seasonal plot: antidiabetic drug sales



Assignment Project Exam Help

- Data plotted against the individual “seasons” in which the data were observed. (In this case a “season” is a month.)
- Something like a time plot except that the data from each season are overlapped.
- Enables the underlying seasonal pattern to be seen more clearly, and also allows any substantial departures from the seasonal pattern to be easily identified.
- In R: `ggseasonplot()`

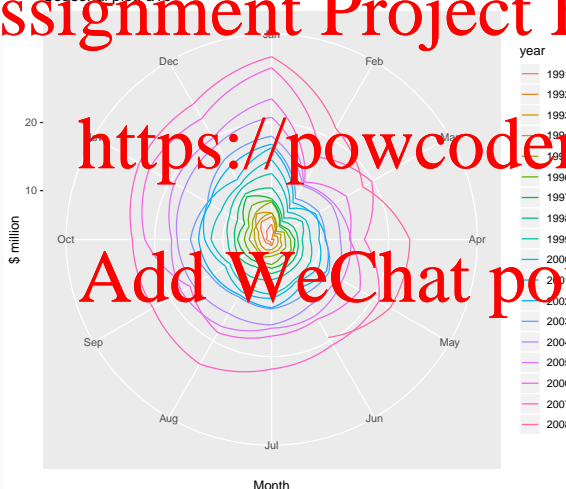
<https://powcoder.com>

Add WeChat powcoder

Seasonal polar plots

```
ggseasonplot(a10, polar=TRUE) + ylab("$ million")
```

Seasonal plot: a10



Assignment Project Exam Help

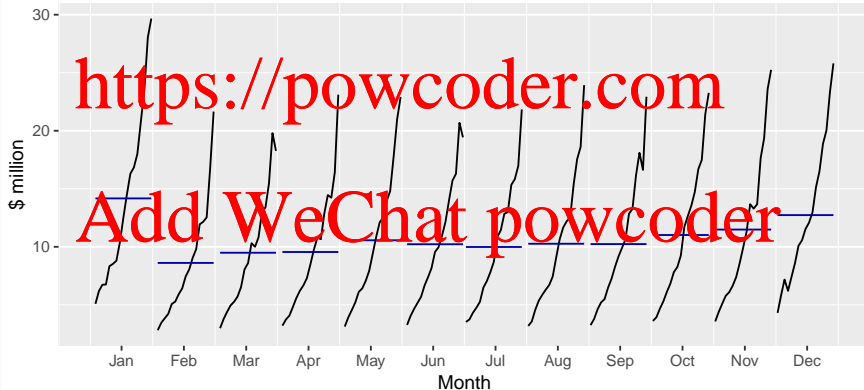
<https://powcoder.com>

Add WeChat powcoder

Seasonal subseries plots

```
ggsubseriesplot(a10) + ylab("$ million") +  
ggtitle("Subseries plot: antidiabetic drug sales")
```

Subseries plot: antidiabetic drug sales



Assignment Project Exam Help

- Data for each season collected together in time plot as separate time series.
- Enables the underlying seasonal pattern to be seen clearly, and changes in seasonality over time to be visualized.
- In R: `ggsubseriesplot()`

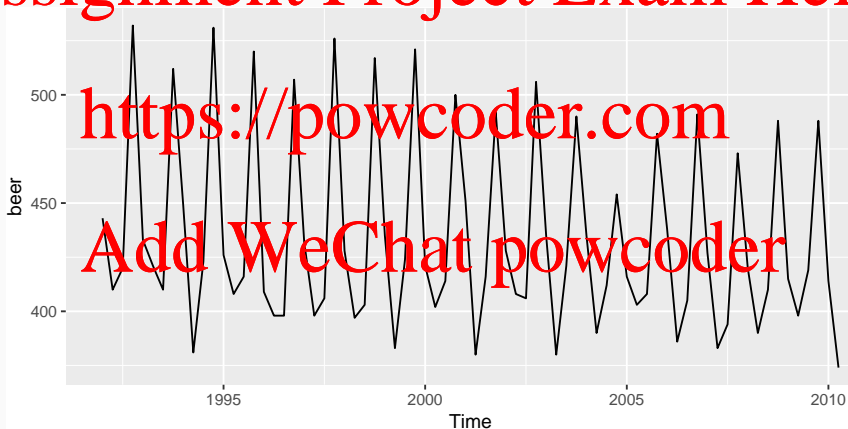
<https://powcoder.com>

Add WeChat powcoder

Quarterly Australian Beer Production

```
beer <- window(ausbeer, start=1992)
```

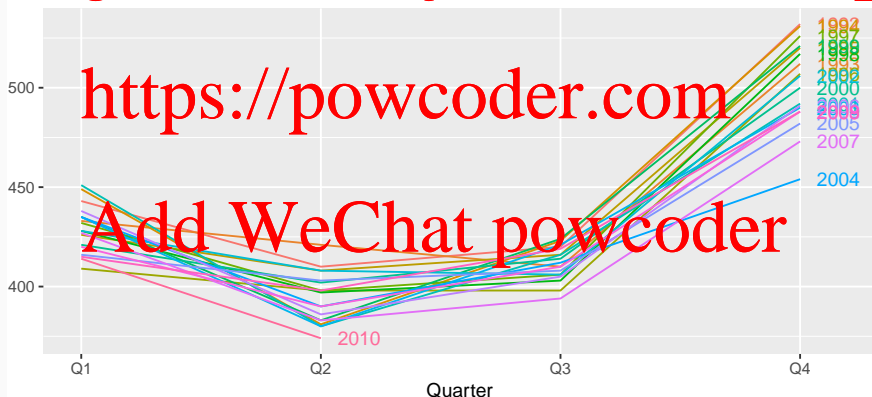
```
autoplot(beer)
```



Quarterly Australian Beer Production

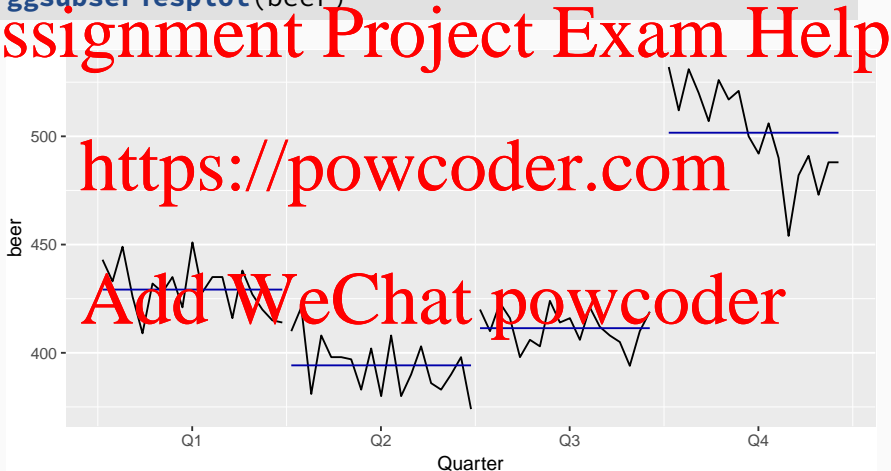
```
ggseasonplot(beer, year.labels=TRUE)
```

Seasonal plot: beer



Quarterly Australian Beer Production

`ggsubseriesplot(beer)`



Assignment Project Exam Help

The arrivals data set comprises quarterly international arrivals (in thousands) to Australia from Japan, New Zealand, UK and the US.

<https://powcoder.com>

- Use `autoplot()` and `ggseasonplot()` to compare the differences between the arrivals from these four countries.
- Can you identify any unusual observations?

Add WeChat powcoder

1 Time series in R

2 Time plots

3 Seasonal plots

4 Seasonal or cyclic?

5 Lag plots and autocorrelation

6 White noise

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Assignment Project Exam Help

Trend pattern exists when there is a long term increase or decrease in the data.

Seasonal pattern exists when a series is influenced by seasonal factors (e.g., the quarter of the year, the month, or day of the week).

Cyclic pattern exists when data exhibit rises and falls that are not of fixed period (duration usually of at least 2 years).

<https://powcoder.com>
Add WeChat powcoder

Assignment Project Exam Help

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

<https://powcoder.com>

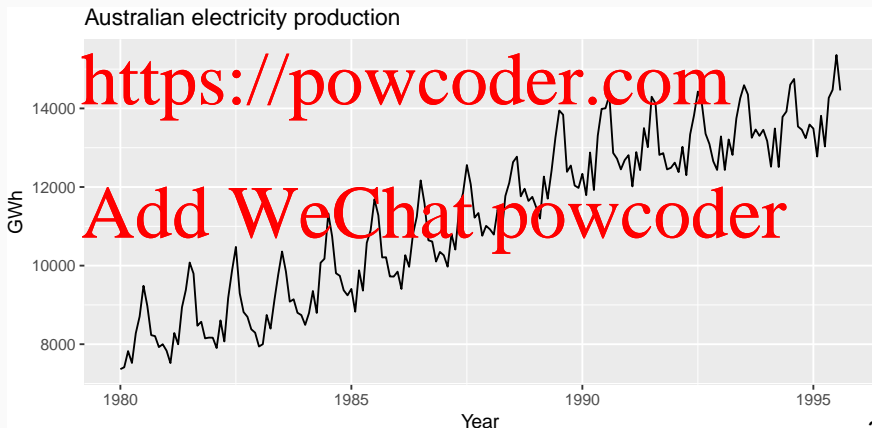
Add WeChat powcoder

Time series patterns

```
autoplot(window(elec, start=1980)) +
```

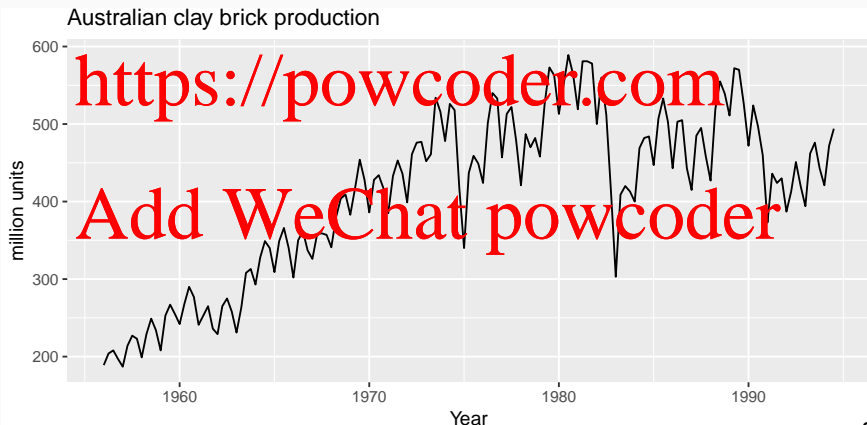
```
  ggtitle("Australian electricity production") +
```

```
  xlab("Year") + ylab("GWh")
```



Time series patterns

```
autoplot(bricksq) +  
  ggtitle("Australian clay brick production") +  
  xlab("Year") + ylab("million units")
```



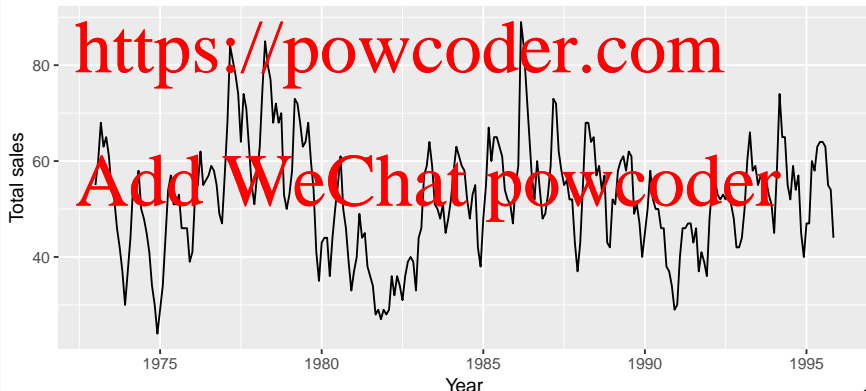
Time series patterns

```
autoplot(hsales) +
```

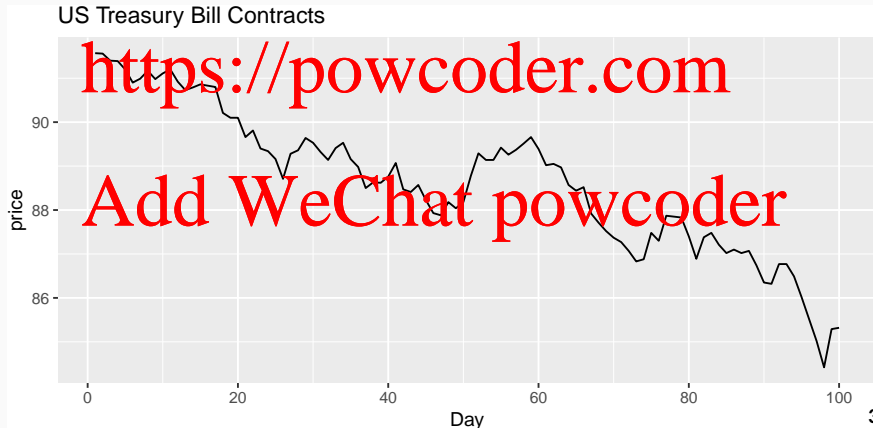
```
  ggtitle("Sales of new one-family houses, USA") +
```

```
  xlab("Year") + ylab("Total sales")
```

Sales of new one-family houses, USA

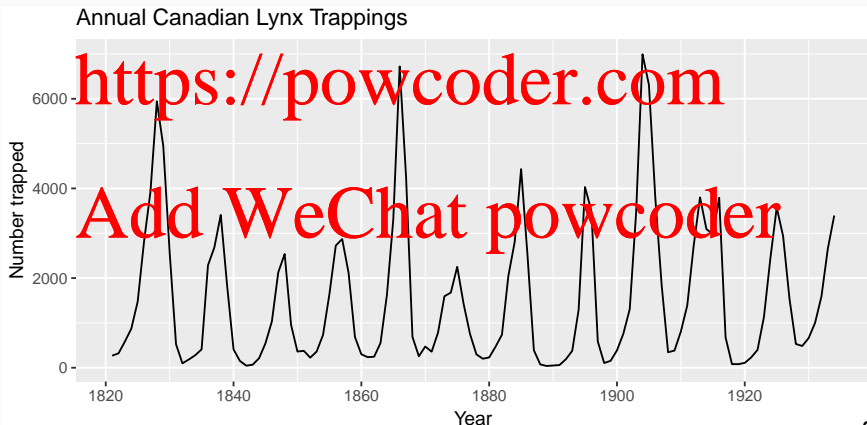


```
autoplot(ustreas) +  
  ggtitle("US Treasury Bill Contracts") +  
  xlab("Day") + ylab("price")
```



Time series patterns

```
autoplot(lynx) +  
  ggtitle("Annual Canadian Lynx Trappings") +  
  xlab("Year") + ylab("Number trapped")
```



Seasonal or cyclic?

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Seasonal or cyclic?

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

Add WeChat powcoder

The timing of peaks and troughs is predictable with seasonal data, but unpredictable in the long term with cyclic data.

1 Time series in R

2 Time plots

3 Seasonal plots

4 Seasonal or cyclic?

5 Lag plots and autocorrelation

6 White noise

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

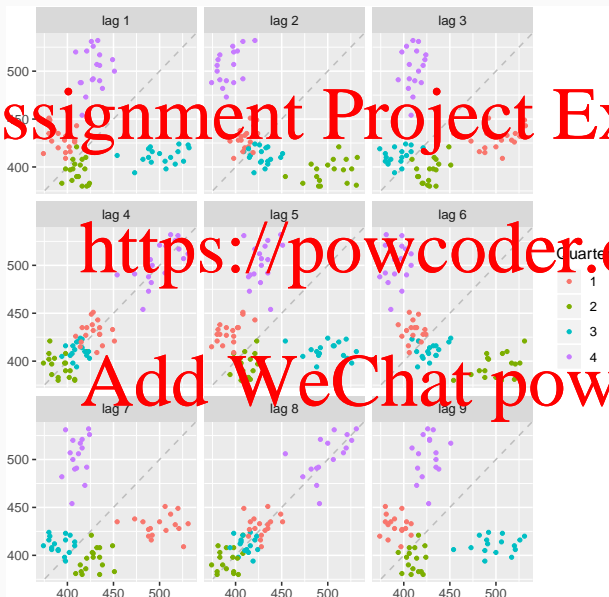
Assignment Project Exam Help

<https://powcoder.com>

```
beer <- window(ausbeer, start=1992)  
gglagplot(beer, do.lines = F)
```

Add WeChat powcoder

Example: Beer production



Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Assignment Project Exam Help

- Each graph shows y_t plotted against y_{t-k} for different values of k .
- The autocorrelations are the correlations associated with these scatterplots.

Add WeChat powcoder

Covariance and correlation: measure extent of linear relationship between two variables (y and x).

Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

Covariance and correlation: measure extent of linear relationship between two variables (y and x).

Autocovariance and autocorrelation: measure linear relationship between lagged values of a time series y .

<https://powcoder.com>

Add WeChat powcoder

Covariance and correlation: measure extent of linear relationship between two variables (y and x).

Autocovariance and autocorrelation: measure linear relationship between lagged values of a time series y .

We measure the relationship between:

- y_t and y_{t-1}
- y_t and y_{t-2}
- y_t and y_{t-3}
- etc.

Autocorrelation

We denote the sample autocovariance at lag k by c_k and the sample autocorrelation at lag k by r_k . Then define

$$c_k = \frac{1}{T} \sum_{t=k+1}^T (y_t - \bar{y})(y_{t-k} - \bar{y})$$

and $r_k = c_k / c_0$

Add WeChat powcoder

Autocorrelation

We denote the sample autocovariance at lag k by c_k and the sample autocorrelation at lag k by r_k . Then define

$$c_k = \frac{1}{T} \sum_{t=k+1}^T (y_t - \bar{y})(y_{t-k} - \bar{y})$$

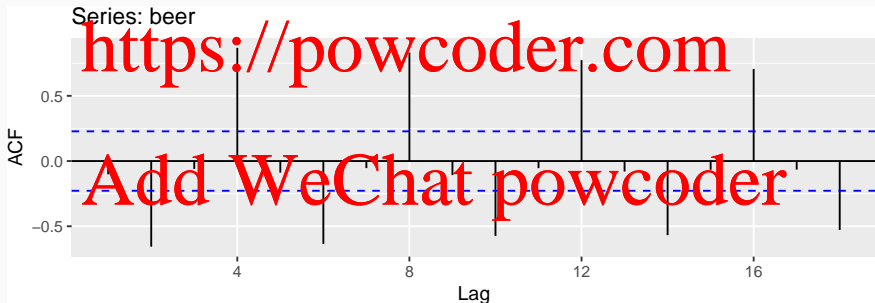
and $r_k = c_k / c_0$

- r_1 indicates how successive values of y relate to each other
- r_2 indicates how y values two periods apart relate to each other
- r_k is *almost* the same as the sample correlation between y_t and y_{t-k} .

Autocorrelation

Results for first 9 lags for beer data:

```
ggAcf(beer)
```



Assignment Project Exam Help

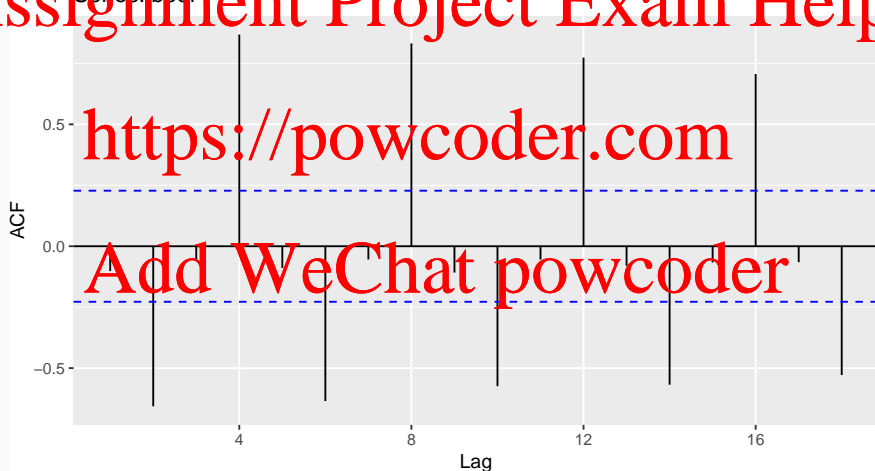
- r_1 higher than for the other lags. This is due to the seasonal pattern in the data: the peaks tend to be 4 quarters apart and the troughs tend to be 2 quarters apart.
- r_2 is more negative than for the other lags because troughs tend to be 2 quarters behind peaks.
- Together, the autocorrelations at lags 1, 2, ..., make up the autocorrelation or ACF.
- The plot is known as a **correlogram**

<https://powcoder.com>

Add WeChat powcoder

```
ggAcf(beer)
```

Series: beer



Assignment Project Exam Help

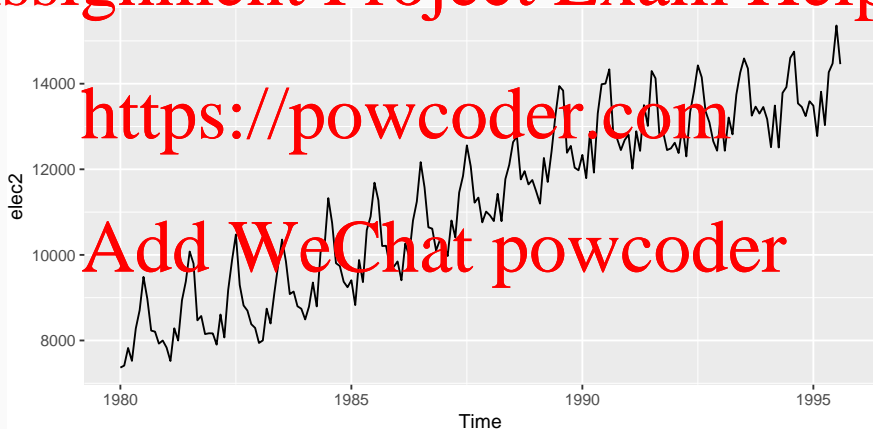
- When data have a trend, the autocorrelations for small lags tend to be large and positive.
- When data are seasonal, the autocorrelations will be larger at the seasonal lags (i.e., at multiples of the seasonal frequency)
- When data are trended and seasonal, you see a combination of these effects.

<https://powcoder.com>

Add WeChat powcoder

Aus monthly electricity production

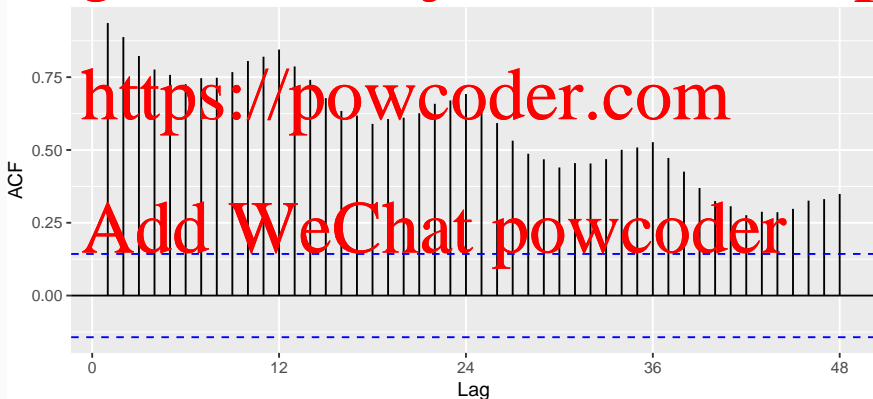
```
elec2 <- window(elec, start=1980)  
autoplot(elec2)
```



Aus monthly electricity production

```
ggAcf(elec2, lag.max=48)
```

Series: elec2



Assignment Project Exam Help

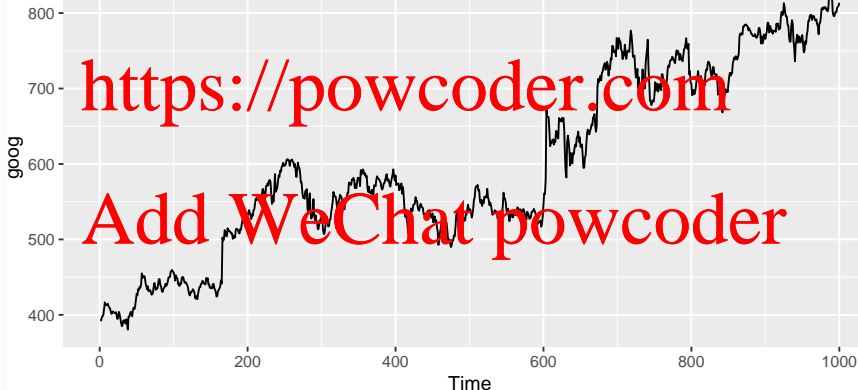
Time plot shows clear trend and seasonality.

The same features are reflected in the ACF.

- The slowly decaying ACF indicates trend.
- The ACF peaks at lags 12, 24, 36, ..., indicate seasonality of length 12.

<https://powcoder.com>
Add WeChat powcoder

`autoplot(goog)`



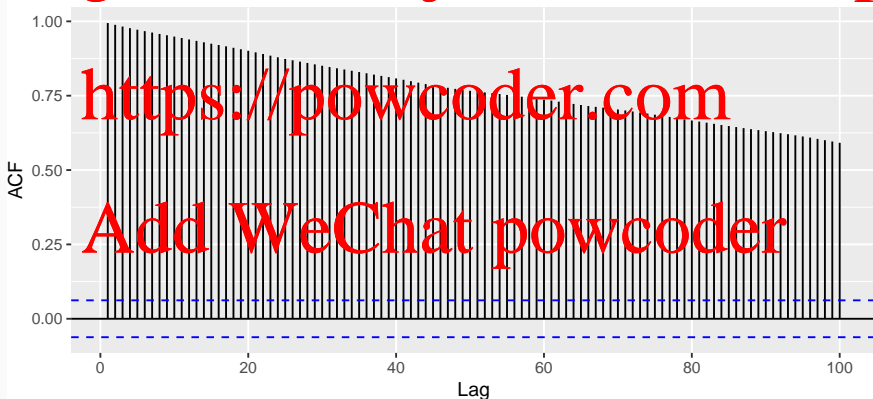
Assignment Project Exam Help

<https://powcoder.com>

Add WeChat powcoder

```
ggAcf(goog, lag.max=100)
```

Series: goog



We have introduced the following graphics functions:

- `ggplot`
- `ggplot2`

Assignment Project Exam Help

Explore the following time series using these functions. Can you spot any seasonality, cyclicity and trend? What do you learn about the series?

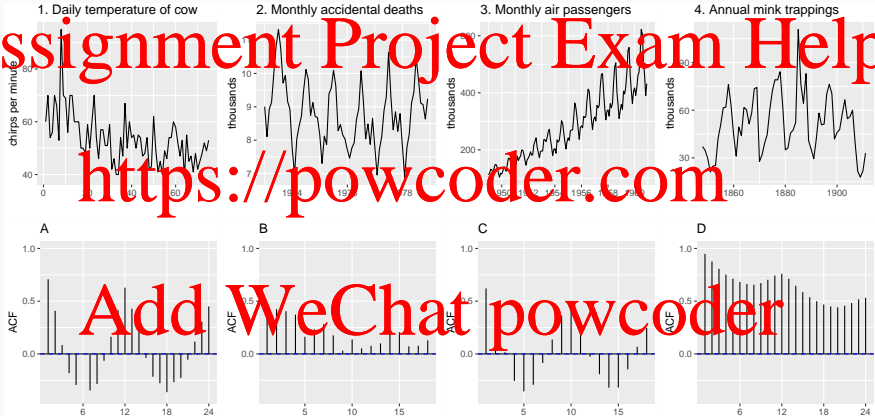
- `hsales`
- `usdeaths`
- `bricksq`
- `sunspotarea`
- `gasoline`

Add WeChat powcoder

Which is which?

Assignment Project Exam Help

<https://powcoder.com>



Add WeChat powcoder

1 Time series in R

2 Time plots

3 Seasonal plots

4 Seasonal or cyclic?

5 Lag plots and autocorrelation

6 White noise

Assignment Project Exam Help

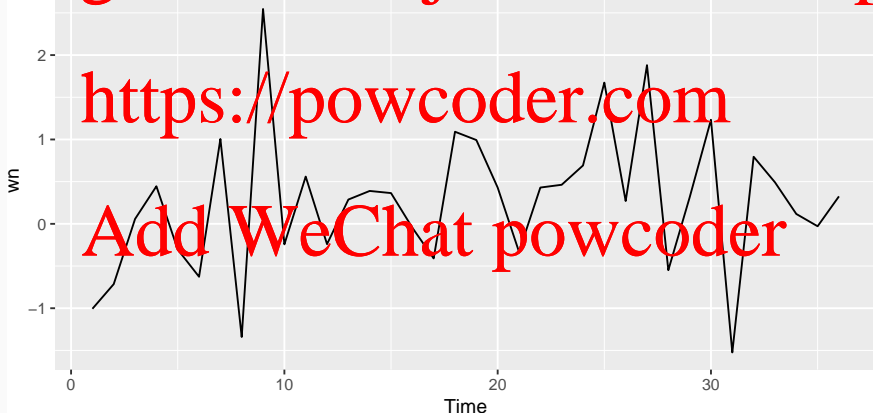
<https://powcoder.com>

Add WeChat powcoder

Example: White noise

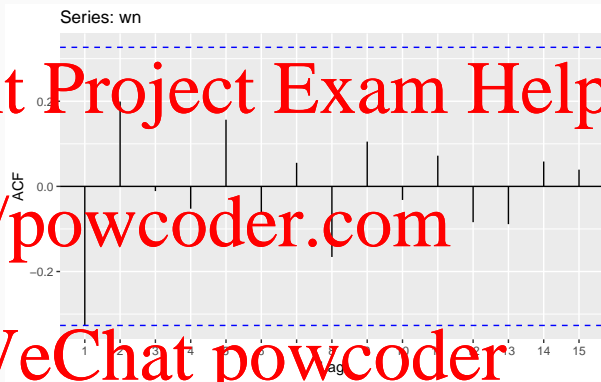
```
wn <- ts(rnorm(36))
```

```
autoplot(wn)
```



Example: White noise

r_1	-0.33
r_2	0.20
r_3	-0.01
r_4	-0.05
r_5	0.16
r_6	-0.06
r_7	0.06
r_8	-0.17
r_9	0.1
r_{10}	-0.03



Sample autocorrelations for white noise series.

We expect each autocorrelation to be close to zero.

Assignment Project Exam Help

Sampling distribution of r_k for white noise data is asymptotically $N(0, 1/T)$.

<https://powcoder.com>

Add WeChat powcoder

Assignment Project Exam Help

Sampling distribution of r_k for white noise data is asymptotically $N(0, 1/T)$.

- 95% of all r_k for white noise must lie within $\pm 1.96/\sqrt{T}$.
- If this is not the case, the series is probably not WN.
- Common to plot lines at $\pm 1.96/\sqrt{T}$ when plotting ACF. These are the **critical values**.

Autocorrelation

Example:

$T = 36$ and so critical values

at $\pm 1.96/\sqrt{36} = \pm 0.327$.

All autocorrelation

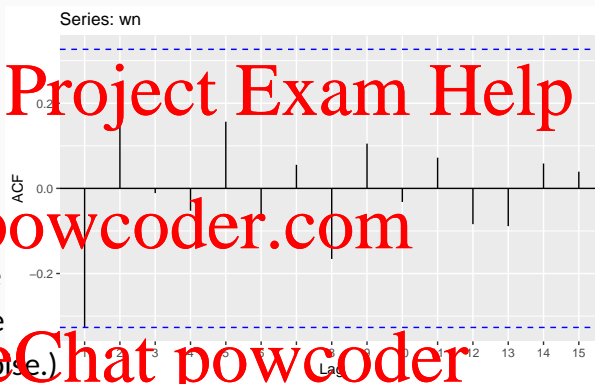
coefficients lie within these

limits, confirming that the

data are white noise. (More

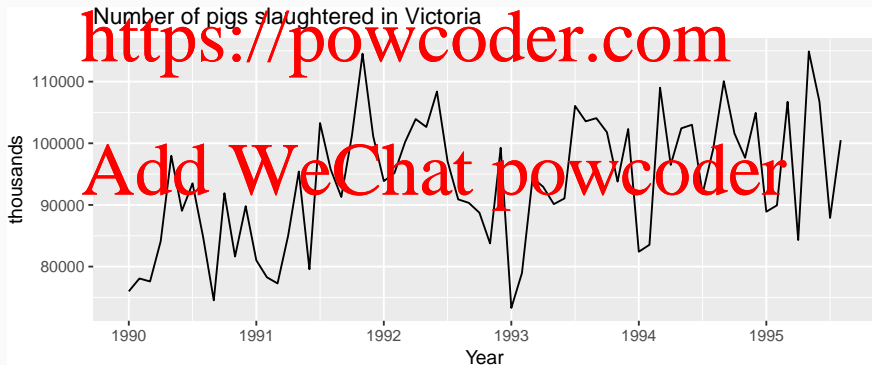
precisely, the data cannot be

distinguished from white noise.)



Example: Pigs slaughtered

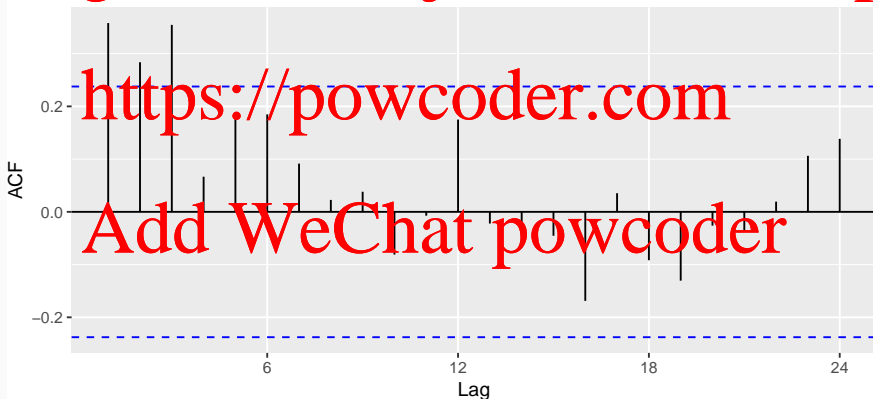
```
pigs2 <- window(pigs, start=1990)
autoplot(pigs2) +
  xlab("Year") + ylab("thousands") +
  ggtitle("Number of pigs slaughtered in Victoria")
```



Example: Pigs slaughtered

```
ggAcf(pigs2)
```

Series: pigs2



Example: Pigs slaughtered

Assignment Project Exam Help

Monthly total number of pigs slaughtered in the state of Victoria Australia, from January 1990 through August 1995. (Source: Australian Bureau of Statistics.)

<https://powcoder.com>

Add WeChat powcoder

Example: Pigs slaughtered

Assignment Project Exam Help

Monthly total number of pigs slaughtered in the state of Victoria Australia, from January 1990 through August 1995. (Source: Australian Bureau of Statistics.)

- Difficult to detect pattern in time plot.
- ACF shows some significant autocorrelation at lags 1, 2, and 3.
- r_{12} relatively large although not significant. This may indicate some slight seasonality.

<https://powcoder.com>
Add WeChat powcoder

Example: Pigs slaughtered

Assignment Project Exam Help

Monthly total number of pigs slaughtered in the state of Victoria Australia, from January 1990 through August 1995. (Source: Australian Bureau of Statistics.)

- Difficult to detect pattern in time plot.
- ACF shows some significant autocorrelation at lags 1, 2, and 3.
- r_{12} relatively large although not significant. This may indicate some slight seasonality.

These show the series is **not a white noise series**.

Assignment Project Exam Help

You can compute the daily changes in the Google stock price using

<https://powcoder.com>

```
dgoog <- diff(goog)
```

Does dgoog look like white noise?

Add WeChat powcoder