MONASH University

MONASH BUSINESS SCHOOL

ETC3550 Applied forecasting for business and economics

Ch7. Time series decomposition

OTexts.org/fpp3/

Outline

Outline

Time series patterns

Recall

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

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

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).

Time series decomposition

$$y_t = f(S_t, T_t, R_t)$$

where $y_t =$ data at period t

$T_t =$ trend-cycle component at period t

$S_t =$ seasonal component at period t

$R_t =$ remainder component at period t

Time series decomposition

$$y_t = f(S_t, T_t, R_t)$$

where	y_t =	data at period t
	T_t =	trend-cycle component at period t
	S_t =	seasonal component at period t
	R_t =	remainder component at period t

Additive decomposition: $y_t = S_t + T_t + R_t$.

Multiplicative decomposition: $y_t = S_t \times T_t \times R_t$.

Time series decomposition

- Additive model appropriate if magnitude of seasonal fluctuations does not vary with level.
- If seasonal are proportional to level of series, then multiplicative model appropriate.
- Multiplicative decomposition more prevalent with economic series
- Alternative: use a Box-Cox transformation, and then use additive decomposition.
- Logs turn multiplicative relationship into an additive relationship:

$$y_t = S_t \times T_t \times E_t \quad \Rightarrow \quad \log y_t = \log S_t + \log T_t + \log R_t.$$

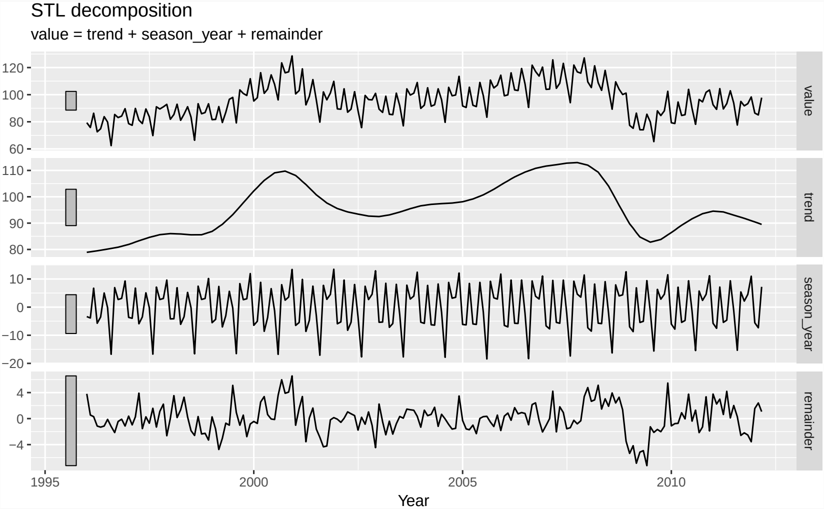
Decomposition dable

```r
dcmp <- elecequip %>% STL(value ~ season(window = 7))
dcmp
```

```
## # A dable:             195 x 6 [1M]
## # STL Decomposition: value = trend + season_year + remainder
##       index value trend season_year remainder seas_adjust
##       <mth> <dbl> <dbl>       <dbl>     <dbl>       <dbl>
##  1 1996 Jan  79.4  78.9       -3.37     3.81         82.7
##  2 1996 Feb  75.8  79.1       -3.87     0.547        79.7
##  3 1996 Mar  86.3  79.3        6.73     0.301        79.6
##  4 1996 Apr  72.6  79.5       -5.74    -1.15         78.3
##  5 1996 May  74.9  79.7       -3.53    -1.31         78.4
##  6 1996 Jun  83.8  79.9        5.03    -1.14         78.8
##  7 1996 Jul  79.8  80.1       -0.222   -0.119        80.0
##  8 1996 Aug  62.4  80.4      -16.8     -1.21         79.2
##  9 1996 Sep  85.4  80.6        6.94    -2.15         78.5
## 10 1996 Oct  83.1  80.9        2.70    -0.442        80.4
## # ... with 185 more rows
```

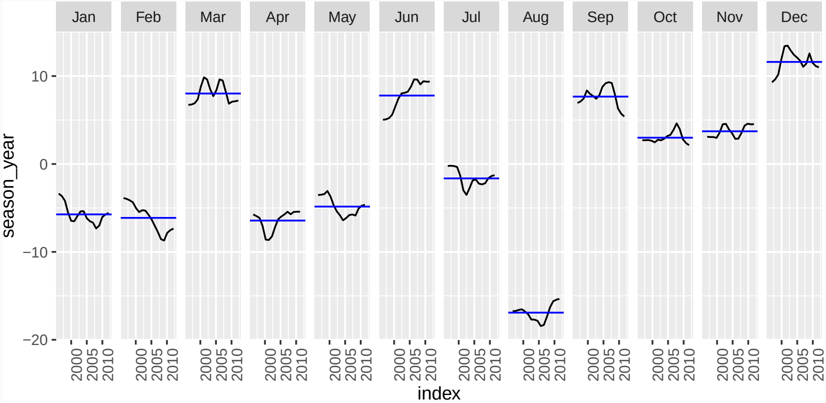
Euro electrical equipment

```r
autoplot(dcmp) + xlab("Year")
```



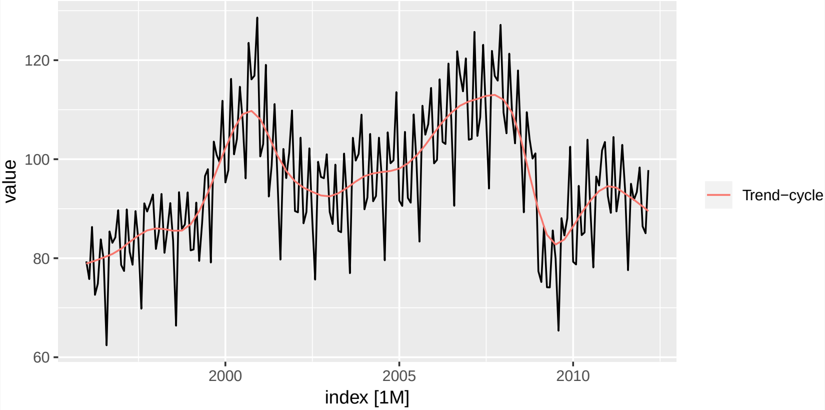
Euro electrical equipment

```
dcmp %>% gg_subseries(season_year)
```



Euro electrical equipment

```
autoplot(elecequip, series="Data") +
  autolayer(dcmp, trend, series="Trend-cycle")
```



Your turn

Repeat the decomposition using

```
elecequip %>%
  STL(value ~ season(window=7) + trend(window=11)) %>%
  autoplot()
```

What happens as you change `s.window` and `t.window`?

Outline

Seasonal adjustment

- Useful by-product of decomposition: an easy way to calculate seasonally adjusted data.
- Additive decomposition: seasonally adjusted data given by

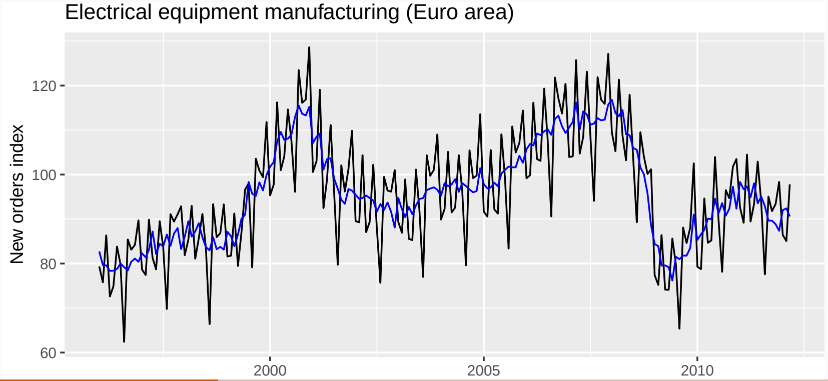
$$y_t - S_t = T_t + R_t$$

- Multiplicative decomposition: seasonally adjusted data given by

$$y_t / S_t = T_t \times R_t$$

Euro electrical equipment

```r
dcmp <- elecequip %>% STL(value ~ season(window=7))
elecequip %>%
  autoplot(value, series="Data") +
    autolayer(dcmp, trend + remainder,
      series="Seasonally Adjusted")
```



Seasonal adjustment

- We use estimates of S based on past values to seasonally adjust a current value.
- Seasonally adjusted series reflect **remainders** as well as **trend**. Therefore they are not “smooth”" and “downturns”" or “upturns” can be misleading.
- It is better to use the trend-cycle component to look for turning points.

The ABS stuff-up

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Treasurer Joe Hockey calls for answers over Australian Bureau of Statistics jobs data

By Michael Vincent and Simon Frazer

Updated 9 Oct 2014, 12:17pm

Federal Treasurer Joe Hockey says he wants answers to the problems the Australian Bureau of Statistics (ABS) has had with unemployment figures.

Mr Hockey, who is in the US to discuss Australia's G20 agenda, said last month's unemployment figures were "extraordinary".

The rate was 6.1 per cent after jumping to a 12-year high of 6.4 per cent the previous month.

The ABS has now taken the rare step of abandoning seasonal adjustment for its latest employment data.

PHOTO: Joe Hockey says he is unhappy with the volatility of ABS unemployment figures. (AAP: Alan Porritt)

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ABS abandons seasonal adjustment for latest jobs data

By business reporter Michael Janda

Updated 8 Oct 2014, 4:19pm

The Australian Bureau of Statistics is taking the rare step of abandoning seasonal adjustment for its latest employment data.

The ABS uses seasonal adjustment, based on historical experience, to account for the normal variation between hiring and firing patterns between different months.

However, after a winter where the seasonally adjusted unemployment rate swung wildly from 6.1 to 6.4 and back to 6.1 per cent, the bureau released a statement saying it will not adjust the original figure for September for seasonal factors.

It will also reset the seasonal adjustment for July and August to one, meaning that these months will

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VIDEO: Westpac chief economist Bill Evans discusses the ABS jobs data changes (ABC News)

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RELATED STORY: Jobs increase record sees unemployment slashed

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MAP: Australia

The ABS stuff-up

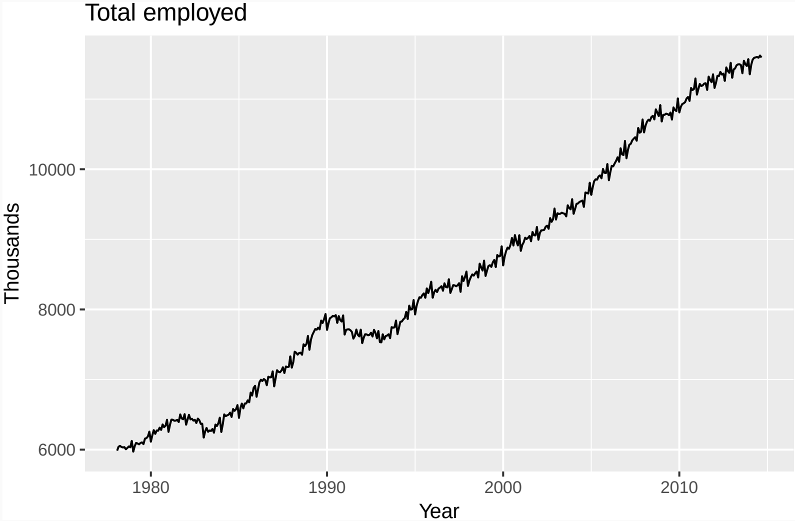
ABS jobs and unemployment figures – key questions answered by an expert

A professor of statistics at Monash University explains exactly what is seasonal adjustment, why it matters and what went wrong in the July and August figures

School leavers come on to the jobs market at the same time, causing a seasonal fluctuation. Photograph: Brian Snyder/Reuters

The Australian Bureau of Statistics has retracted its seasonally adjusted employment data for July and August, which recorded huge swings in the jobless rate. The ABS is also planning to review the methods it uses for seasonal adjustment to ensure its figures are as accurate as possible. Rob Hyndman, a professor of statistics at Monash University and member of the bureau's methodology advisory board, answers our questions:

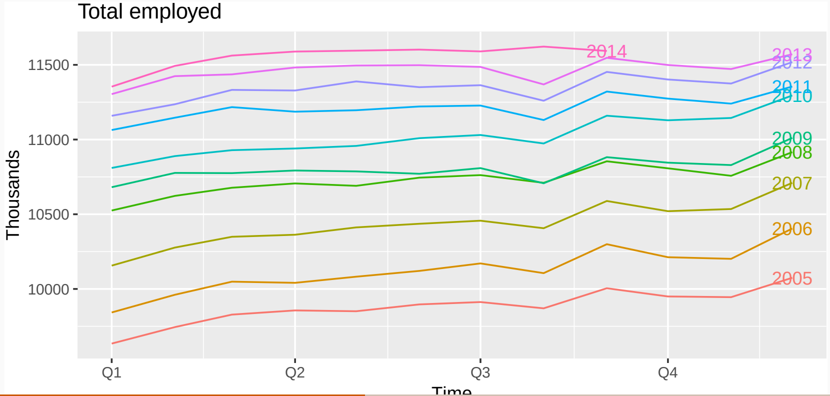
The ABS stuff-up



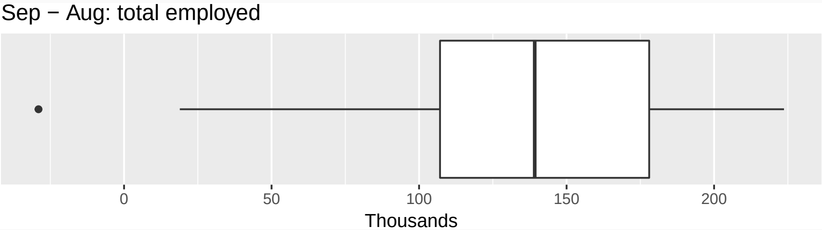
The ABS stuff-up

The ABS stuff-up

```r
x %>%
  filter(year(Time) >= 2005) %>%
  gg_season(Employed, label='right') +
  ggtitle("Total employed") + ylab("Thousands")
```

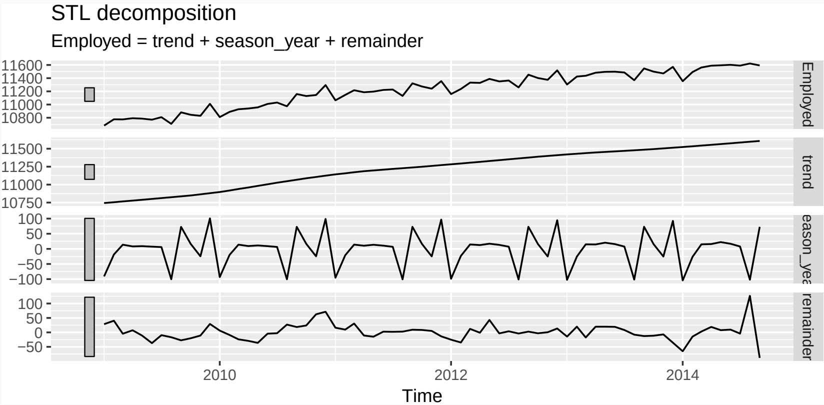


The ABS stuff-up

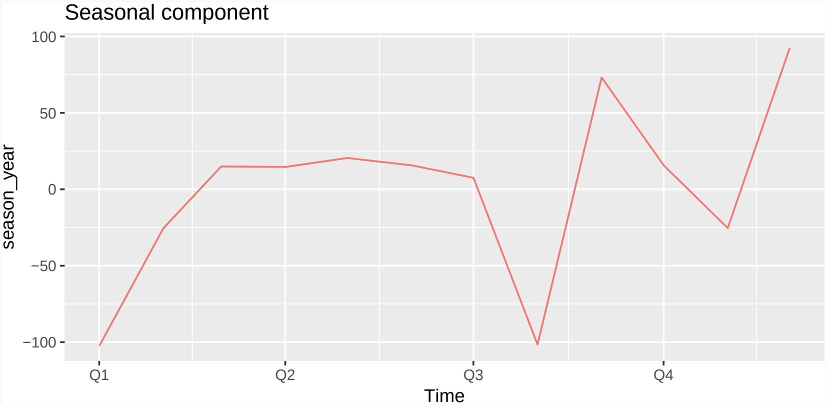


The ABS stuff-up

```
dcmp <- x %>%
  filter(year(Time) >= 2009) %>%
  STL(Employed ~ season(window = 11), robust = TRUE)
autoplot(dcmp)
```

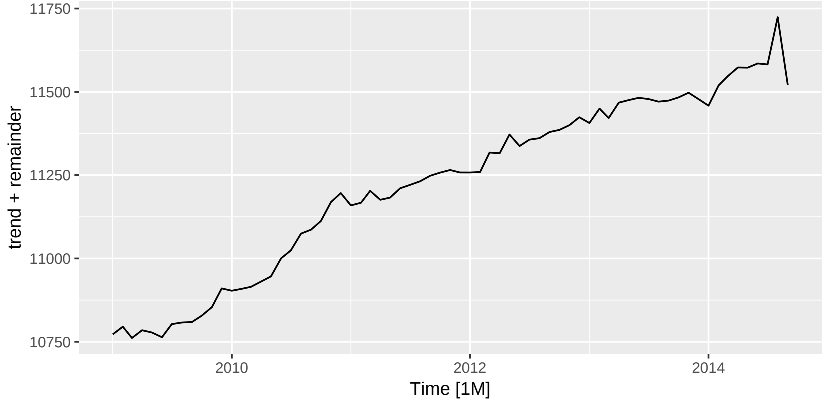


The ABS stuff-up



The ABS stuff-up

```
dcmp %>% as_tsibble %>%
  autoplot(trend + remainder)
```



The ABS stuff-up

- August 2014 employment numbers higher than expected.
- Supplementary survey usually conducted in August for employed people.
- Most likely, some employed people were claiming to be unemployed in August to avoid supplementary questions.
- Supplementary survey not run in 2014, so no motivation to lie about employment.
- In previous years, seasonal adjustment fixed the problem.
- The ABS has now adopted a new method to avoid the bias.

History of time series decomposition

- Classical method originated in 1920s.
- Census II method introduced in 1957. Basis for X-11 method and variants (including X-12-ARIMA, X-13-ARIMA)
- STL method introduced in 1983
- TRAMO/SEATS introduced in 1990s.

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- STL method introduced in 1983
- TRAMO/SEATS introduced in 1990s.

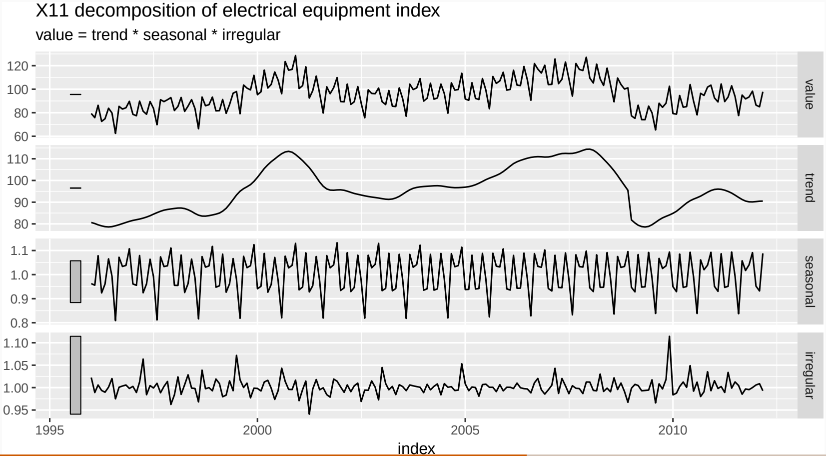
National Statistics Offices

- ABS uses X-12-ARIMA
- US Census Bureau uses X-13-ARIMA-SEATS
- Statistics Canada uses X-12-ARIMA
- ONS (UK) uses X-12-ARIMA
- EuroStat use X-13-ARIMA-SEATS

Outline

X-11 decomposition

```
elecequip %>% X11(value, type="multiplicative") %>%
  autoplot() +
  ggtitle("X11 decomposition of electrical equipment index")
```



(Dis)advantages of X-11

Advantages

- Relatively robust to outliers
- Completely automated choices for trend and seasonal changes
- Very widely tested on economic data over a long period of time.

(Dis)advantages of X-11

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- Relatively robust to outliers
- Completely automated choices for trend and seasonal changes
- Very widely tested on economic data over a long period of time.

Disadvantages

- No prediction/confidence intervals
- Ad hoc method with no underlying model
- Only developed for quarterly and monthly data

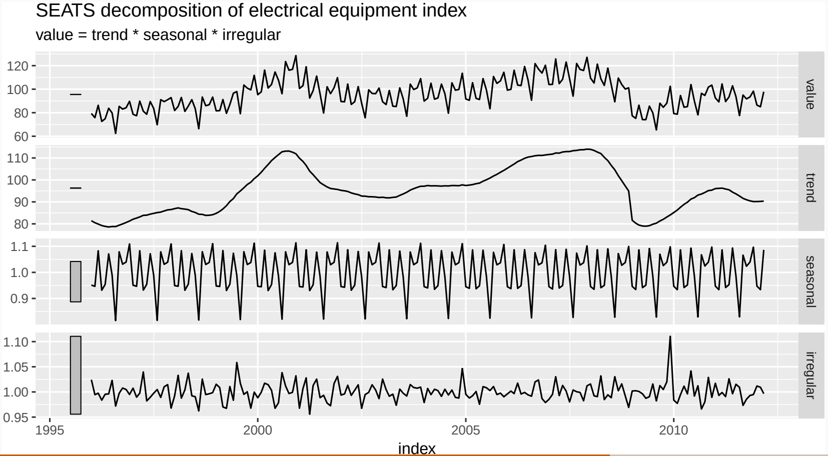
Extensions: X-12-ARIMA and X-13-ARIMA

- The X-11, X-12-ARIMA and X-13-ARIMA methods are based on Census II decomposition.
- These allow adjustments for trading days and other explanatory variables.
- Known outliers can be omitted.
- Level shifts and ramp effects can be modelled.
- Missing values estimated and replaced.
- Holiday factors (e.g., Easter, Labour Day) can be estimated.

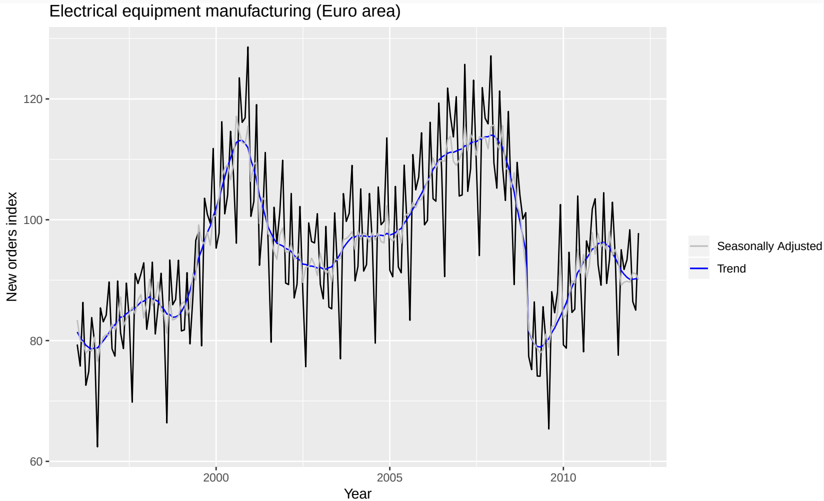
Outline

SEATS decomposition

```
elecequip %>% SEATS(value) %>%
  autoplot() +
  ggtitle("SEATS decomposition of electrical equipment index")
```

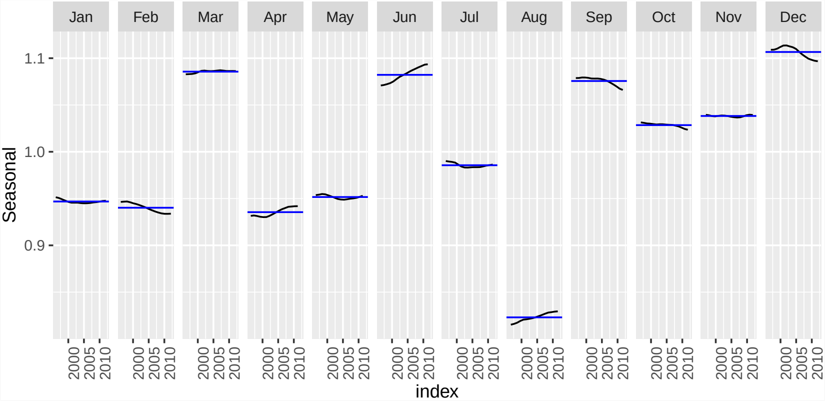


SEATS decomposition



SEATS decomposition

```
fit %>%
  gg_subseries(seasonal) + ylab("Seasonal")
```



(Dis)advantages of SEATS

Advantages

- Model-based
- Smooth trend estimate
- Allows estimates at end points
- Allows changing seasonality
- Developed for economic data

(Dis)advantages of SEATS

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Disadvantages

- Only developed for quarterly and monthly data

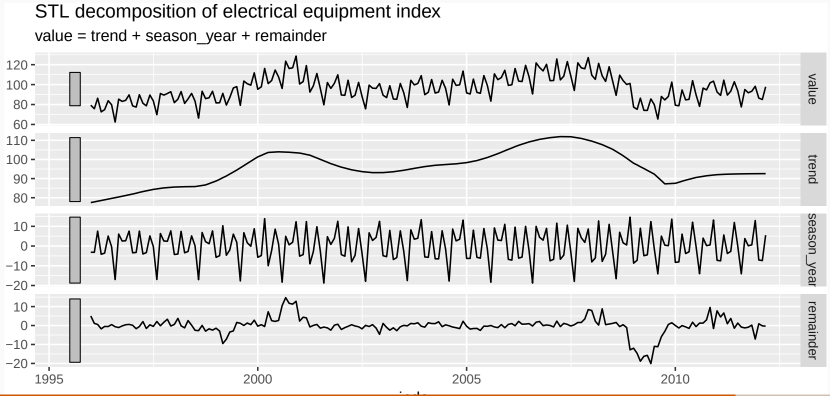
Outline

STL decomposition

- STL: "Seasonal and Trend decomposition using Loess"
- Very versatile and robust.
- Unlike X-12-ARIMA, STL will handle any type of seasonality.
- Seasonal component allowed to change over time, and rate of change controlled by user.
- Smoothness of trend-cycle also controlled by user.
- Robust to outliers
- Not trading day or calendar adjustments.
- Only additive.
- Take logs to get multiplicative decomposition.
- Use Box-Cox transformations to get other decompositions.

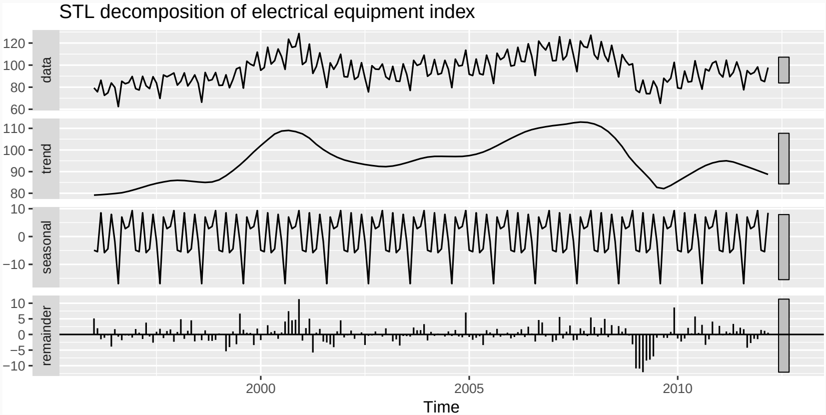
STL decomposition

```r
dcmp <- elecequip %>%
  STL(value ~ season(window = 5), robust = TRUE)
autoplot(dcmp) +
  ggtitle("STL decomposition of electrical equipment index")
```



STL decomposition

```
fit <- stl(elecequip, s.window="periodic", robust=TRUE)
autoplot(fit) +
  ggtitle("STL decomposition of electrical equipment index")
```



STL decomposition

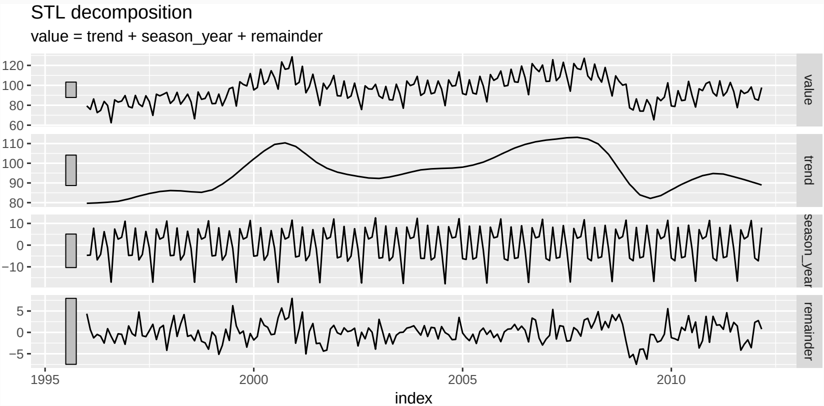
```
elecequip %>%
  STL(value ~ season(window = 5))

elecequip %>%
  STL(value ~ trend(window=15) + season(window="periodic"),
      robust = TRUE)
```

- `trend(window = ?)` controls wiggliness of trend component.
- `season(window = ?)` controls variation on seasonal component.

STL decomposition

```
elecequip %>% STL(value) %>% autoplot()
```



- `STL()` chooses `s.window=13` by default
- Can include transformations.

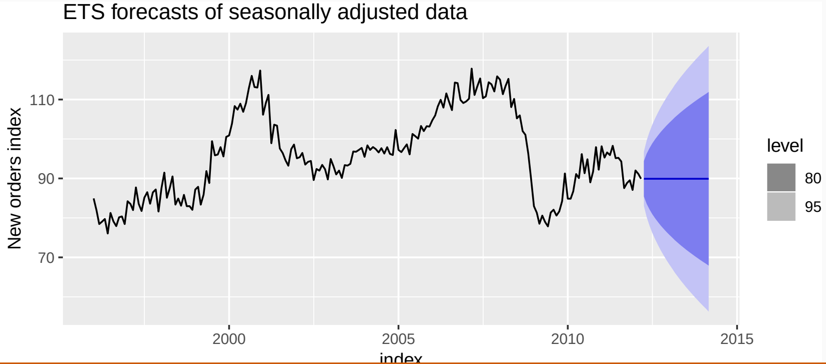
Outline

Forecasting and decomposition

- Forecast seasonal component by repeating the last year
- Forecast seasonally adjusted data using non-seasonal time series method.
- Combine forecasts of seasonal component with forecasts of seasonally adjusted data to get forecasts of original data.
- Sometimes a decomposition is useful just for understanding the data before building a separate forecasting model.

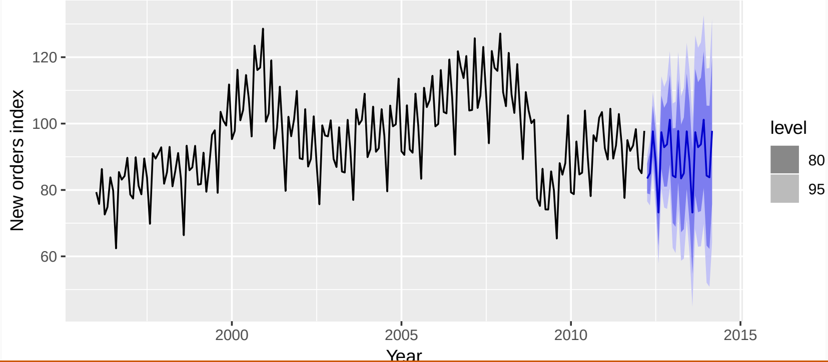
Electrical equipment

```r
dcmp <- elecequip %>%
  STL(value ~ trend(window=13) + season(window="periodic"))
dcmp %>%
  model(NAIVE(seas_adjust)) %>% forecast() %>%
  autoplot(dcmp) + ylab("New orders index") +
  ggtitle("ETS forecasts of seasonally adjusted data")
```



Electrical equipment

```
dcmp_def <- dcmp_model(STL,
  value ~ trend(window = 13) + season(window = "periodic"),
  NAIVE(seas_adjust))
elecequip %>%
  model(STLM = dcmp_def) %>% forecast() %>%
  autoplot(elecequip) + ylab("New orders index") + xlab("Year")
```



Decomposition and prediction intervals

- It is common to take the prediction intervals from the seasonally adjusted forecasts and modify them with the seasonal component.
- This ignores the uncertainty in the seasonal component estimate.
- It also ignores the uncertainty in the future seasonal pattern.