



MONASH
University

MONASH
BUSINESS
SCHOOL

Tidy Time Series & Forecasting in R



3. Transformations

robjhyndman.com/workshop2020

Outline

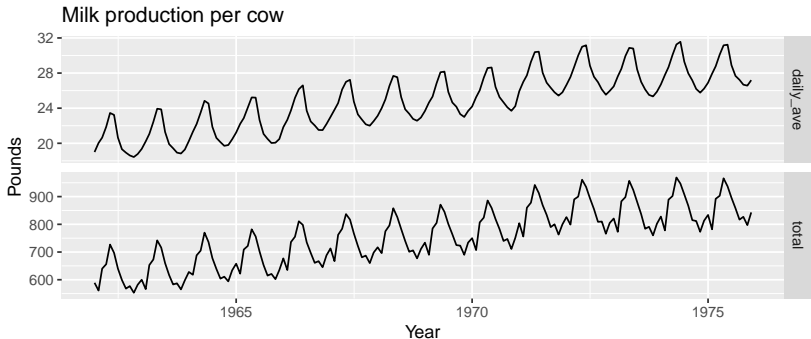
- 1 Calendar adjustments
- 2 Per capita adjustments
- 3 Lab Session 6
- 4 Inflation adjustments
- 5 Mathematical transformations
- 6 Lab Session 7

Outline

- 1 Calendar adjustments
- 2 Per capita adjustments
- 3 Lab Session 6
- 4 Inflation adjustments
- 5 Mathematical transformations
- 6 Lab Session 7

Calendar adjustments

```
as_tsibble(fma::milk) %>%  
  rename(total = value) %>%  
  mutate(daily_ave = total / days_in_month(as_date(index))) %>%  
  pivot_longer(-index, names_to = "Series", values_to = "Milk") %>%  
  ggplot(aes(x=index, y=Milk)) + geom_line() +  
    facet_grid(Series ~ ., scales='free') + xlab("Year") +  
    ylab("Pounds") + ggtitle("Milk production per cow")
```

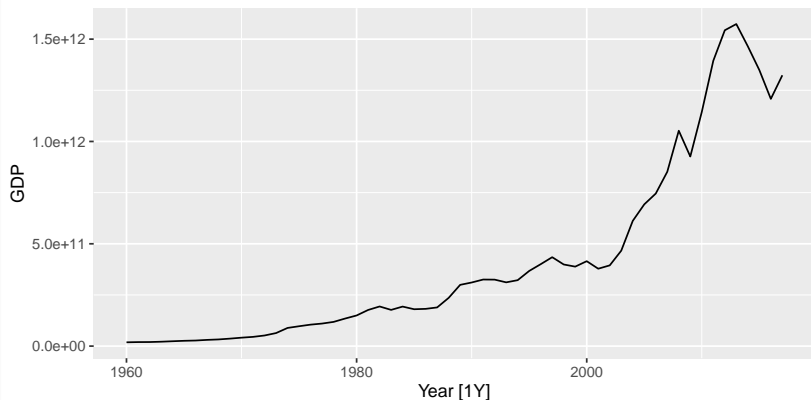


Outline

- 1 Calendar adjustments
- 2 Per capita adjustments
- 3 Lab Session 6
- 4 Inflation adjustments
- 5 Mathematical transformations
- 6 Lab Session 7

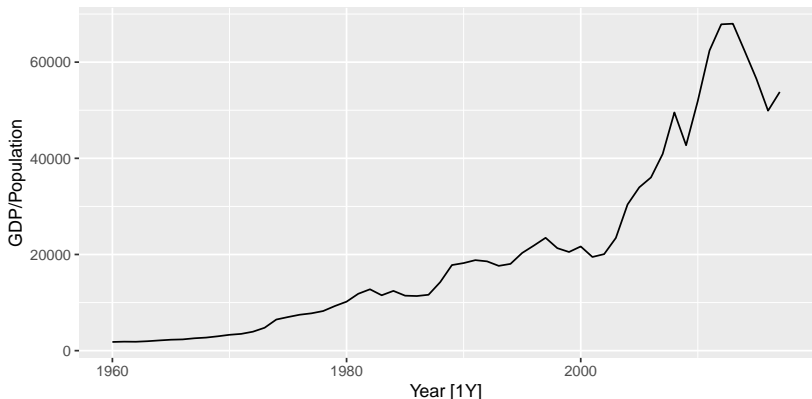
Per capita adjustments

```
global_economy %>%  
  filter(Country == "Australia") %>%  
  autoplot(GDP)
```



Per capita adjustments

```
global_economy %>%  
  filter(Country == "Australia") %>%  
  autoplot(GDP / Population)
```



Outline

- 1 Calendar adjustments
- 2 Per capita adjustments
- 3 Lab Session 6
- 4 Inflation adjustments
- 5 Mathematical transformations
- 6 Lab Session 7

Lab Session 6

Consider the GDP information in `global_economy`.
Plot the GDP per capita for each country over time.
Which country has the highest GDP per capita? How
has this changed over time?

Outline

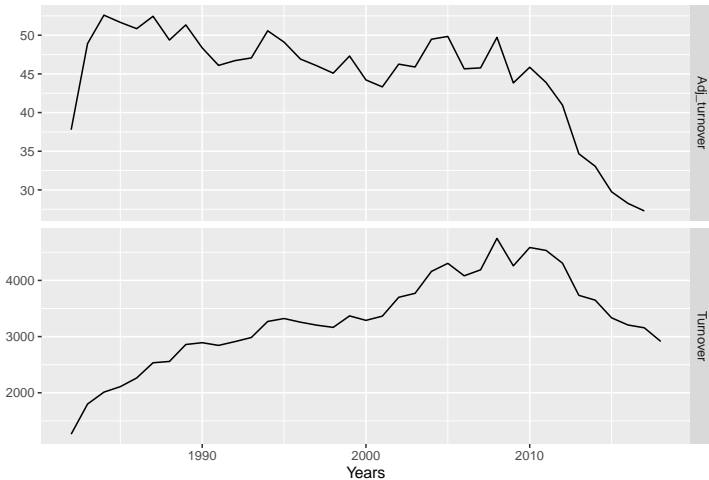
- 1 Calendar adjustments
- 2 Per capita adjustments
- 3 Lab Session 6
- 4 Inflation adjustments**
- 5 Mathematical transformations
- 6 Lab Session 7

Inflation adjustments

```
print_retail <- aus_retail %>%  
  filter(Industry == "Newspaper and book retailing") %>%  
  group_by(Industry) %>%  
  index_by(Year = year(Month)) %>%  
  summarise(Turnover = sum(Turnover))  
aus_economy <- filter(global_economy, Code == "AUS")  
print_retail %>%  
  left_join(aus_economy, by = "Year") %>%  
  mutate(Adj_turnover = Turnover / CPI) %>%  
  pivot_longer(c(Turnover, Adj_turnover),  
               names_to = "Type", values_to = "Turnover") %>%  
  ggplot(aes(x = Year, y = Turnover)) +  
    geom_line() +  
    facet_grid(vars(Type), scales = "free_y") +  
    xlab("Years") + ylab(NULL) +  
    ggtitle("Turnover: Australian print media industry")
```

Inflation adjustments

Turnover: Australian print media industry



Outline

- 1 Calendar adjustments
- 2 Per capita adjustments
- 3 Lab Session 6
- 4 Inflation adjustments
- 5 Mathematical transformations
- 6 Lab Session 7

Variance stabilization

If the data show different variation at different levels of the series, then a transformation can be useful.

Variance stabilization

If the data show different variation at different levels of the series, then a transformation can be useful.

Denote original observations as y_1, \dots, y_n and transformed observations as w_1, \dots, w_n .

Variance stabilization

If the data show different variation at different levels of the series, then a transformation can be useful.

Denote original observations as y_1, \dots, y_n and transformed observations as w_1, \dots, w_n .

Mathematical transformations for stabilizing variation

Square root	$w_t = \sqrt{y_t}$	↓
Cube root	$w_t = \sqrt[3]{y_t}$	Increasing
Logarithm	$w_t = \log(y_t)$	strength

Variance stabilization

If the data show different variation at different levels of the series, then a transformation can be useful.

Denote original observations as y_1, \dots, y_n and transformed observations as w_1, \dots, w_n .

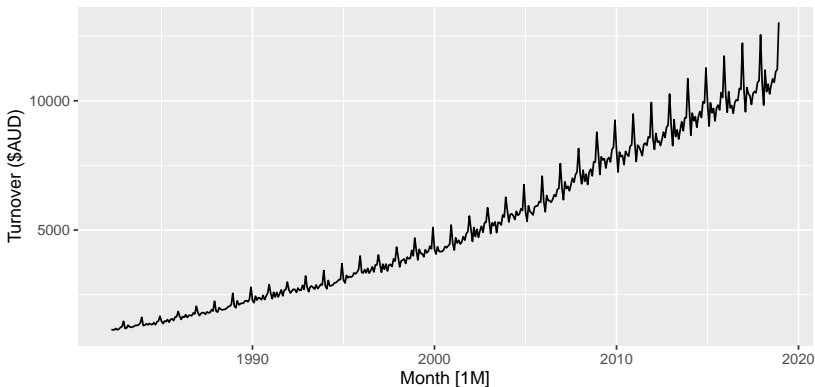
Mathematical transformations for stabilizing variation

Square root	$w_t = \sqrt{y_t}$	↓
Cube root	$w_t = \sqrt[3]{y_t}$	Increasing
Logarithm	$w_t = \log(y_t)$	strength

Logarithms, in particular, are useful because they are more interpretable: changes in a log value are **relative (percent) changes on the original scale**.

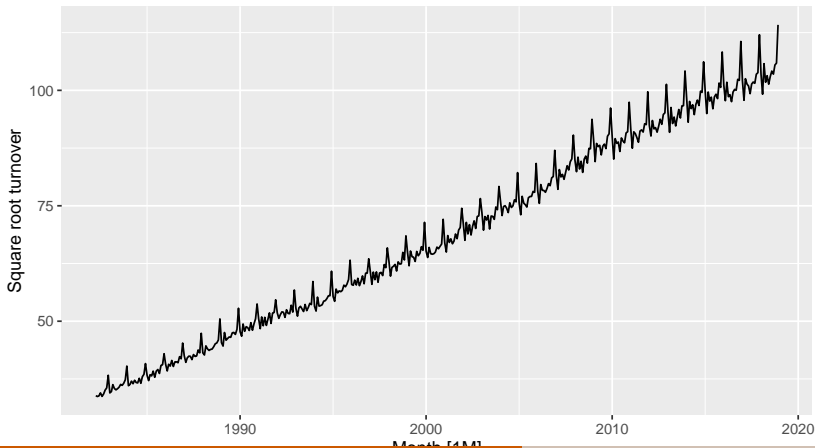
Variance stabilization

```
food <- aus_retail %>%  
  filter(Industry == "Food retailing") %>%  
  summarise(Turnover = sum(Turnover))
```



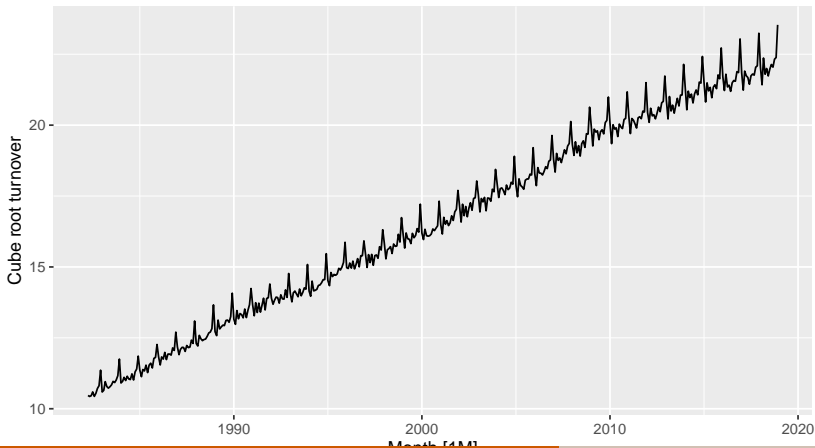
Variance stabilization

```
food %>% autoplot(sqrt(Turnover)) +  
  labs(y = "Square root turnover")
```



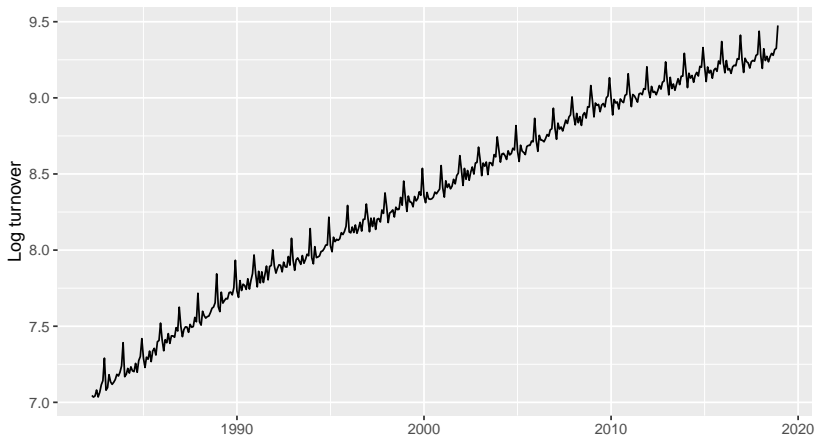
Variance stabilization

```
food %>% autoplot(Turnover^(1/3)) +  
  labs(y = "Cube root turnover")
```



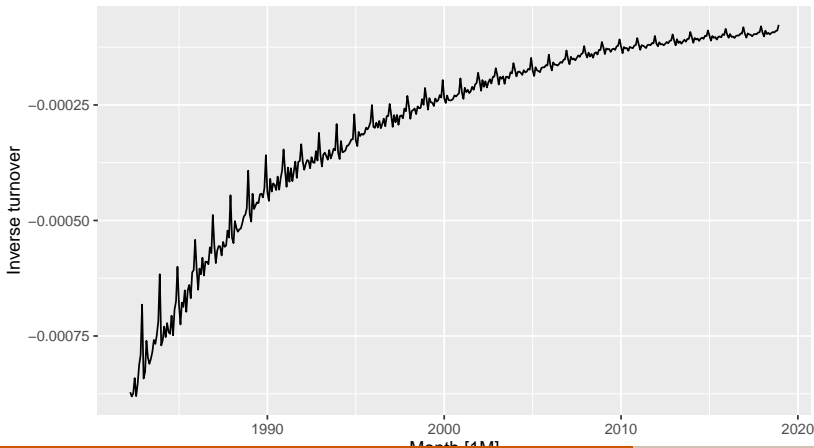
Variance stabilization

```
food %>% autoplot(log(Turnover)) +  
  labs(y = "Log turnover")
```



Variance stabilization

```
food %>% autoplot(-1/Turnover) +  
  labs(y = "Inverse turnover")
```



Box-Cox transformations

Each of these transformations is close to a member of the family of **Box-Cox transformations**:

$$w_t = \begin{cases} \log(y_t), & \lambda = 0; \\ (y_t^\lambda - 1)/\lambda, & \lambda \neq 0. \end{cases}$$

Box-Cox transformations

Each of these transformations is close to a member of the family of **Box-Cox transformations**:

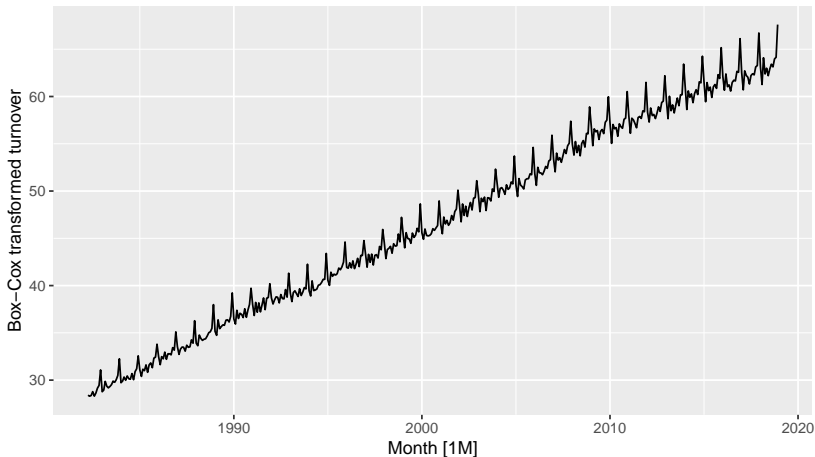
$$w_t = \begin{cases} \log(y_t), & \lambda = 0; \\ (y_t^\lambda - 1)/\lambda, & \lambda \neq 0. \end{cases}$$

- $\lambda = 1$: (No substantive transformation)
- $\lambda = \frac{1}{2}$: (Square root plus linear transformation)
- $\lambda = 0$: (Natural logarithm)
- $\lambda = -1$: (Inverse plus 1)

Box-Cox transformations

Box-Cox transformations

```
food %>% autoplot(box_cox(Turnover, 1/3)) +  
  labs(y = "Box-Cox transformed turnover")
```



Box-Cox transformations

```
food %>%
```

```
  features(Turnover, features = guerrero)
```

```
## # A tibble: 1 x 1
```

```
##   lambda_guerrero
```

```
##           <dbl>
```

```
## 1           0.0524
```

Box-Cox transformations

```
food %>%
```

```
  features(Turnover, features = guerrero)
```

```
## # A tibble: 1 x 1
```

```
##   lambda_guerrero
```

```
##           <dbl>
```

```
## 1           0.0524
```

- This attempts to balance the seasonal fluctuations and random variation across the series.
- Always check the results.
- A low value of λ can give extremely large prediction intervals.

Transformations

- Often no transformation needed.
- Simple transformations are easier to explain and work well enough.
- Transformations can have very large effect on PI.
- If the data contains zeros, then don't take logs.
- If some data are negative, no power transformation is possible unless a constant is added to all values.
- Choosing logs is a simple way to force forecasts to be positive
- Transformations must be reversed to obtain forecasts on the original scale. (Handled automatically by `fable`.)

Outline

- 1 Calendar adjustments
- 2 Per capita adjustments
- 3 Lab Session 6
- 4 Inflation adjustments
- 5 Mathematical transformations
- 6 Lab Session 7

Lab Session 7

- 1 For the following series, find an appropriate transformation in order to stabilise the variance.
 - ▶ United States GDP from `global_economy`
 - ▶ Slaughter of Victorian “Bulls, bullocks and steers” in `aus_livestock`
 - ▶ Gas production from `aus_production`
 - ▶ Tobacco from `aus_production`
 - ▶ Economy class passengers between Melbourne and Sydney from `ansett`
 - ▶ Victorian Electricity Demand from `vic_elec`.
- 2 Why is a Box-Cox transformation unhelpful for the `expsmooth::cangas` data?