R

2022-02-26

Contents

Chapter 1

url: your book url like https://bookdown.org/yihui/bookdown

Placeholder

Chapter 2

Placeholder

2.1

2.1.1 (cross-sectional data)

2.1.2

2.2

2.2.1 `ts`

2.2.2

2.2.3 Seasonal

Chapter 3

Placeholder

3.1

3.2

3.2.1

3.2.2

3.3 STL

Chapter 4

(Exponential smoothing) 1950 . . , .

, . simple exponential smoothing , Holt's linear trend method , Holt-Winter's seasonal method . , .

. ETS , .

ETS . , . . , .

4.1

, . training data test data , training data test data .

, $y_1, \ldots, y_T$ training data , $y_{T+1}, y_{T+2}, \ldots$ test data . Test data 20% , `h` .

Training data $(y_1, \ldots, y_T)$, $(\hat{y}_t)$ (y_t) $(e_t = y_t - \hat{y}_t)$, $t = 1, \ldots, T$. Training data , test data . training data over-fitting , test data .

Test data $(y_{T+1}, y_{T+2}, \ldots)$. $(e_{T+h} = y_{T+h} - \hat{y}_{T+h},\ \ h = 1, 2, 3, \ldots)$, .

- MAE (Mean Absolute Error) : $mean(\ |e_t|\ )$
- RMSE (Root Mean Squared Error) : $\sqrt{mean(e_t^2)}$

MAE RMSE . , , .
.

- MAPE (Mean Absolute Percentage Error) : $mean(|100 \times \frac{e_t}{y_y}|)$

MAPE , 0 0 .
training data naive forecast ($\hat{y}_{t+1} = y_t$) MAE .

- MASE (Mean Absolute Scaled Error) : $mean(|\frac{e_t}{E}|), \quad E = \frac{1}{T-1}\sum_{t=2}^{T}|y_t - y_{t-1}|$

MASE , MAPE . MASE 1 , training data naive forecast .

`forecast::accuracy()` . .

4.2

simple exponential smmothing Holt's trend method, Holt-Winter's seasonal method . .

4.2.1 Simple exponential smoothing

, (level) .

Simple exponential smoothing $y_1, \ldots, y_t$ $(t+1)$ 1- $\hat{y}_{t+1|t}$.

$$\hat{y}_{t+1|t} = \alpha y_t + \alpha(1-\alpha)y_{t-1} + \alpha(1-\alpha)^2 y_{t-2} + \cdots \tag{4.1}$$

, $0 \leq \alpha \leq 1$.

(??) simple exponential smoothing 1- . t , . α , , 1 .

(??) , y_t $\hat{y}_{t|t-1}$.

$$\hat{y}_{t+1|t} = \alpha y_t + (1-\alpha)\hat{y}_{t|t-1} \tag{4.2}$$

Simple exponential smoothing , (level) . (**??**) .

- h

$$\hat{y}_{t+h|t} = l_t \tag{4.3}$$

-

$$l_t = \alpha y_y + (1-\alpha) l_{t-1} \tag{4.4}$$

, l_t t , α .

Simple exponential smoothing `forecast::ses()` , `ses(y, h = 10, level = c(80, 95))` . `y` `ts` , `h` 10 . `level` , , **??** ETS simple exponential smoothing .

- : `fpp2::oil`

`fpp2::oil` 1965 2013 Saudi Arabia . 1996 simple exponential smoothing .

```
library(fpp2)
oil_1996 <- window(oil, start = 1996)
```

1996 .

```
autoplot(oil_1996) +
  labs(title = "Annual oil production in Saudi Arabia since 1996", y = NULL)
```

`ses()` 2014 ~ 2016 .

```
ses(oil_1996, h = 3) %>%
  summary()
```

Figure 4.1: 1996 Saudi Arabia

```
##
## Forecast method: Simple exponential smoothing
##
## Model Information:
## Simple exponential smoothing
##
## Call:
##  ses(y = oil_1996, h = 3)
##
##   Smoothing parameters:
##     alpha = 0.8339
##
##   Initial states:
##     l = 446.5868
##
##   sigma:  29.8282
##
##      AIC     AICc      BIC
## 178.1430 179.8573 180.8141
##
## Error measures:
##                      ME     RMSE      MAE      MPE     MAPE      MASE        ACF1
```

```
## Training set 6.401975 28.12234 22.2587 1.097574 4.610635 0.9256774 -0.03377748
##
## Forecasts:
##      Point Forecast    Lo 80    Hi 80    Lo 95    Hi 95
## 2014       542.6806 504.4541 580.9070 484.2183 601.1429
## 2015       542.6806 492.9073 592.4539 466.5589 618.8023
## 2016       542.6806 483.5747 601.7864 452.2860 633.0752
```

Level $\alpha = 0.8339$ level . .

```
ses(oil_1996, h = 3) %>%
  autoplot() +
  labs(y = NULL)
```

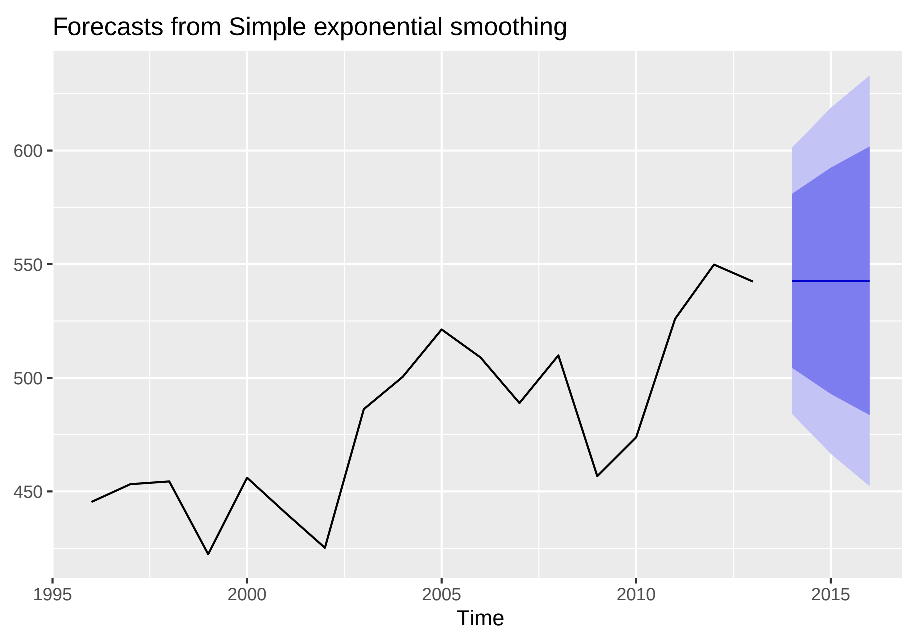

Figure 4.2: 1996 Saudi Arabia 2014

level , `h` . 80% , 95% . .

4.2.2 Trend method

, . Holt's linear trend method . , over-forecast . Damped Holt's trend method , , . .

1. Holt's linear trend method

level trend . h .

- t level

$$l_t = \alpha y_t + (1-\alpha)(l_{t-1} + b_{t-1}) \tag{4.5}$$

- t trend

$$b_t = \beta(l_t - l_{t-1}) + (1-\beta)b_{t-1} \tag{4.6}$$

-

$$\hat{y}_{t+h|t} = l_t + hb_t \tag{4.7}$$

, $0 \leq \alpha \leq 1$ level , $0 \leq \beta \leq 1$ trend .

(**??**) `h` level trend h . , h $(b_t > 0)$ $(b_t < 0)$, over-forecast .

2. Damped Holt's trend method

Holt's linear trend method over-forecast . level trend `h` .

- t level

$$l_t = \alpha y_t + (1-\alpha)(l_{t-1} + \phi b_{t-1}) \tag{4.8}$$

- t trend

$$b_t = \beta(l_t - l_{t-1}) + (1-\beta)\phi b_{t-1} \tag{4.9}$$

-

$$\hat{y}_{t+h|t} = l_t + (\phi + \phi^2 + \cdots + \phi^h)b_t \tag{4.10}$$

, $0 \le \alpha \le 1$ level , $0 \le \beta \le 1$ trend . $0 \le \phi \le 1$ damping , . $\phi = 1$ Holt's linear trend method .

(**??**) `h` , . , over-forecast .

Trend method `forecast::holt()` , `holt(y, h = 10, damped = FALSE, level = c(80, 95))` . Holt's linear trend method , `damped = FALSE` , damped Holt's trend method , `damped = TRUE` .

- : `fpp2::ausair`

`fpp2::ausair` 1970 2016 . Holt's linear trend damped Holt's trend .

.

Figure 4.3: 1970 2016

Holt's linear trend `holt()` , 15 .

```
holt(ausair, h = 15) %>%
  autoplot()
```

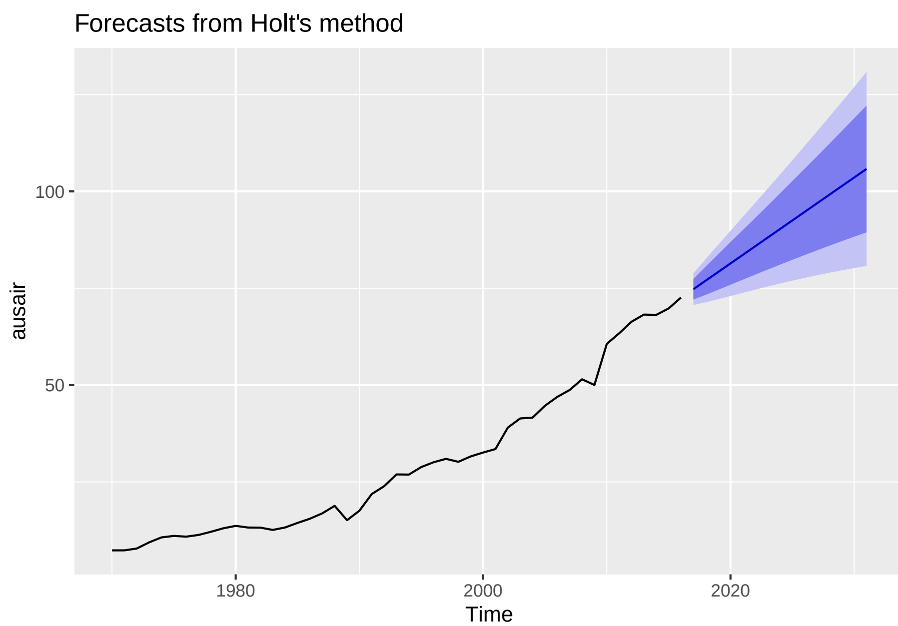

Figure 4.4: `ausair` Holt's linear trend method

Damped Holt's trend .

```
holt(ausair, h = 15, damped = TRUE) %>%
  autoplot()
```

Figure **??** Holt's linear trend method , damped Holt's trend method Figure **??** .

4.2.3 Holt-Winters' seasonal method

Holt-Winters' seasonal method Holt's trend method . level trend season , .

Holt-Winters' method , , (level) . , , .

Holt-Winters' additive seasonal method .

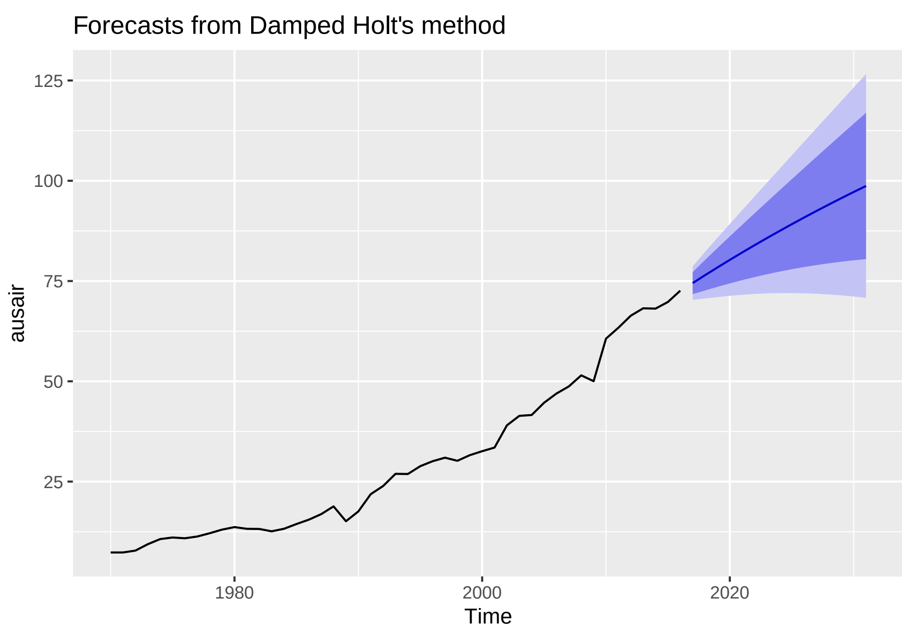

Figure 4.5: `ausair` damped Holt's trend method

- t level

$$l_t = \alpha(y_t - s_{t-m}) + (1-\alpha)(l_{t-1} + b_{t-1}) \tag{4.11}$$

- t trend

$$b_t = \beta(l_t - l_{t-1}) + (1-\beta)b_{t-1} \tag{4.12}$$

- t season

$$s_t = \gamma(y_t - l_{t-1} - b_{t-1}) + (1-\gamma)s_{t-m} \tag{4.13}$$

-

$$\hat{y}_{t+h} = l_t + hb_t + s_{t+h-m(k+1)} \tag{4.14}$$

, α, β, γ , m $m = 12$, $m = 4$. k $(h-1)/m$.

Holt-Winters' multiplicative seasonal method .

- t level

$$l_t = \alpha \frac{y_t}{s_{t-m}} + (1-\alpha)(l_{t-1} + b_{t-1}) \tag{4.15}$$

- t trend

$$b_t = \beta(l_t - l_{t-1}) + (1-\beta)b_{t-1} \tag{4.16}$$

- t season

$$s_t = \gamma \frac{y_t}{(l_{t-1} + b_{t-1}} + (1-\gamma)s_{t-m} \tag{4.17}$$

-

$$\hat{y}_{t+h} = (l_t + hb_t)s_{t+h-m(k+1)} \tag{4.18}$$

Holt-Winters' seasonal method damping . Holt-Winters' seasonal method damping additive seasonal method, damped additive seasonal method, multiplicative seasonal method, damped multiplicative seasonal method 4 .

`forecast::hw()` , .

```
hw(y, damped = FALSE, h = 2*frequency(y), level = c(80, 95),
seasonal = c("additive", "multiplicative"))
```

- : `fpp2::austourists`

`fpp2::austourists` 199 2015 . Holt-Winters' seasonal . .

.

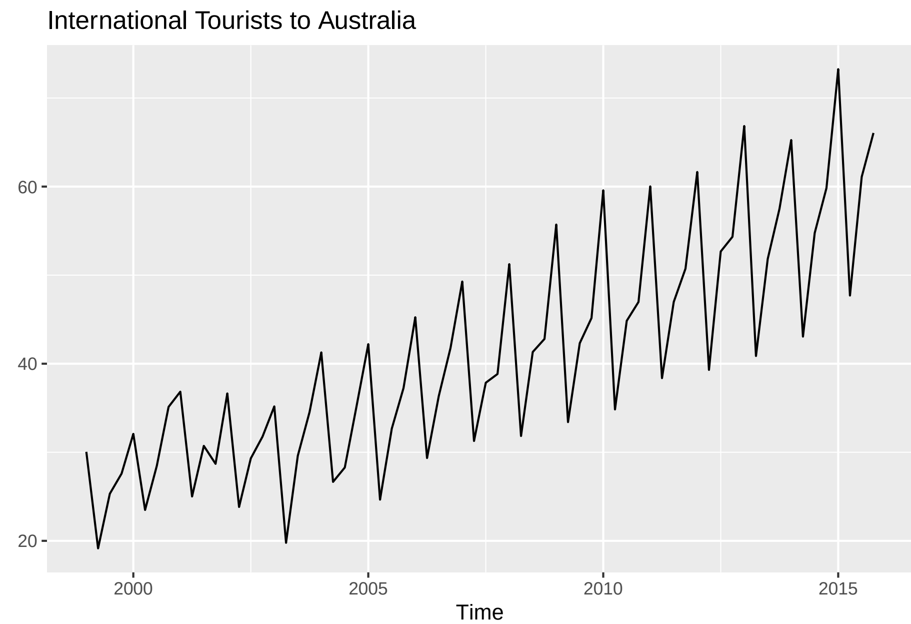

Figure 4.6: 199 2015

```
hw(austourists) %>%
  autoplot() + labs(y = NULL)
```

.

```
hw(austourists, seasonal = "multiplicative") %>%
  autoplot() + labs(y = NULL)
```

4.3 ETS

4.3.1

?? . h , . , .

ETS . ETS , .

•

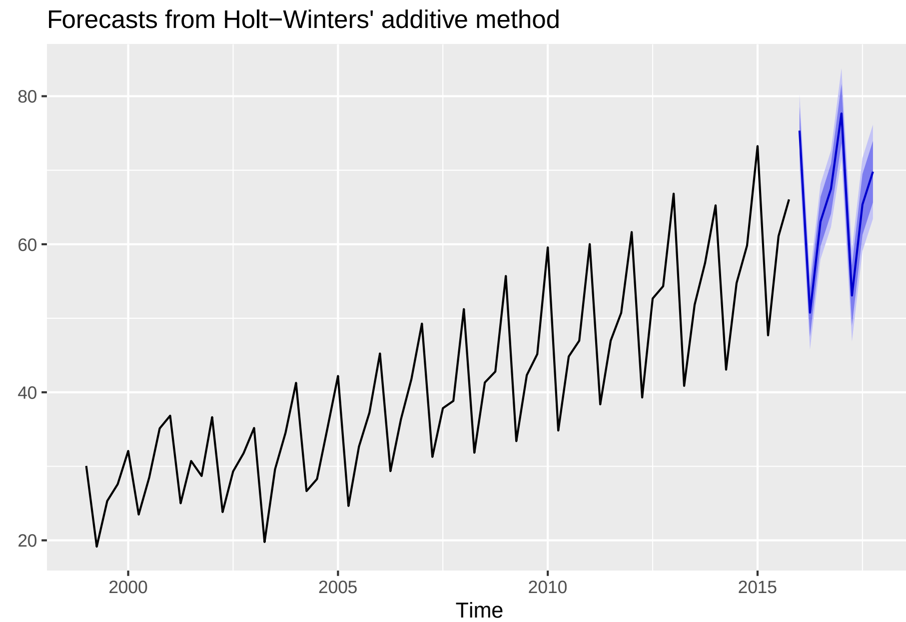

Figure 4.7: `austourists` Holt-Winters' additive seasonal method

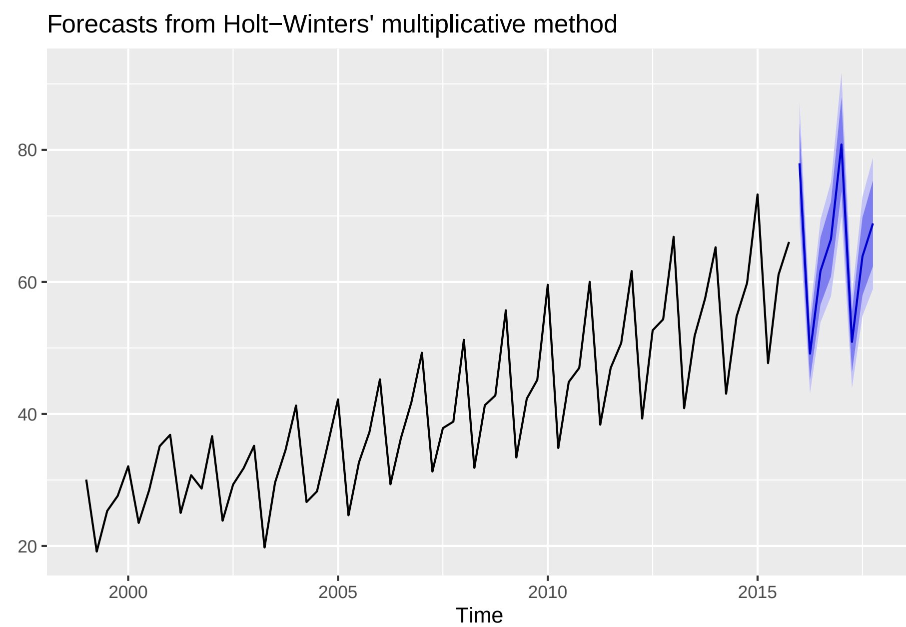

Figure 4.8: `austourists` Holt-Winters' multiplicative seasonal method