Time Series Analysis & Forecasting Using R

bit.ly/fable2022

4. Seasonality and trends

Outline

Outline

Time series decomposition

Trend-Cycle aperiodic changes in level over time.

Seasonal (almost) periodic changes in level due to seasonal factors (e.g., the quarter of the year, the month, or day of the week).

Additive decomposition

$$y_t = S_t + T_t + R_t$$

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

STL decomposition

- STL: "Seasonal and Trend decomposition using Loess"
- Very versatile and robust.
- Seasonal component allowed to change over time, and rate of change controlled by user.
- Smoothness of trend-cycle also controlled by user.
- Optionally robust to outliers
- No trading day or calendar adjustments.
- Only additive.
- Take logs to get multiplicative decomposition.
- Use Box-Cox transformations to get other decompositions.

US Retail Employment

```
us_retail_employment <- us_employment ▷
  filter(year(Month) ≥ 1990, Title == "Retail Trade") ▷
  select(-Series_ID)
us_retail_employment
```

```
## # A tsibble: 357 x 3 [1M]
##        Month Title         Employed
##        <mth> <chr>            <dbl>
##  1 1990 Jan Retail Trade    13256.
##  2 1990 Feb Retail Trade    12966.
##  3 1990 Mar Retail Trade    12938.
##  4 1990 Apr Retail Trade    13012.
##  5 1990 May Retail Trade    13108.
##  6 1990 Jun Retail Trade    13183.
##  7 1990 Jul Retail Trade    13170.
##  8 1990 Aug Retail Trade    13160.
## 9 1990 Sep Retail Trade     13113
```

US Retail Employment

```r
us_retail_employment ▷
  autoplot(Employed) +
  labs(y = "Persons (thousands)", title = "Total employment in US retail")
```


Total employment in US retail
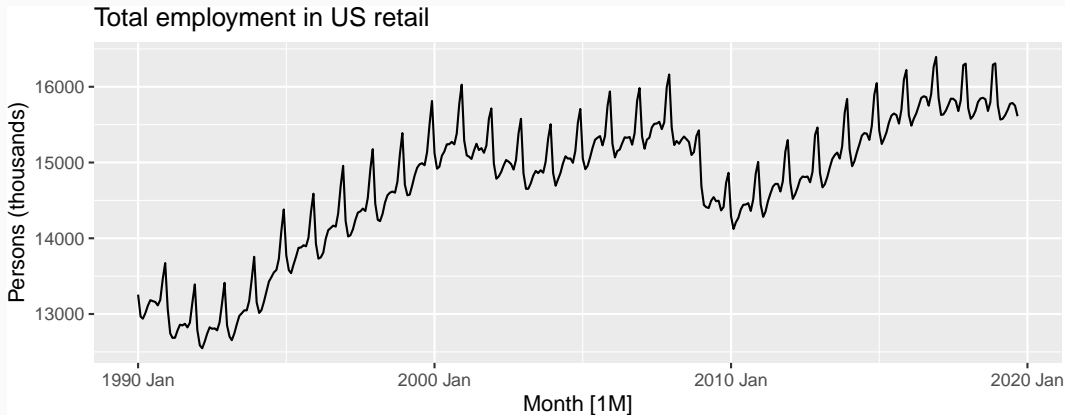
US Retail Employment

```
dcmp <- us_retail_employment |>
  model(stl = STL(Employed))
dcmp

## # A mable: 1 x 1
##        stl
##    <model>
## 1    <STL>
```

US Retail Employment

```
components(dcmp)
```

```
## # A dable: 357 x 7 [1M]
## # Key:       .model [1]
## # :          Employed = trend + season_year + remainder
##      .model    Month Employed   trend season_year remainder season_adjust
##      <chr>     <mth>    <dbl>   <dbl>       <dbl>     <dbl>         <dbl>
## 1 stl       1990 Jan   13256. 13288.      -33.0     0.836         13289.
## 2 stl       1990 Feb   12966. 13269.      -258.    -44.6          13224.
## 3 stl       1990 Mar   12938. 13250.      -290.    -22.1          13228.
## 4 stl       1990 Apr   13012. 13231.      -220.      1.05         13232.
## 5 stl       1990 May   13108. 13211.      -114.     11.3          13223.
## 6 stl       1990 Jun   13183. 13192.       -24.3    15.5          13207.
## 7 stl       1990 Jul   13170. 13172.       -23.2    21.6          13193.
## 8 stl       1990 Aug   13160. 13151.        -9.52   17.8          13169.
## 9 stl       1990 Sep   13113. 13131.       -39.5    22.0          13153.
```
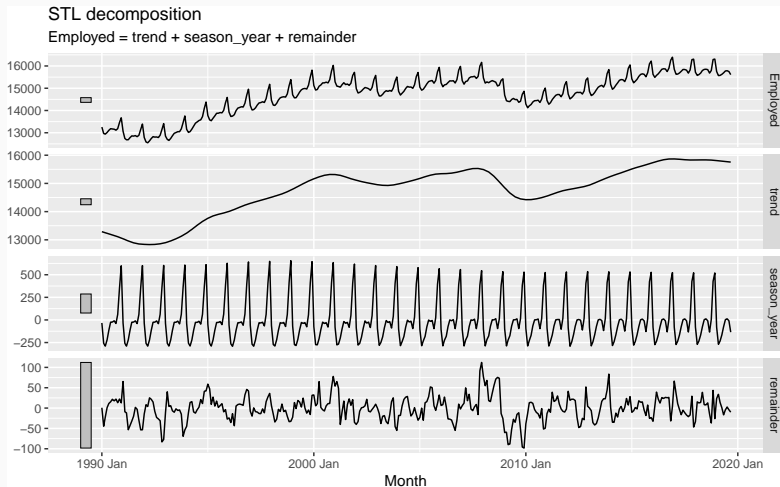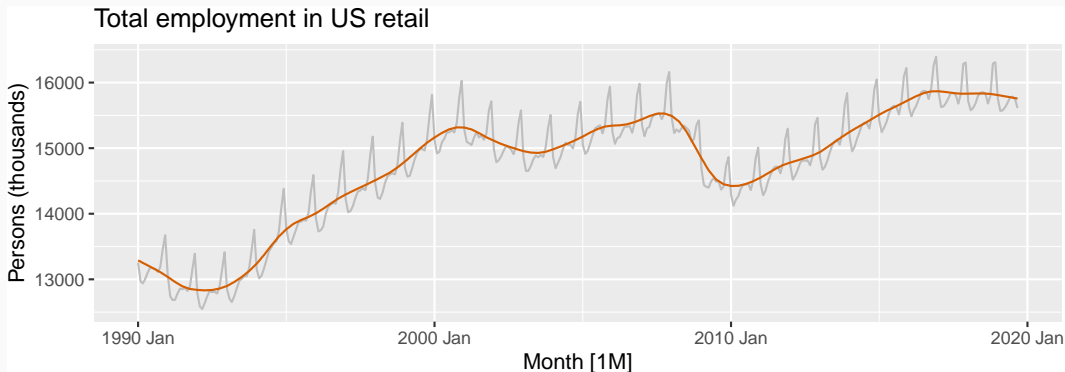
US Retail Employment

```
components(dcmp) ▷ autoplot()
```


STL decomposition
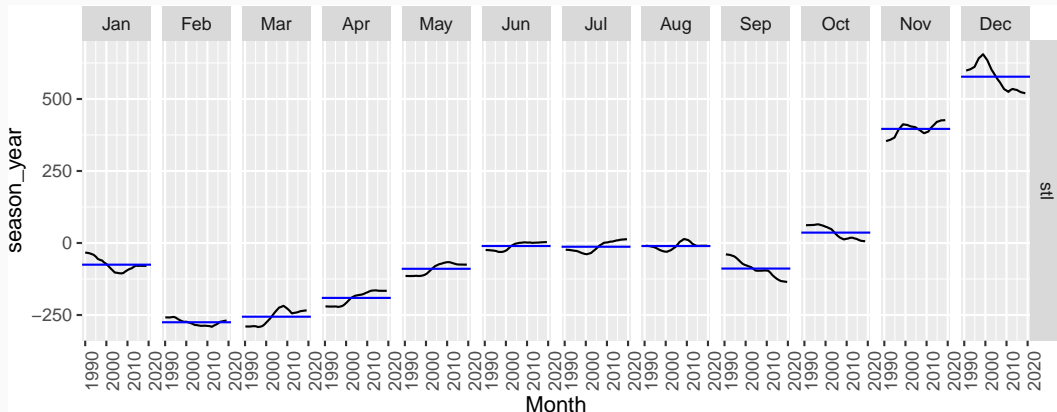Employed = trend + season_year + remainder

US Retail Employment

```
us_retail_employment ▷
  autoplot(Employed, color = "gray") +
  autolayer(components(dcmp), trend, color = "#D55E00") +
  labs(y = "Persons (thousands)", title = "Total employment in US retail")
```


Total employment in US retail

US Retail Employment


```
components(dcmp) ▷ gg_subseries(season_year)
```

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

US Retail Employment

```
us_retail_employment ▷
  autoplot(Employed, color = "gray") +
  autolayer(components(dcmp), season_adjust, color = "#0072B2") +
  labs(y = "Persons (thousands)", title = "Total employment in US retail")
```


Total employment in US retail
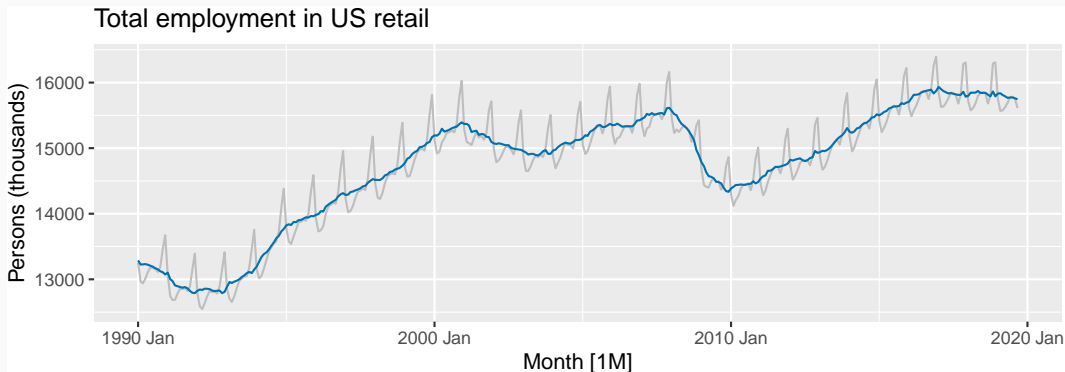
Seasonal adjustment

- 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.
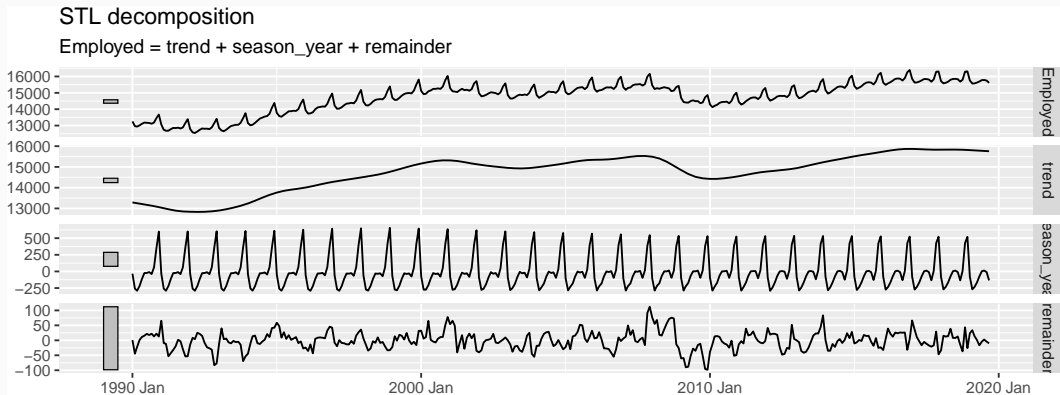
STL decomposition

STL decomposition

```
us_retail_employment ▷
  model(STL(Employed ~ trend(window = 15) + season(window = "periodic"),
    robust = TRUE
  )) ▷
  components()
```

- ■ trend(window = ?) controls wiggliness of trend component.
- ■ season(window = ?) controls variation on seasonal component.
- ■ season(window = 'periodic') is equivalent to an infinite window.
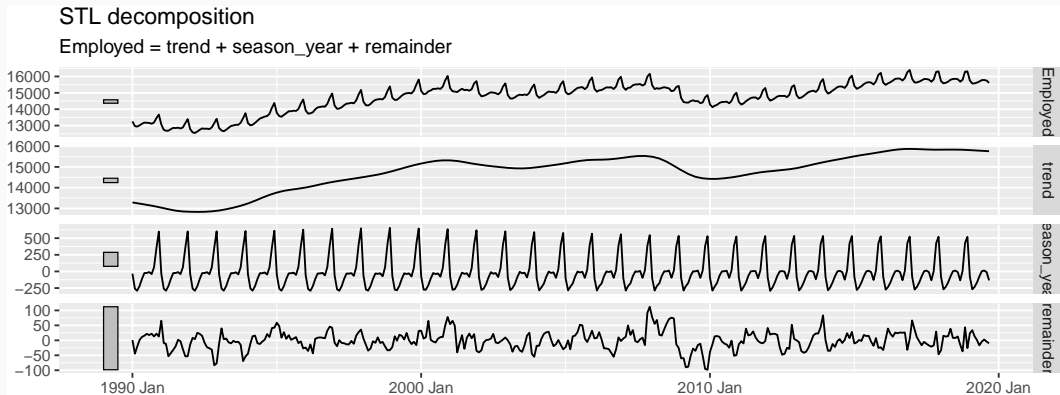
STL decomposition

```
us_retail_employment ▷
  model(STL(Employed)) ▷
  components() ▷
  autoplot()
```


STL decomposition
Employed = trend + season_year + remainder

STL decomposition

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

```
us_retail_employment  ▷
  model(STL(Employed))  ▷
  components()  ▷
  autoplot()
```


STL decomposition
Employed = trend + season_year + remainder

STL decomposition

- Algorithm that updates trend and seasonal components iteratively.
- Starts with $\hat{T}_t = 0$
- Uses a mixture of loess and moving averages to successively refine the trend and seasonal estimates.
- trend window controls loess bandwidth on deasonalised values.
- season window controls loess bandwidth on detrended subseries.
- Robustness weights based on remainder.
- Default season: `window = 13`
- Default trend:

  `window = nextodd(ceiling((1.5*period)/(1-(1.5/s.window))))`
- `window` values should be odd numbers for symmetry.

Australian holidays

```
holidays ▷ autoplot(Trips) +
  labs(y = "thousands of trips", x = "Year",
       title = "Australian domestic holiday nights")
```


Australian domestic holiday nights
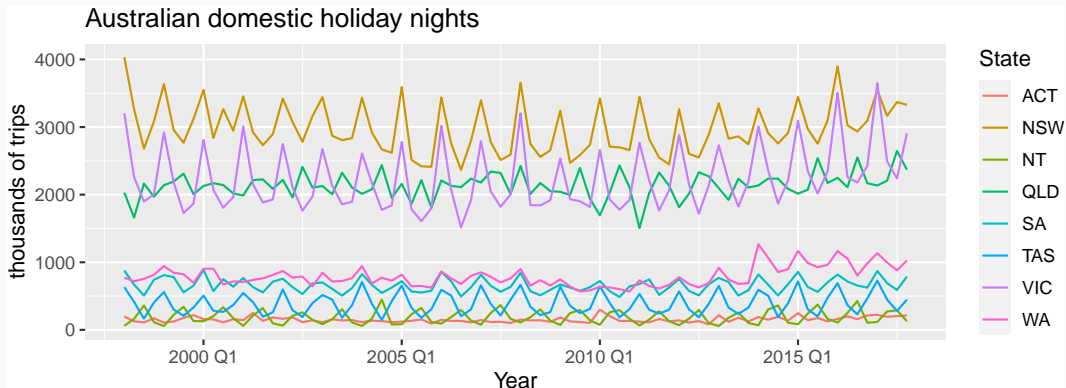
Australian holidays

```
holidays ▷
  model(stl = STL(Trips)) ▷
  components() ▷
  autoplot()
```
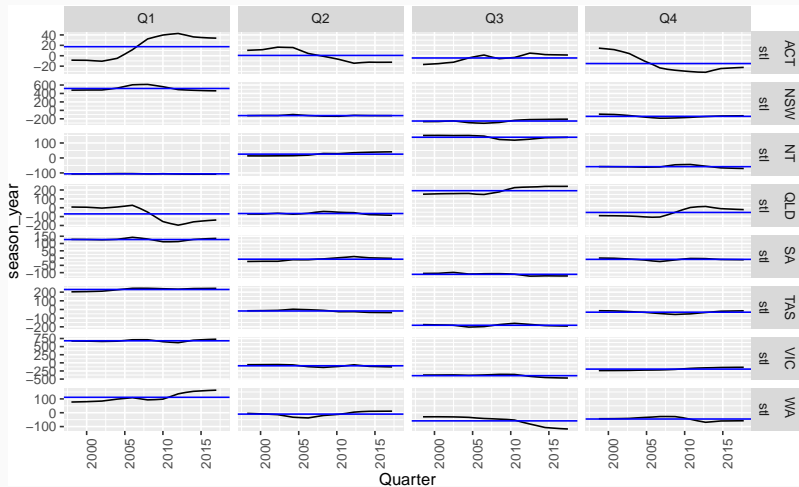

STL decomposition
Trips = trend + season_year + remainder
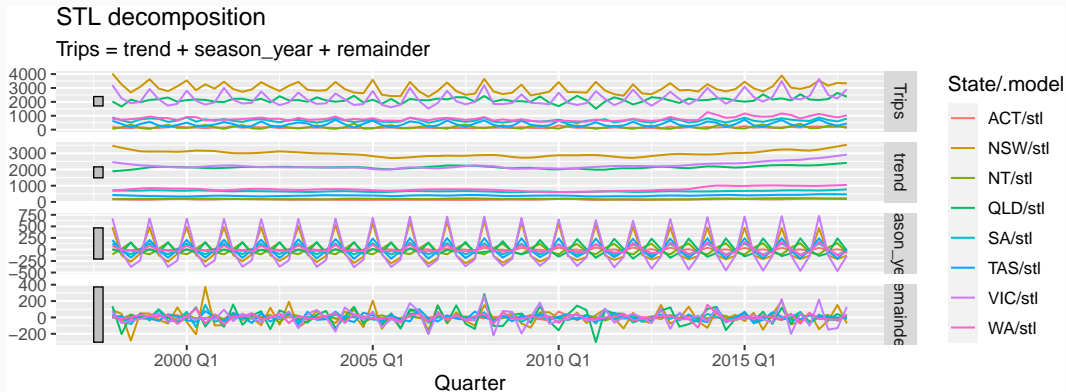
Holidays decomposition

```
dcmp <- holidays ▷
  model(stl = STL(Trips)) ▷
  components()
dcmp
```

```
## # A dable: 640 x 8 [1Q]
## # Key:      State, .model [8]
## # :         Trips = trend + season_year + remainder
##    State .model Quarter Trips trend season_year remainder season_adjust
##    <chr> <chr>    <qtr> <dbl> <dbl>       <dbl>     <dbl>         <dbl>
## 1 ACT    stl    1998 Q1  196.  172.       -8.48      32.6          205.
## 2 ACT    stl    1998 Q2  127.  157.       10.3      -40.6          116.
## 3 ACT    stl    1998 Q3  111.  142.      -16.8      -14.5          128.
## 4 ACT    stl    1998 Q4  170.  130.       14.6       25.6          156.
## 5 ACT    stl    1999 Q1  108.  135.       -8.63     -18.3          116.
## 6 ACT    stl    1999 Q2  125.  148.       11.0      -34.6          114.
## 7 ACT    stl    1999 Q3  178.  166.      -16.0       28.3          194.
## 8 ACT    stl    1999 Q4  218.  177.       13.2       27.5          204.
```
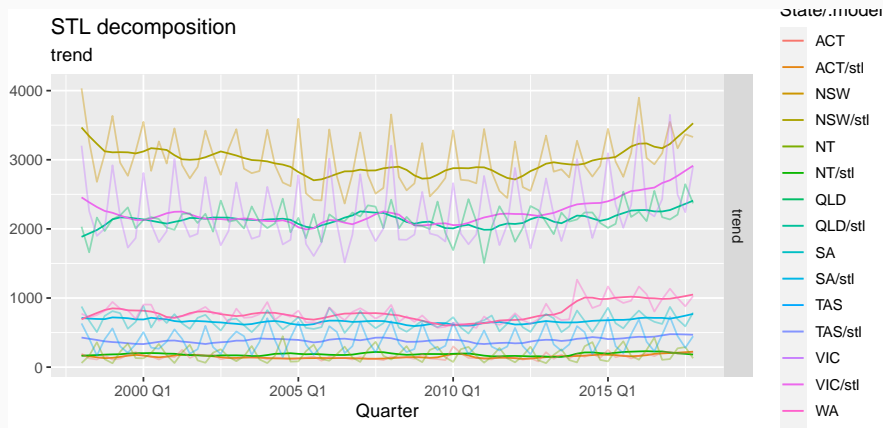
Holidays decomposition

```
dcmp  ▷ gg_subseries(season_year)
```

Holidays decomposition

```
autoplot(dcmp, trend, scale_bars = FALSE) +
  autolayer(holidays, alpha = 0.4)
```

Outline

Lab Session 8

1. Produce the following decomposition

```
canadian_gas  ▷
  model(STL(Volume ~ season(window=7) + trend(window=11)))  ▷
  components()  ▷
  autoplot()
```

2. What happens as you change the values of the two `window` arguments?

3. How does the seasonal shape change over time? [Hint: Try plotting the seasonal component using `gg_season`.]

4. Can you produce a plausible seasonally adjusted series? [Hint: `season_adjust` is one of the variables returned by STL.]

Outline

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Multiple seasonality

```
vic_elec ▷
  model(STL(Demand)) ▷
  components() ▷
  autoplot()
```


STL decomposition

Demand = trend + season_year + season_week + season_day + season_hour + remainder
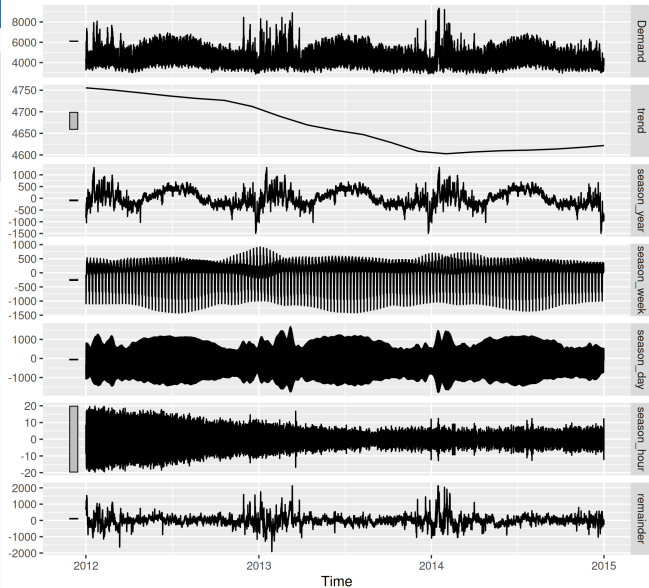
Outline

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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The ABS stuff-up

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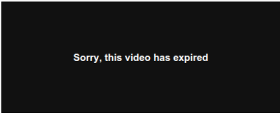
ABS abandons seasonal adjustment for latest jobs data

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 also reflect the original figures.

Sorry, this video has expired

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

RELATED STORY: Unemployment surges to 12-year high at 6.4 pc

MAP: Australia

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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:
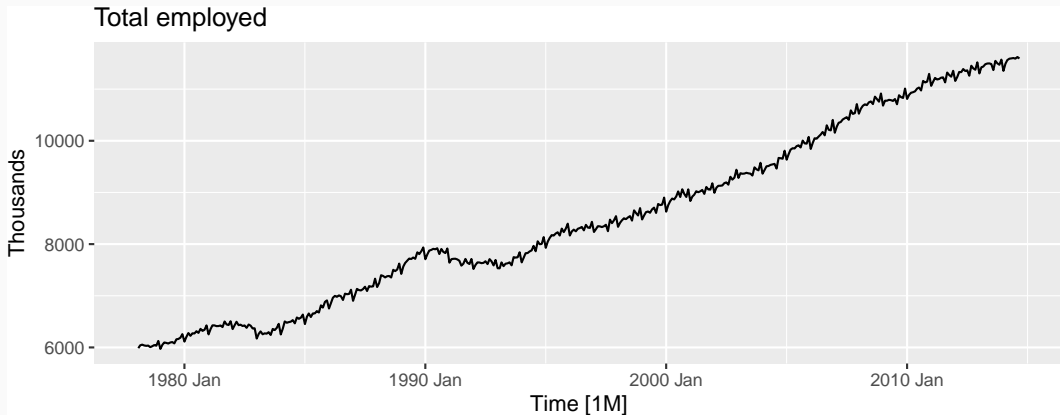
The ABS stuff-up

```
employed
```

```
## # A tsibble: 440 x 4 [1M]
##        Time Month  Year Employed
##       <mth> <ord> <dbl>    <dbl>
##  1 1978 Feb Feb    1978    5986.
##  2 1978 Mar Mar    1978    6041.
##  3 1978 Apr Apr    1978    6054.
##  4 1978 May May    1978    6038.
##  5 1978 Jun Jun    1978    6031.
##  6 1978 Jul Jul    1978    6036.
##  7 1978 Aug Aug    1978    6005.
##  8 1978 Sep Sep    1978    6024.
##  9 1978 Oct Oct    1978    6046.
## 10 1978 Nov Nov    1978    6034.
## # ... with 430 more rows
```
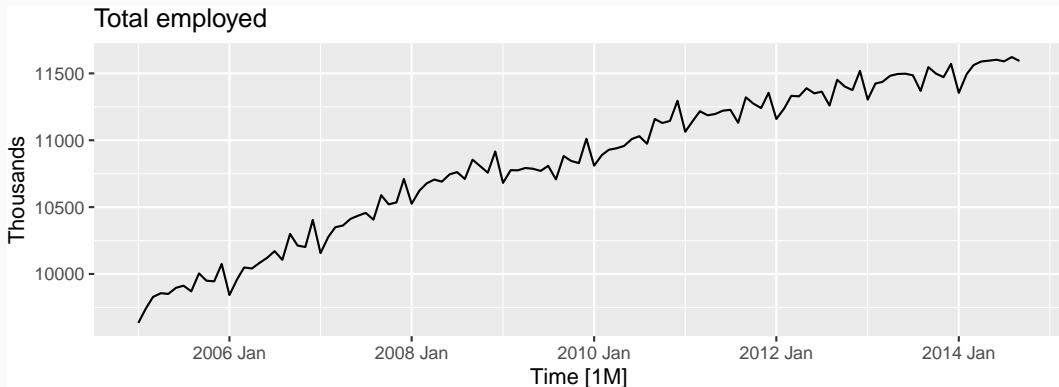
The ABS stuff-up

```
employed ▷
  autoplot(Employed) +
  labs(title = "Total employed", y = "Thousands")
```
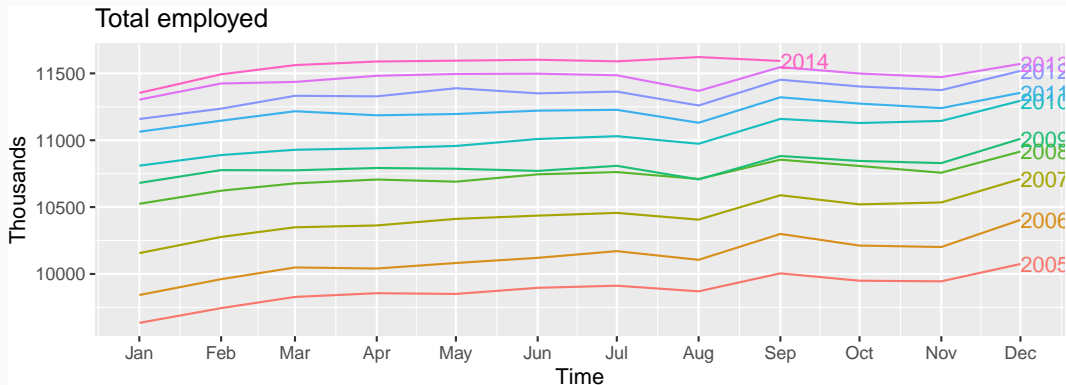

Total employed

The ABS stuff-up

```
employed ▷
  filter(Year ≥ 2005) ▷
  autoplot(Employed) +
  labs(title = "Total employed", y = "Thousands")
```
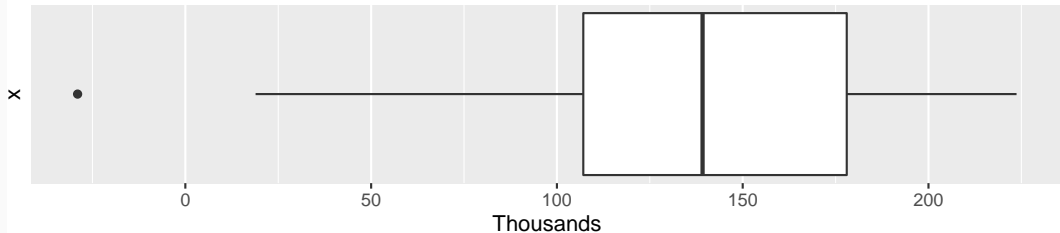

Total employed

The ABS stuff-up

```
employed ▷
  filter(Year ≥ 2005) ▷
  gg_season(Employed, labels = "right") +
  labs(title = "Total employed", y = "Thousands")
```


Total employed

The ABS stuff-up

```
employed ▷
  mutate(diff = difference(Employed)) ▷
  filter(Month == "Sep") ▷
  ggplot(aes(y = diff, x = 1)) +
  geom_boxplot() +
  coord_flip() +
  labs(title = "Sep - Aug: total employed", y = "Thousands") +
  scale_x_continuous(breaks = NULL, labels = NULL)
```


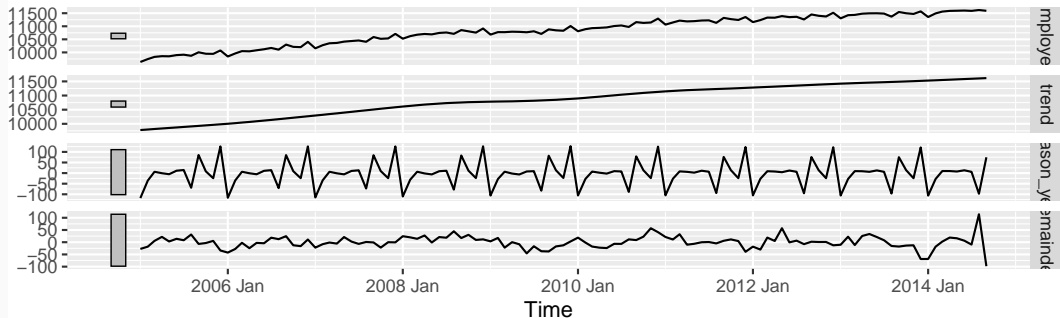
Sep – Aug: total employed

The ABS stuff-up

```
dcmp <- employed ▷
  filter(Year ≥ 2005) ▷
  model(stl = STL(Employed ~ season(window = 11), robust = TRUE))
components(dcmp) ▷ autoplot()
```
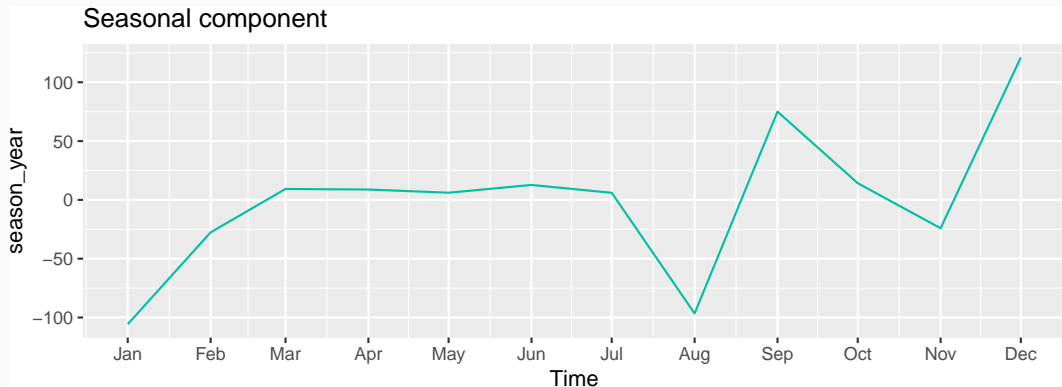

STL decomposition
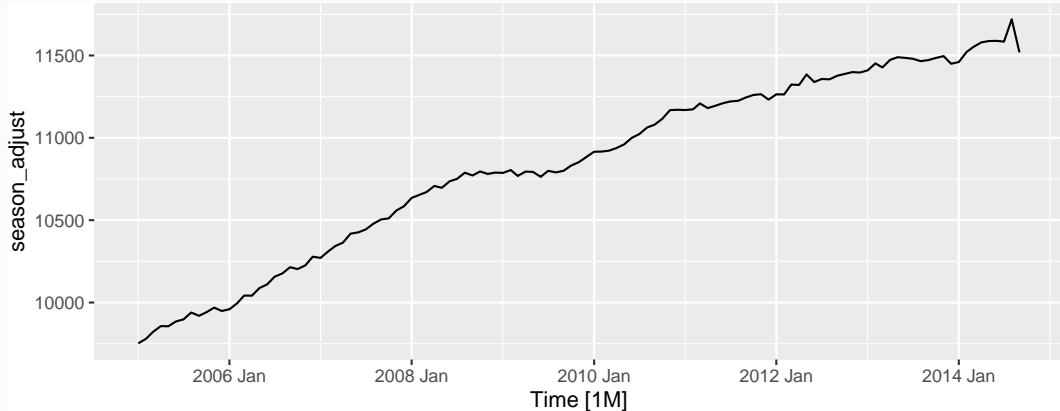Employed = trend + season_year + remainder

The ABS stuff-up

```
components(dcmp) ▷
  filter(year(Time) == 2013) ▷
  gg_season(season_year) +
  labs(title = "Seasonal component") + guides(colour = "none")
```

The ABS stuff-up

```
components(dcmp) ▷
  as_tsibble() ▷
  autoplot(season_adjust)
```

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.