

# Tidy Time Series & Forecasting in R



## 6. Automatic forecasting algorithms

[robjhyndman.com/workshop2020](http://robjhyndman.com/workshop2020)

# Outline

- 1 What can we forecast?
- 2 Some case studies
- 3 The statistical forecasting perspective
- 4 Forecast accuracy measures

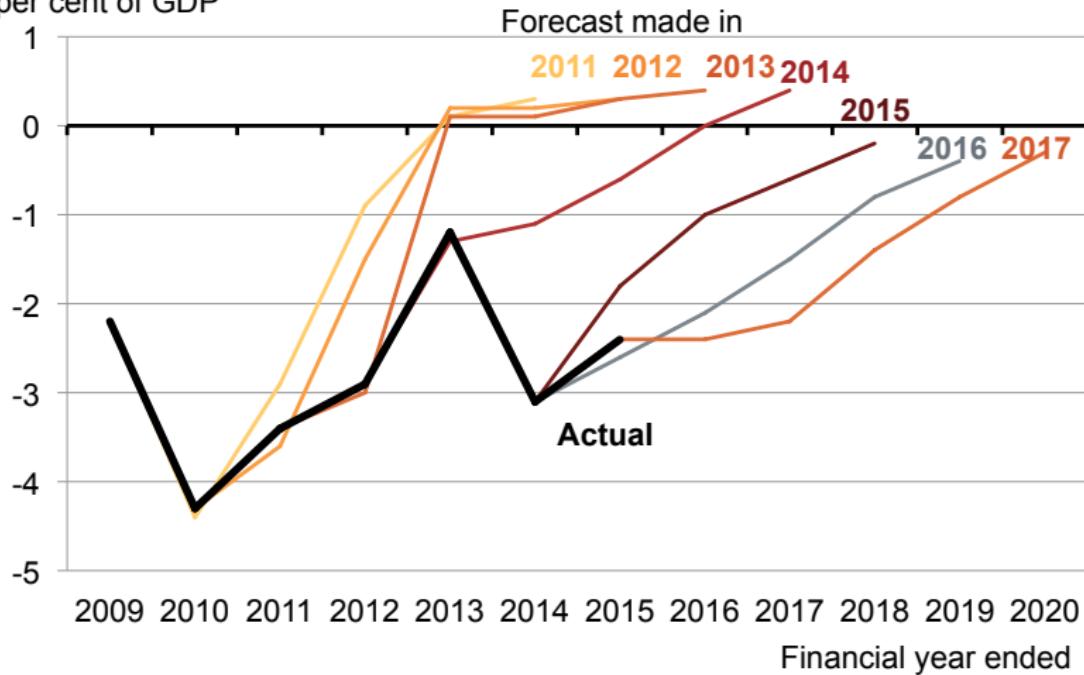
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# Forecasting is difficult

Commonwealth plans to drift back to surplus **GRATTAN Institute**  
show the triumph of experience over hope

Actual and forecast Commonwealth underlying cash balance  
per cent of GDP



# Forecasting is difficult

## A Timeline of Very Bad Future Predictions

1800



“ Rail travel at high speed is not possible, because passengers, unable to breathe, would die of asphyxia.”

Dr. Dionysus Larder, Professor of Natural Philosophy & Astronomy, University College London

1859



“ Drill for oil? You mean drill into the ground to try and find oil? You’re crazy!”

Associates of Edwin L. Drake refusing his suggestion to drill for oil in 1859 (Later that year, Drake succeeded in drilling the first oil well.)

1876



“ This telephone has too many shortcomings to be seriously considered as a means of communication.”

Western Union internal memo

1880



“ Everyone acquainted with the subject will recognize it as a conspicuous failure.”

Henry Morton, president of the Stevens Institute of Technology, on Edison's light bulb

1916



“ The idea that cavalry will be replaced by these iron coaches is absurd. It is little short of treasonous.”

Comment of Aide-de-camp to Field Marshal Haig, at tank demonstration

1946



“ Television won't last because people will soon get tired of staring at a plywood box every night.”

Darryl Zanuck, movie producer, 20th Century Fox

1902



“ Flight by machines heavier than air is unpractical and insignificant, if not utterly impossible.”

Simon Newcomb, Canadian-American astronomer and mathematician, 18 months before the Wright Brothers' flight at Kittyhawk

1916



“ The cinema is little more than a fad. It's canned drama. What audiences really want to see is flesh and blood on the stage.”

Charlie Chaplin, actor, producer, director, and studio founder

1977



“ There is no reason for any individual to have a computer in his home.”

Ken Olson, president, chairman and founder of Digital Equipment Corporation

1903



“ The horse is here to stay, but the automobile is only a novelty, a fad.”

The president of the Michigan Savings Bank, advising Henry Ford's lawyer not to invest in the Ford Motor Company

1921



“ The wireless music box has no imaginable commercial value. Who would pay for a message sent to no one in particular?”

Associates of commercial radio and television pioneer, David Sarnoff, responding to his call for investment in the radio



Read  
Newspapers  
Online



“ The truth is no online database will replace your daily newspaper.”

Clifford Stoll, Newsweek article entitled *The Internet? Bah!*

## What can we forecast?



# What can we forecast?



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# What can we forecast?

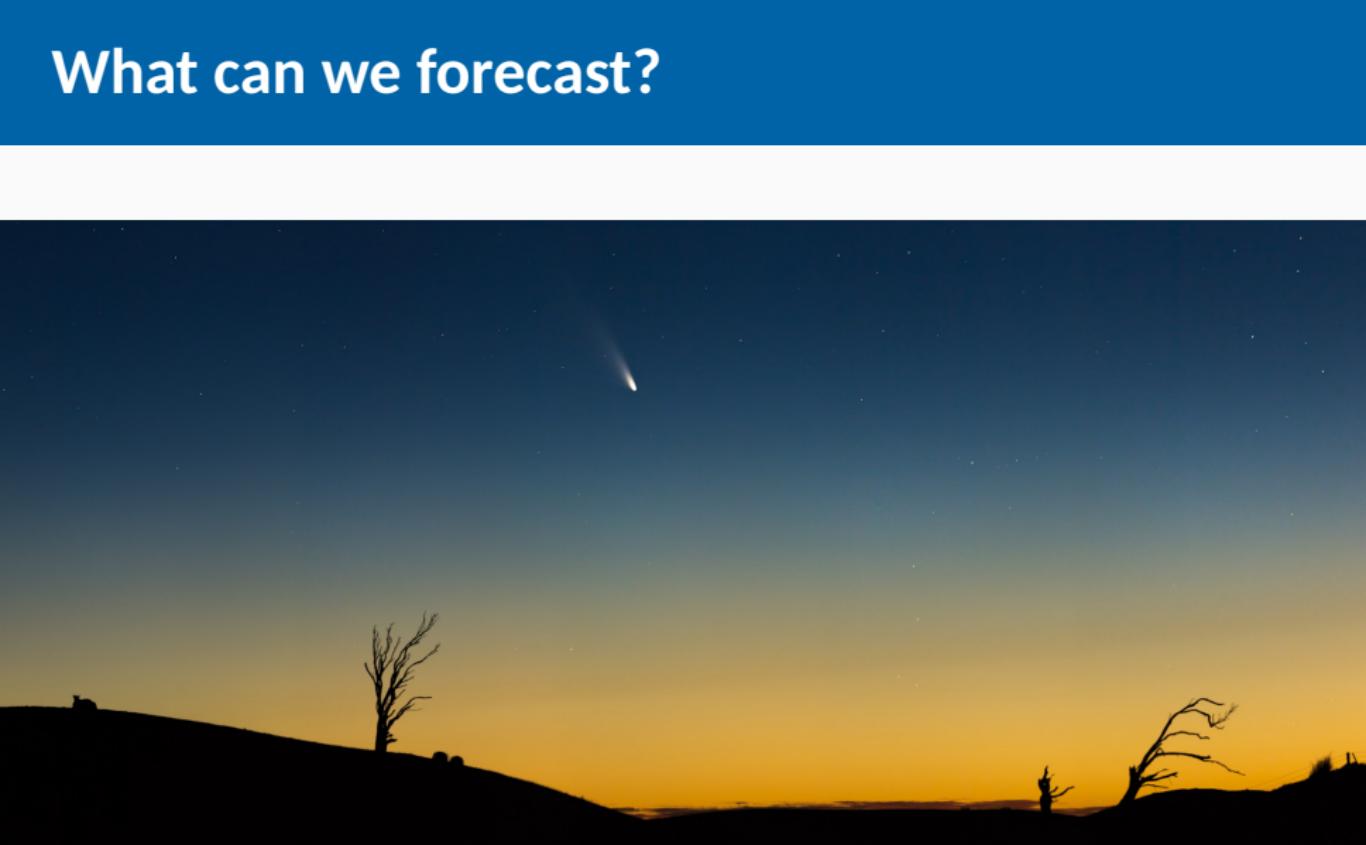
## TOMORROW



# What can we forecast?



# What can we forecast?



# Which is easiest to forecast?

- 1 daily electricity demand in 3 days time
- 2 timing of next Halley's comet appearance
- 3 time of sunrise this day next year
- 4 Google stock price tomorrow
- 5 Google stock price in 6 months time
- 6 maximum temperature tomorrow
- 7 exchange rate of \$US/AUS next week
- 8 total sales of drugs in Australian pharmacies next month

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- how do we measure “easiest”?
- what makes something easy/difficult to forecast?

# Factors affecting forecastability

Something is easier to forecast if:

- we have a good understanding of the factors that contribute to it
- there is lots of data available;
- the forecasts cannot affect the thing we are trying to forecast.
- there is relatively low natural/unexplainable random variation.
- the future is somewhat similar to the past

# Improving forecasts

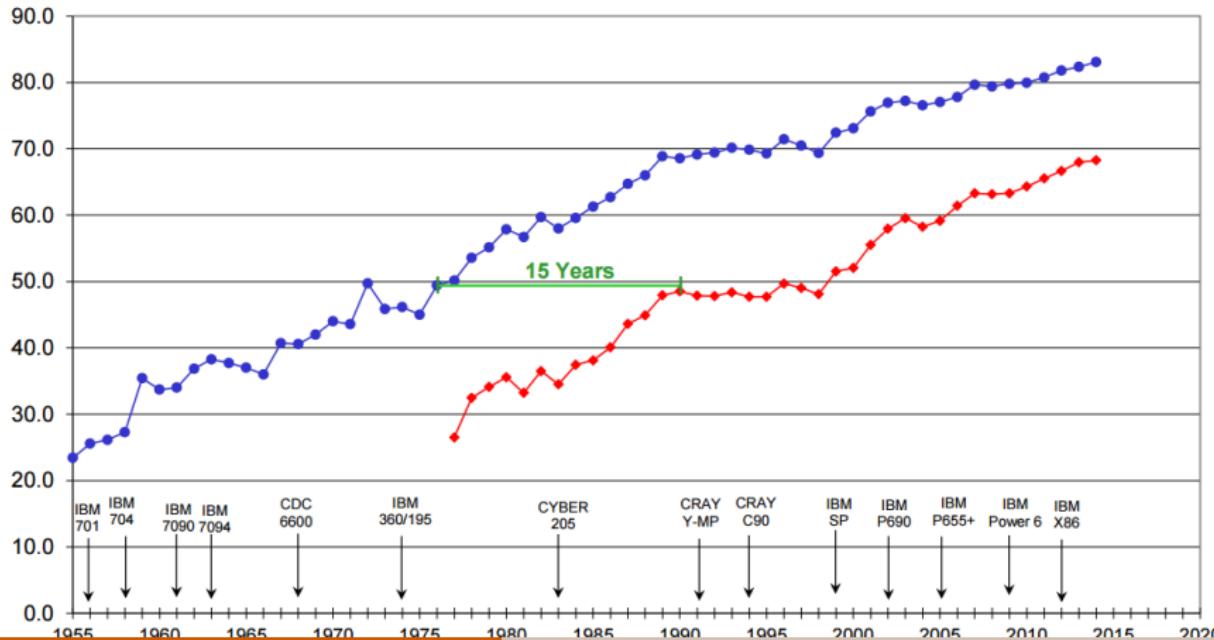


## NCEP Operational Forecast Skill

36 and 72 Hour Forecasts @ 500 MB over North America  
[ $100 * (1 - S1/70)$  Method]



—●— 36 Hour Forecast      —●— 72 Hour Forecast



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# CASE STUDY 1: Paperware company

**Problem:** Want forecasts of each of hundreds of items. Series can be stationary, trended or seasonal. They currently have a large forecasting program written in-house but it doesn't seem to produce sensible forecasts. They want me to tell them what is wrong and fix it.



## Additional information

- Program written in COBOL making numerical calculations limited. It is not possible to do any optimisation.
- Their programmer has little experience in numerical computing.
- They employ no statisticians and want

# CASE STUDY 1: Paperware company

## Methods currently used

- A 12 month average
- C 6 month average
- E straight line regression over last 12 months
- G straight line regression over last 6 months
- H average slope between last year's and this year's values. (Equivalent to differencing at lag 12 and taking mean.)
- I Same as H except over 6 months.
- K I couldn't understand the explanation.

## CASE STUDY 2: PBS



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**The Pharmaceutical Benefits Scheme (PBS) is the Australian government drugs subsidy scheme.**

- Many drugs bought from pharmacies are subsidised to allow more equitable access to modern drugs.
- The cost to government is determined by the number and types of drugs purchased. Currently nearly 1% of GDP.
- The total cost is budgeted based on forecasts of drug usage.

# CASE STUDY 2: PBS



# ABC News Online

AUSTRALIAN BROADCASTING CORPORATION



NewsRadio  
Streaming audio news  
LISTEN: [WMP](#) | [Real](#)

Select a Topic  
from the list below

- ▶ [Top Stories](#)
- ▶ [Just In](#)
- ▶ [World](#)
- ▶ [Asia-Pacific](#)
- ▶ [Business](#)
- ▶ [Sport](#)
- ▶ [Arts](#)
- ▶ [Sci Tech](#)
- ▶ [Indigenous](#)
- ▶ [Weather](#)
- ▶ [Rural](#)
- ▶ [Local News](#)
- ▶ [Broadband](#)

Click "Refresh" or "Reload"  
on your browser for the latest edition.

## POLITICS

### Opp demands drug price restriction after PBS budget blow-out

The Federal Opposition has called for tighter controls on drug prices after the Pharmaceutical Benefits Scheme (PBS) budget blew out by almost \$800 million.

The money was spent on two new drugs including the controversial anti-smoking aid Zyban, which dropped in price from \$220 to \$22 after it was listed on the PBS.

This Bulletin: Wed, May 30 2001 6:22 PM AEST



[For a fresh perspective on the federal election, reach into ABC Online's campaign weblog, The Poll Vault.](#)

[Audio News Online](#)

## CASE STUDY 2: PBS

- In 2001: \$4.5 billion budget, under-forecasted by \$800 million.
- Thousands of products. Seasonal demand.
- Subject to covert marketing, volatile products, uncontrollable expenditure.
- Although monthly data available for 10 years, data are aggregated to annual values, and only the first three years are used in estimating the forecasts.
- All forecasts being done with the FORECAST function in MS-Excel!

## CASE STUDY 3: Car fleet company

**Client:** One of Australia's largest car fleet companies

**Problem:** how to forecast resale value of vehicles?

How should this affect leasing and sales policies?

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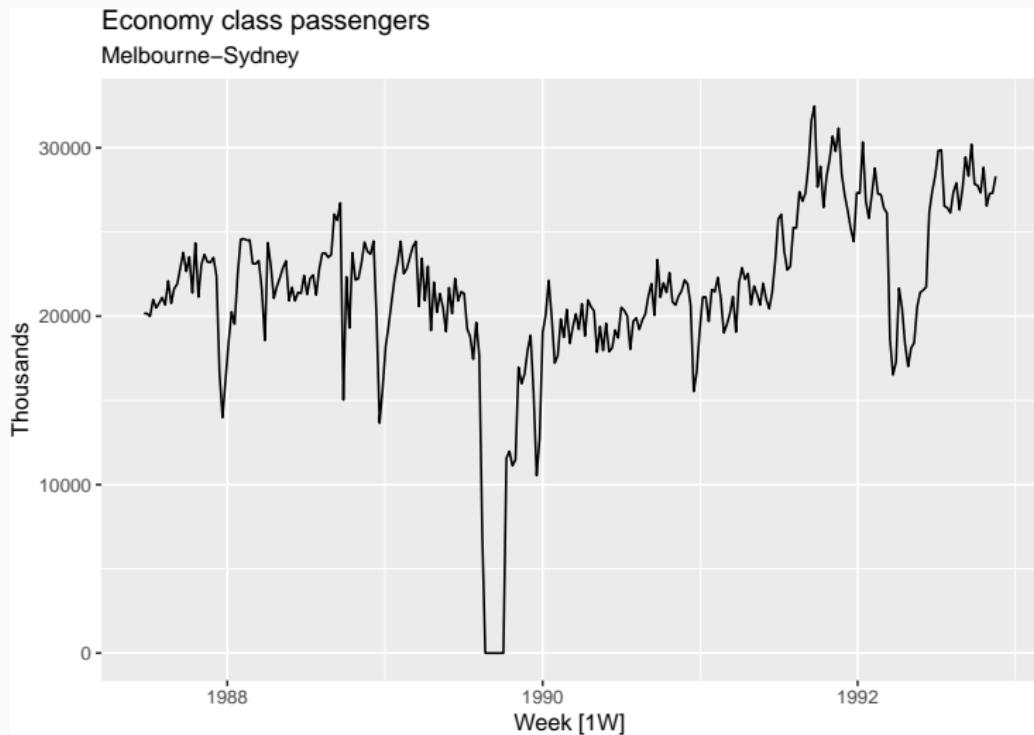
### Additional information

- They can provide a large amount of data on previous vehicles and their eventual resale values.
- The resale values are currently estimated by a group of specialists. They see me as a threat and do not cooperate.

## CASE STUDY 4: Airline



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**Problem:** how to forecast passenger traffic on major routes?

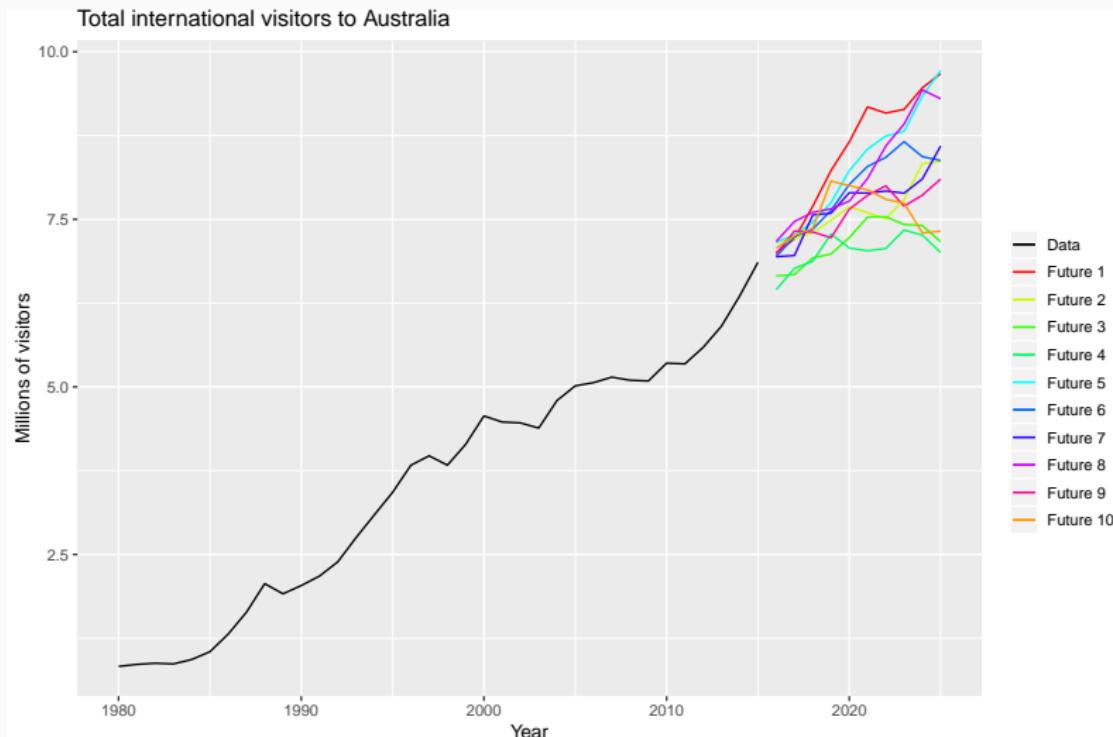
## Additional information

- They can provide a large amount of data on previous routes.
- Traffic is affected by school holidays, special events such as the Grand Prix, advertising campaigns, competition behaviour, etc.
- They have a highly capable team of people who are able to do most of the computing.

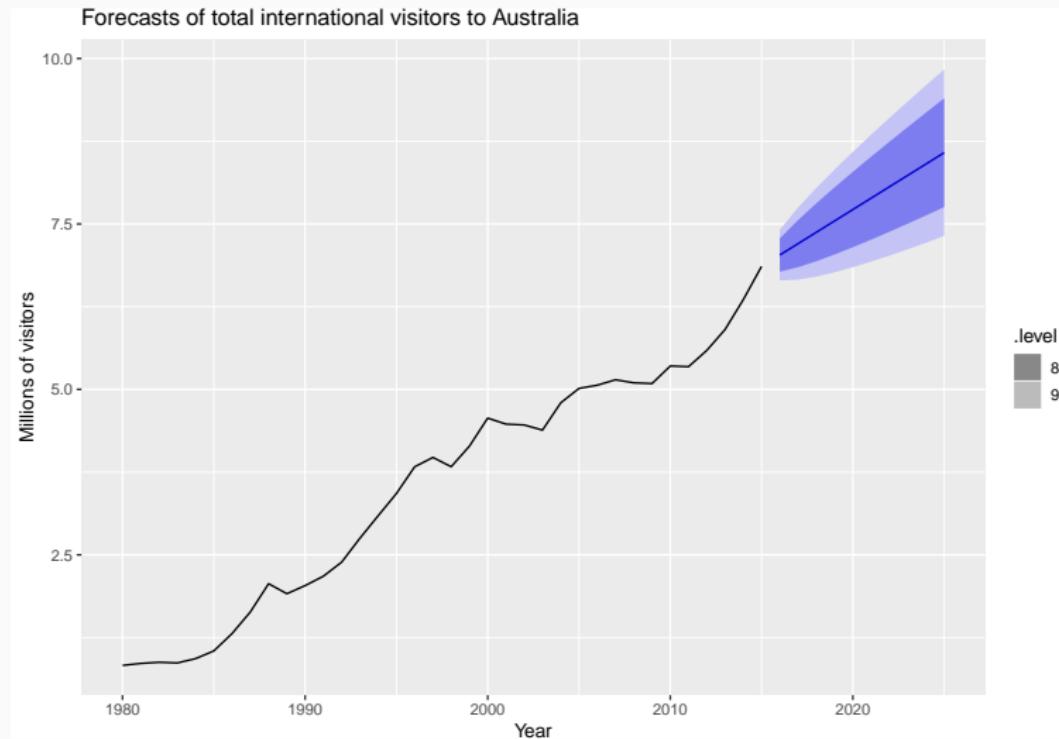
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# Sample futures



# Forecast intervals



# Statistical forecasting

- Thing to be forecast: a random variable,  $y_t$ .
- Forecast distribution: If  $\mathcal{I}$  is all observations, then  $y_t|\mathcal{I}$  means “the random variable  $y_t$  given what we know in  $\mathcal{I}$ ”.
- The “point forecast” is the mean (or median) of  $y_t|\mathcal{I}$
- The “forecast variance” is  $\text{var}[y_t|\mathcal{I}]$
- A prediction interval or “interval forecast” is a range of values of  $y_t$  with high probability.
- With time series,  $y_{t|t-1} = y_t|\{y_1, y_2, \dots, y_{t-1}\}$ .
- $\hat{y}_{T+h|T} = E[y_{T+h}|y_1, \dots, y_T]$  (an  $h$ -step forecast taking account of all observations up to time  $T$ ).

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# Training and test sets



- A model which fits the training data well will not necessarily forecast well.
- Forecast accuracy is based only on the test set.

## Forecast errors

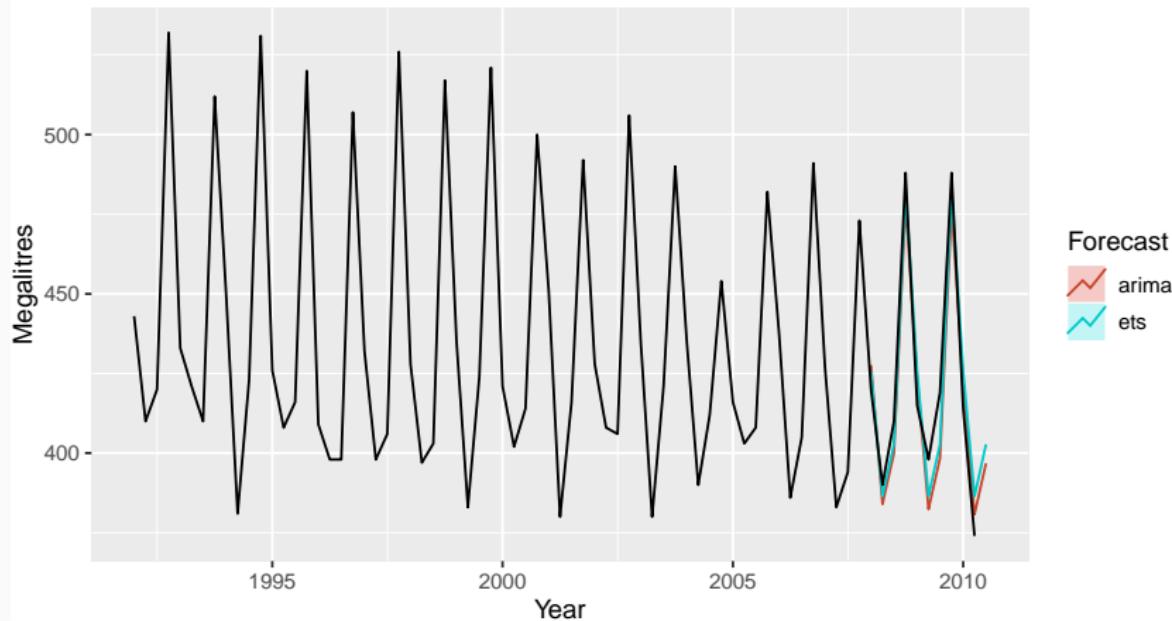
Forecast “error”: the difference between an observed value and its forecast.

$$e_{T+h} = y_{T+h} - \hat{y}_{T+h|T},$$

where the training data is given by  $\{y_1, \dots, y_T\}$

# Measures of forecast accuracy

Forecasts for quarterly beer production



## Measures of forecast accuracy

$y_{T+h}$  =  $(T + h)$ th observation,  $h = 1, \dots, H$

$\hat{y}_{T+h|T}$  = its forecast based on data up to time  $T$ .

$e_{T+h} = y_{T+h} - \hat{y}_{T+h|T}$

MAE =  $\text{mean}(|e_{T+h}|)$

MSE =  $\text{mean}(e_{T+h}^2)$

RMSE =  $\sqrt{\text{mean}(e_{T+h}^2)}$

MAPE =  $100\text{mean}(|e_{T+h}| / |y_{T+h}|)$

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- MAE, MSE, RMSE are all scale dependent.
- MAPE is scale independent but is only sensible if  $y_t \gg 0$  for all  $t$ , and  $y$  has a natural zero.

# Measures of forecast accuracy

## Mean Absolute Scaled Error

$$\text{MASE} = \text{mean}(|e_{T+h}|)/Q$$

where Q is a stable measure of the scale of the time series  $\{y_t\}$ .

Proposed by Hyndman and Koehler (IJF, 2006).

For non-seasonal time series,

$$Q = (T - 1)^{-1} \sum_{t=2}^T |y_t - y_{t-1}|$$

works well. Then MASE is equivalent to MAE relative to a naïve method.

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For seasonal time series,

$$Q = (T - m)^{-1} \sum_{t=m+1}^T |y_t - y_{t-m}|$$

works well. Then MASE is equivalent to MAE relative to a seasonal naïve method.

# Measures of forecast accuracy

```
recent_production <- aus_production %>%  
  filter(year(Quarter) >= 1992)  
train <- recent_production %>% filter(year(Quarter) <= 2007)  
beer_fit <- train %>%  
  model(  
    ets = ETS(Beer),  
    arima = ARIMA(Beer)  
  )  
beer_fc <- forecast(beer_fit, h="4 years")  
accuracy(beer_fc, aus_production)
```

```
## # A tibble: 2 x 9  
##   .model .type     ME   RMSE    MAE    MPE    MAPE    MASE    ACF1  
##   <chr>  <chr> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 arima   Test   4.18  11.2  10.4  0.940  2.47  0.657  0.145  
## 2 ets     Test   0.854  9.80  8.99  0.151  2.18  0.568  0.207
```