

# **ETC3550**

## **Applied forecasting for business and economics**

Ch7. Time series decomposition

[OTexts.org/fpp3/](https://OTexts.org/fpp3/)

# Outline

- 1 Time series components
- 2 Seasonal adjustment
- 3 X-11 decomposition
- 4 X-13ARIMA-SEATS decomposition
- 5 STL decomposition
- 6 Forecasting and decomposition

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# 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

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**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

```
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 season_adjust
##      <mtx> <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 7
## # with 185 more rows
```

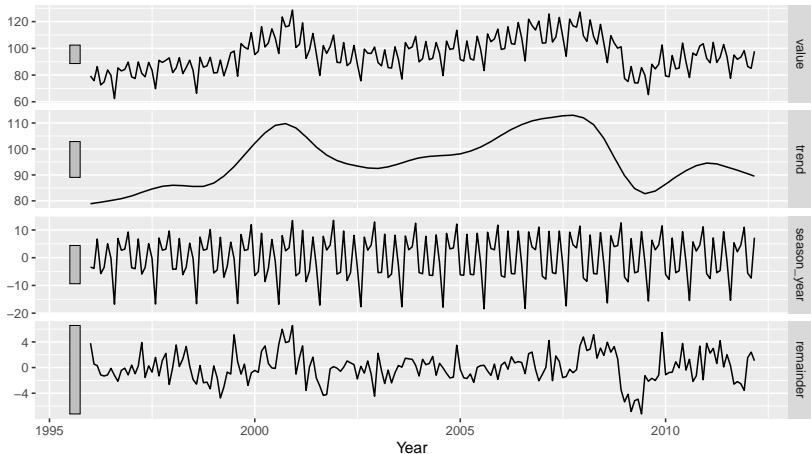


# Euro electrical equipment

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

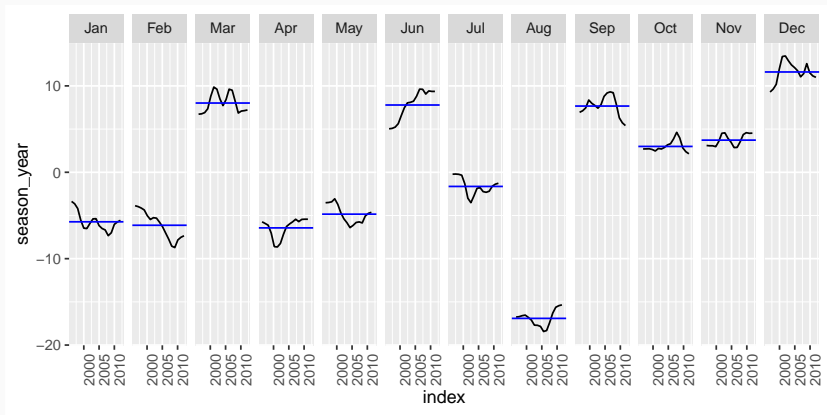
## STL decomposition

value = trend + season\_year + remainder



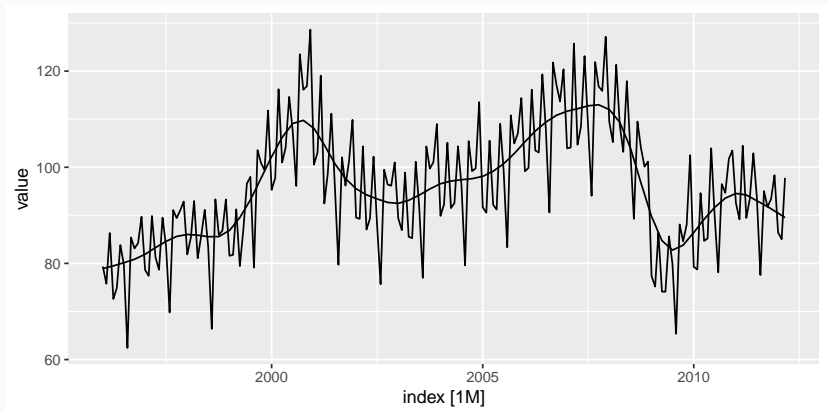
# Euro electrical equipment

```
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 `season(window = ???)` and `trend(window = ???)`?

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# 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

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

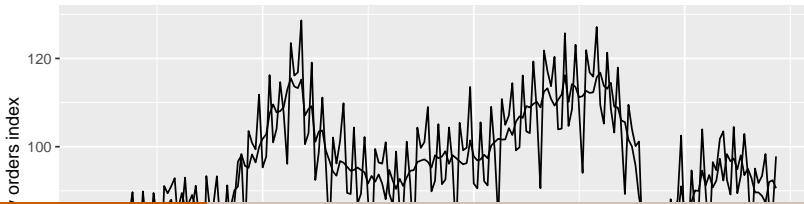
# Euro electrical equipment

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

```
## Warning: Ignoring unknown parameters: series
```

```
## Warning: Ignoring unknown parameters: series
```

Electrical equipment manufacturing (Euro area)




# 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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## BREAKING NEWS

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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)

**RELATED STORY:** [ABS abandons seasonal adjustment for](#)

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## BREAKING NEWS

Police arrest man in connection with stabbing death of 17-year-old Masa Vukotic in Mel

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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

Sorry, this video has expired

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

**RELATED STORY:** [Doubt the record breaking jobs figures? So does the ABS](#)

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# The ABS stuff-up

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

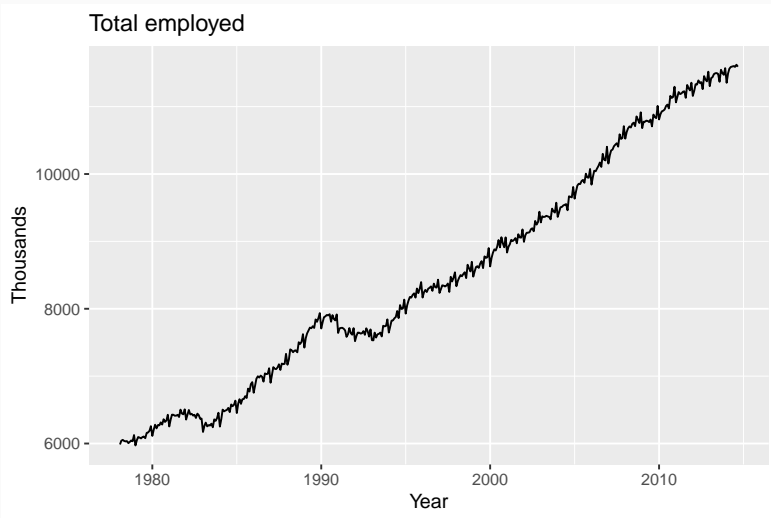
A professor of statistics at Monash University explains exactly what is seasonal adjustment, why it matters and what went wrong in the July and August figures



📷 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



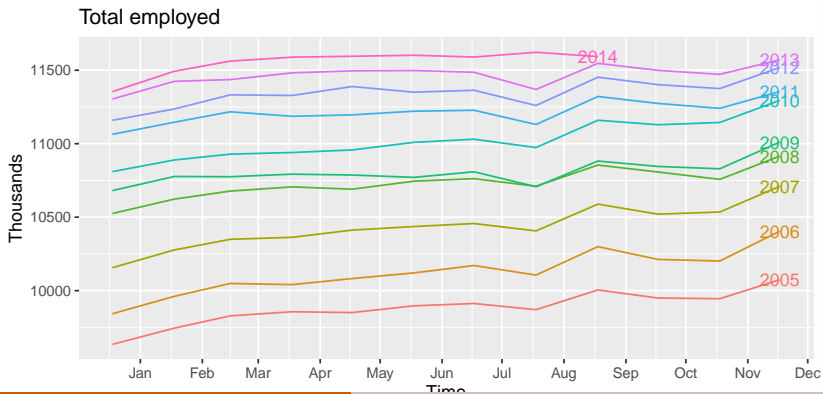
# The ABS stuff-up

x %>%

```
filter(year(Time) >= 2005) %>%
```

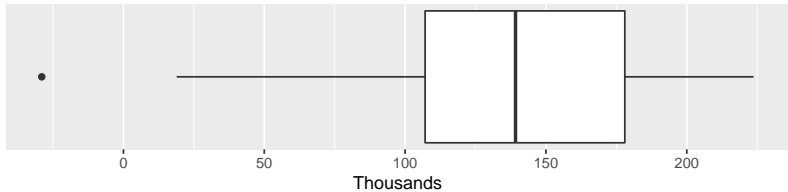
```
gg_season(Employed, label='right') +
```

```
ggtitle("Total employed") + ylab("Thousands")
```



# The ABS stuff-up

Sep – Aug: total employed

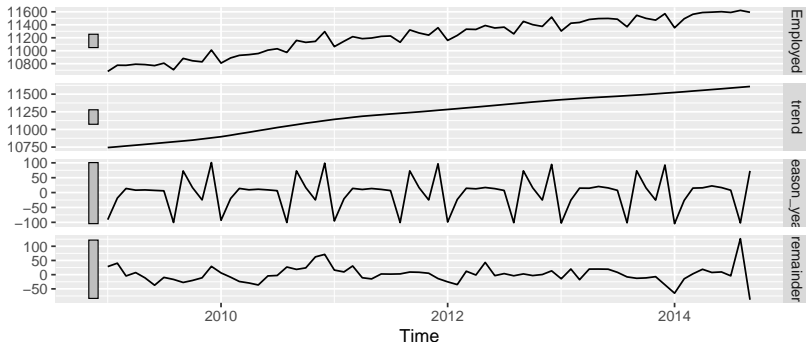


# The ABS stuff-up

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

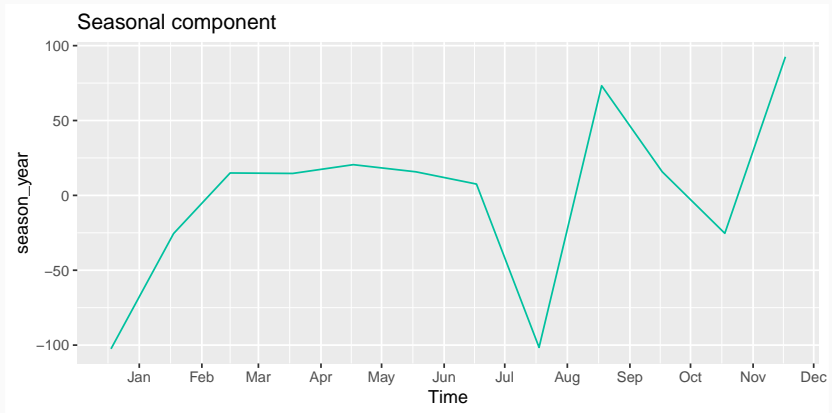
## STL decomposition

$\text{Employed} = \text{trend} + \text{season\_year} + \text{remainder}$



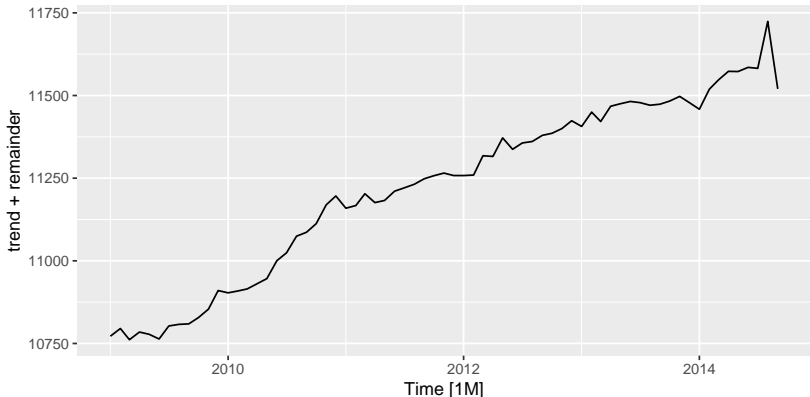


# The ABS stuff-up



# 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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- TRAMO/SEATS introduced in 1990s.

## National Statistics Offices

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

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# 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

## 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.

## 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.

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# X-13ARIMA-SEATS decomposition

```
elecequip %>% SEATS(value) %>%  
  autoplot() +  
  ggtitle("X-13ARIMA-SEATS decomposition of electrical equipment i
```

# X-13ARIMA-SEATS decomposition

# X-13ARIMA-SEATS decomposition

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

# (Dis)advantages of X-13ARIMA-SEATS

## Advantages

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

# (Dis)advantages of X-13ARIMA-SEATS

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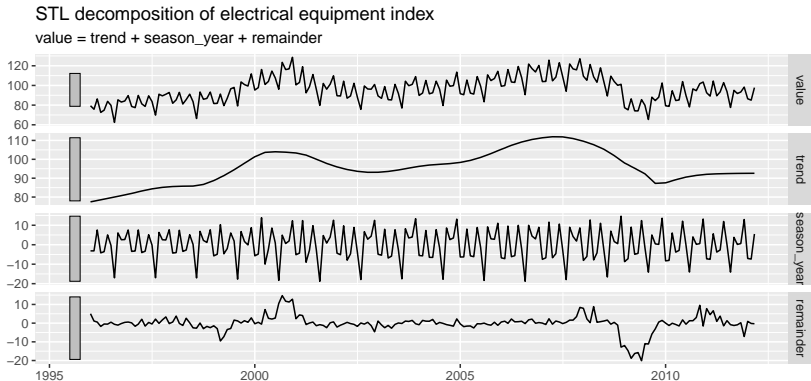
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# STL decomposition

- 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.

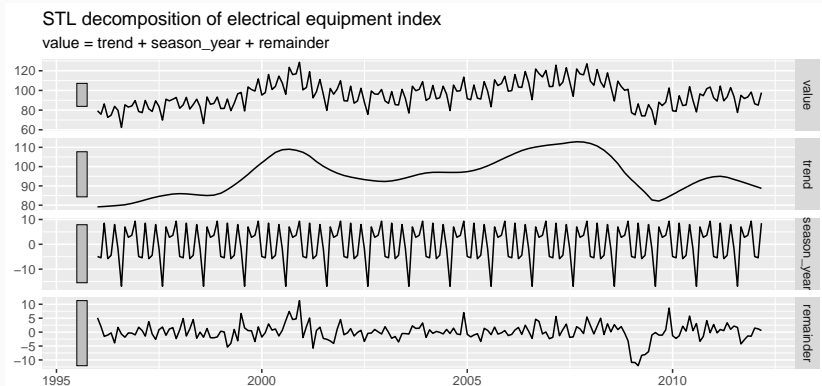
# STL decomposition

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



# STL decomposition

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



# STL decomposition

```
elecequip %>%
```

```
  STL(value ~ season(window = 5))
```

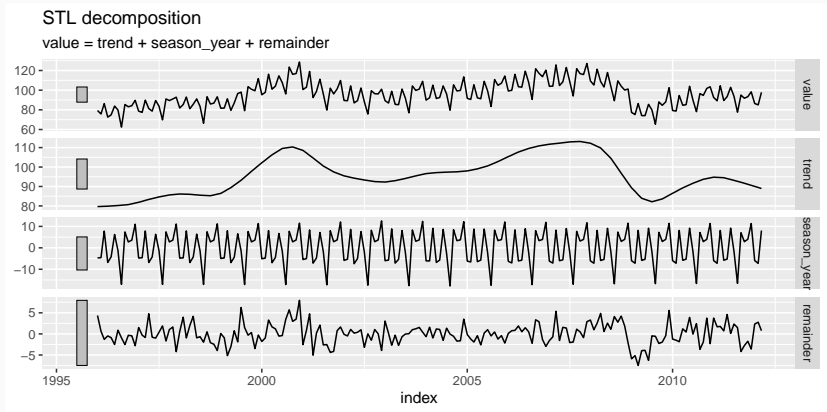
```
elecequip %>%
```

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

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

# STL decomposition

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



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

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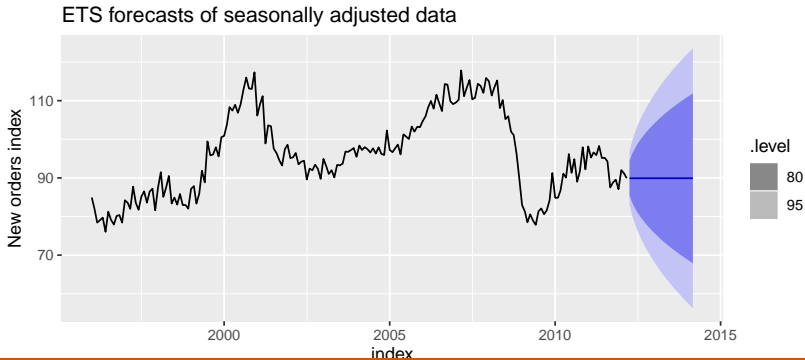
# Forecasting and decomposition

- 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

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

# Decomposition models

`dcmp_model()` creates a decomposition model

- You must provide a method for forecasting the `season_adjust` series.
- A seasonal naive method is used by default for the `seasonal` components.

# 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.

The fable package combines the uncertainty from both the seasonally adjusted and seasonal forecasts. When using `dcmp_model()` to produce forecasts, the seasonal uncertainty is not ignored!