MSCI152: Introduction to Business Intelligence and Analytics

Lecture 13: Introduction to Forecasting

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Agenda

1. Recap
2. Decision making and forecasting
3. Time series data
4. Introduction to forecasting
   - Objects of forecasting
   - Forecasting methods
   - Evaluation

More details can be found in Camms et al., Sections 8.1 and 8.2

Recap

Descriptive analytics

describes what has happened in the past

Predictive analytics

using models constructed from past data to predict the future or ascertain the impact of one variable on another

Prescriptive analytics (not covered in this module)

indicates a course of action to take, having a decision as the main output

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Predictive analytics

- What is the main focus for predictive analytics?
  - To analyse current and historical facts to make predictions about future or otherwise unknown events

- What tools can we use here? Any ideas?
  - Linear regression;
  - Time series analysis;
  - Extrapolation techniques;
  - Data mining and machine learning;
  - Simulation.

Decision making and forecasting

- Why do we check the weather forecast?

  - idle curiosity?
  - guiding our plans (to go out or not) and decisions (what to wear, to take an umbrella or not)?
- The forecast helps us plan, and planning, in turn, may improve our quality of life, compared with just rushing out the door.

Decision making and forecasting

Decision making in organisations has at its core an element of forecasting.

- Accurate forecasts lead to reduced uncertainty $\Rightarrow$ better decisions
- Forecasts may be implicit or explicit

What is a difference between **forecasts**, **plans** and **targets**?

Forecasts vs targets

- Forecasts aims to provide information about the future, conditional on historical and current knowledge
- Company targets and plans aim to provide direction towards a desirable future.

The difference between targets and forecasts, at different horizons, provide useful feedback.

Decision making and forecasting

Forecasts are central in decisions relating to:

- Inventory management
- Promotional and marketing activities
- Logistics
- Human resource planning
- Purchasing and procurement
- Cash flow management
- Energy consumption
- ...

Accurate forecasts can support

- Decision making
- Identifying and capitalising on opportunities
- Cost saving

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Types of data

Definition

Cross-sectional data are measurements on multiple units, recorder in a *single time period*.

A time series is a set of comparable measurements recorder on a single variable *over multiple time periods*.

Panel data are cross-sectional measurements that are repeated *over time*.

We focus on time series data, but you might need to predict any of these types.

Time series data

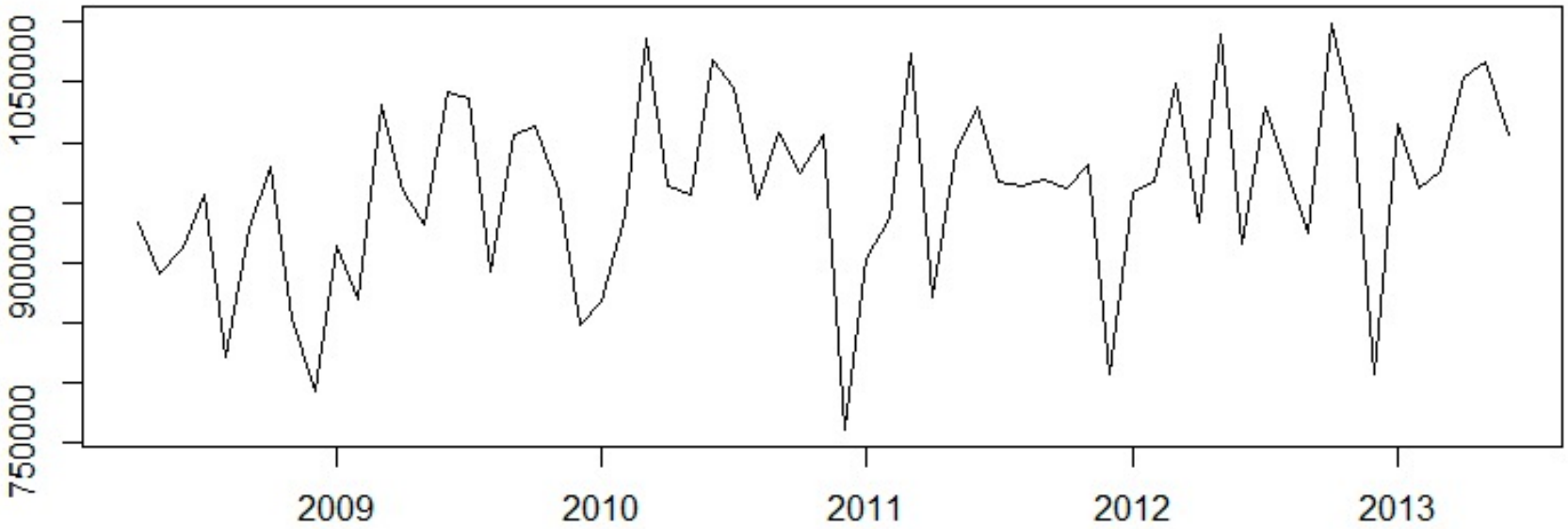
Here is a time series:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008				933976	890852	912027	955852	821916	928176	979219	853812	792731
2009	913787	869255	1030853	959455	931591	1041274	1035852	892341	1005862	1014031	960223	848466
2010	866842	938286	1086902	962974	955879	1068749	1045414	953327	1008101	974120	1005801	761033
2011	902306	937570	1073486	871337	992857	1029712	967990	962804	968900	961030	980589	807212
2012	958019	967395	1048667	934227	1089364	915222	1029949	976422	924795	1098958	1020188	807210
2013	1014811	962444	975386	1053440	1067057	1007016						

- Can somebody describe its structure?
  - Does it have an upward/downward trend?
  - Does it have seasonality?
  - Any special events?
  - Is it very erratic or with relatively low variability?

Time series data

Here is the same time series:

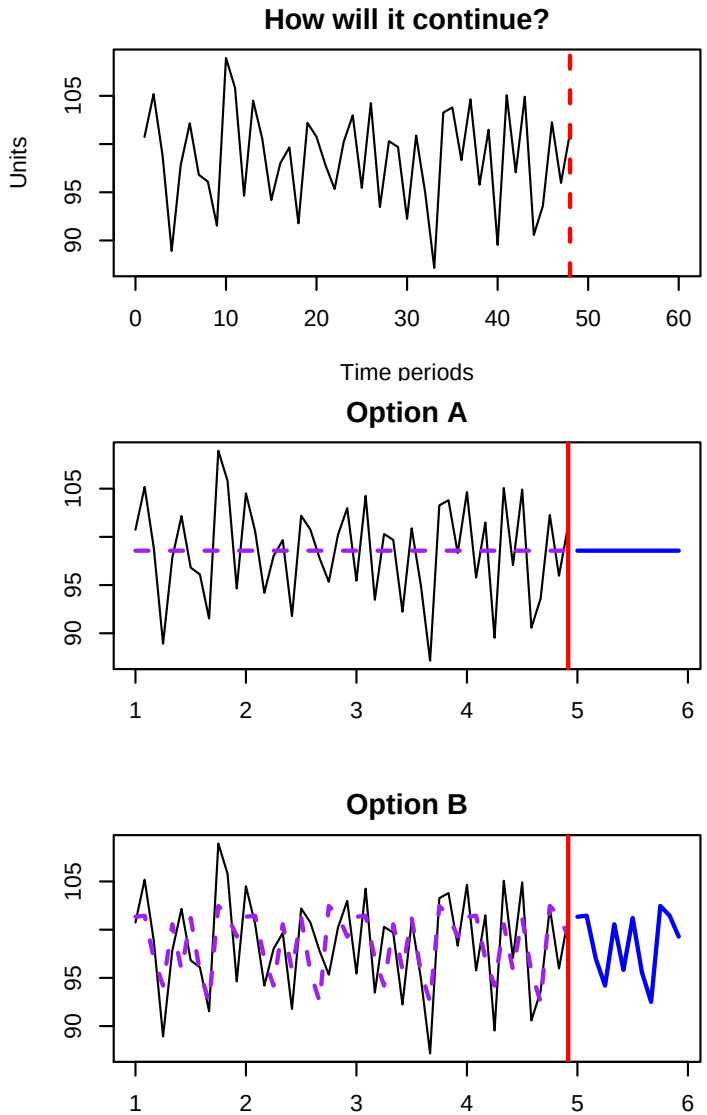


- Can somebody describe its structure?
  - Does it have an upward/downward trend?
  - Does it have seasonality?
  - Any special events?
  - Is it very erratic or with relatively low variability?

Visualise your data - allows to quickly assess the characteristics of a time series

Forecasting exercise

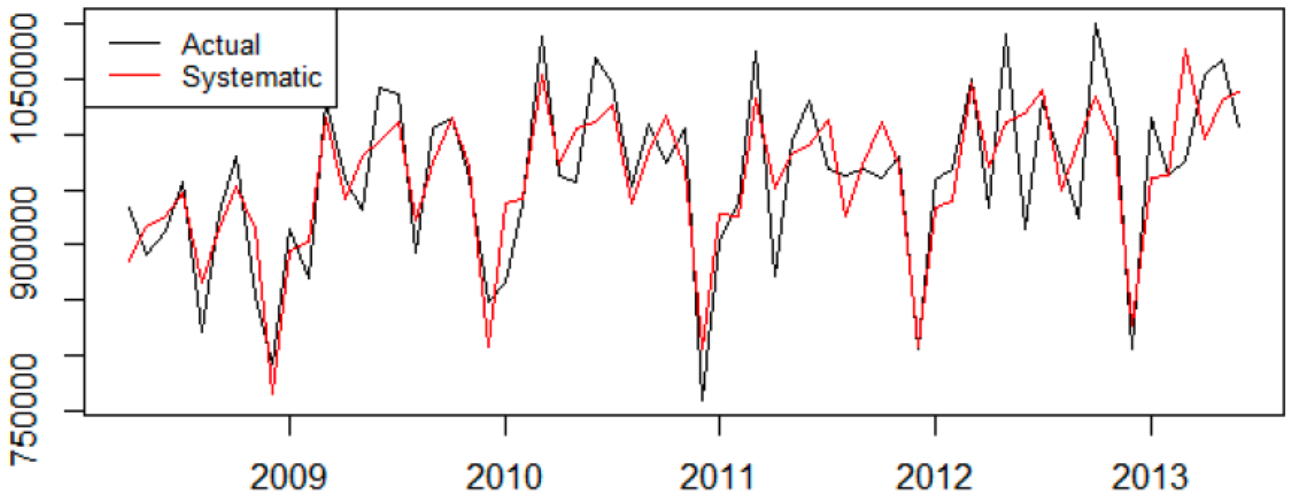
What is the best forecast: Option A or B?



Time series components

The time series we observed can be thought of as having two parts:

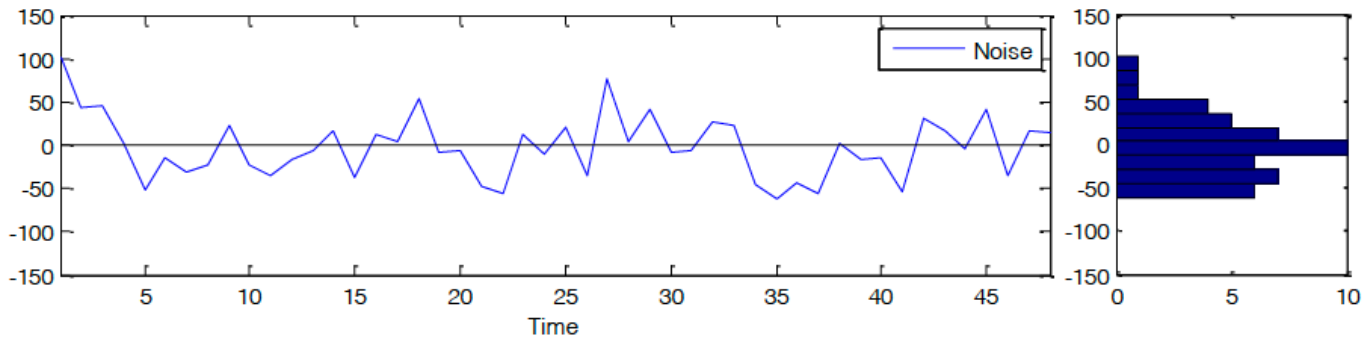
- a **systematic** part
- a **random** part



These two we cannot observe and the time series we model is the combination of both, however **only the systematic part can be forecasted**.
Forecasting models are tasked to capture this systematic part, while removing the random to give us a prediction.

What is noise (randomness)?

Noise (or random part) is inherently unforecastable since it has no structure, otherwise it should be captured by the forecasting method used.



It is impossible to predict whether the noise time series will go up or down, as there is no structure.

We may be fooled in seeing patterns in the noise, but there are none! Noise cannot be forecasted!

Time series components

A time series is generally regarded to have the following:

- Level
- Trend
- Season
- Error or irregular or random part (noise)

The first two make up the systematic part of the series.

Level

if a time series lacks a trend/cycle then it fluctuates around a level. The level itself can effectively be described as part of the trend component.

Trend

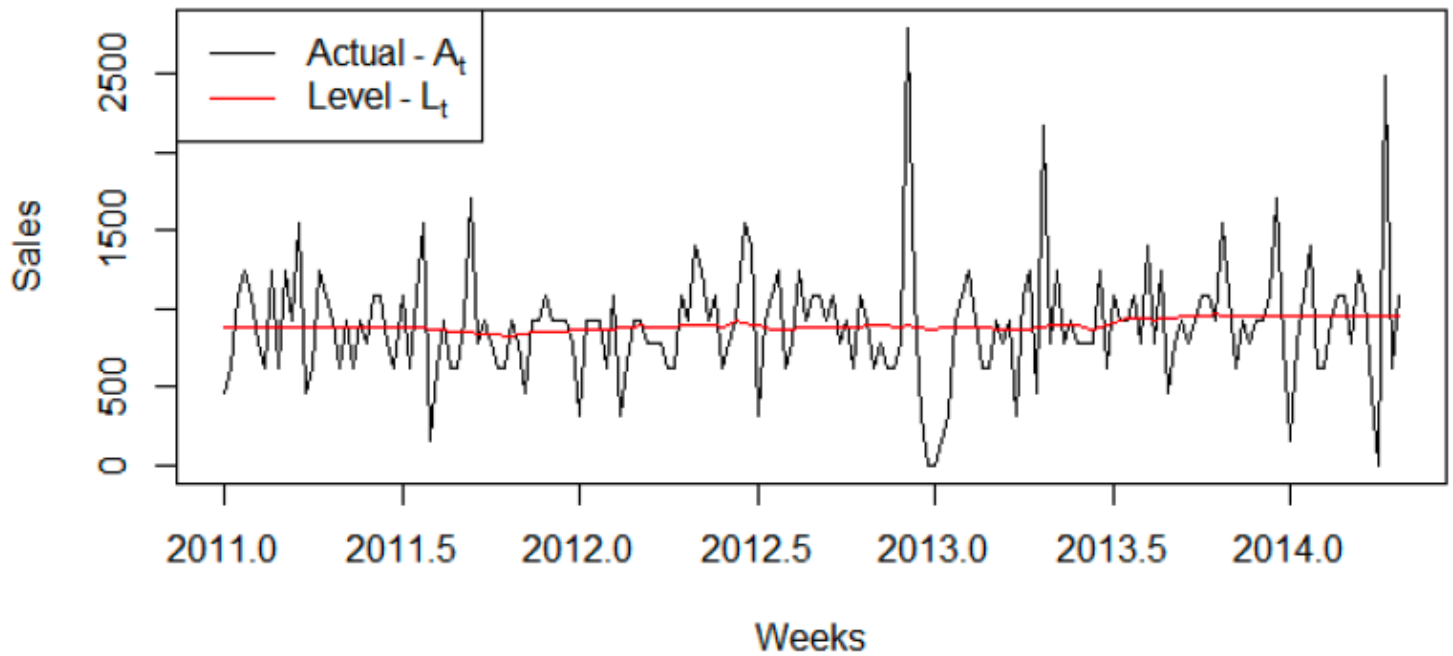
it is the long term increase or decrease in the data. It does not have to be linear. The trend may change over time. The same is true for its rate of change.

Season

it is a repeating pattern of fixed period. Its duration does not change.

Time series components: Level

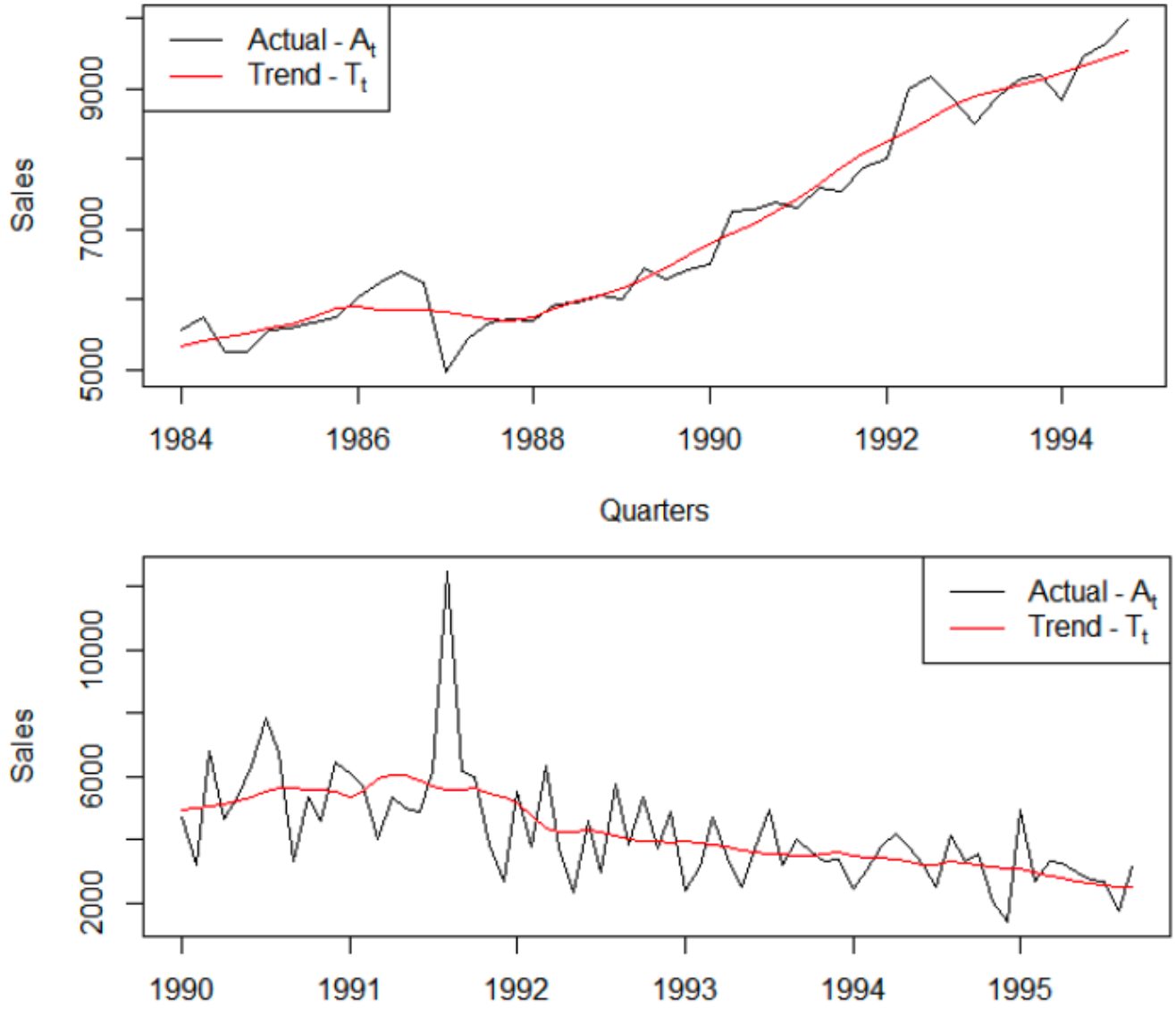
Series that are comprised only by a level component (+ noise) are often referred to as level or constant.



The level may fluctuate locally, but in the long term, it does increase or decrease.
The difference between the underlying level and the actual time series gives us the randomness contained in the series.

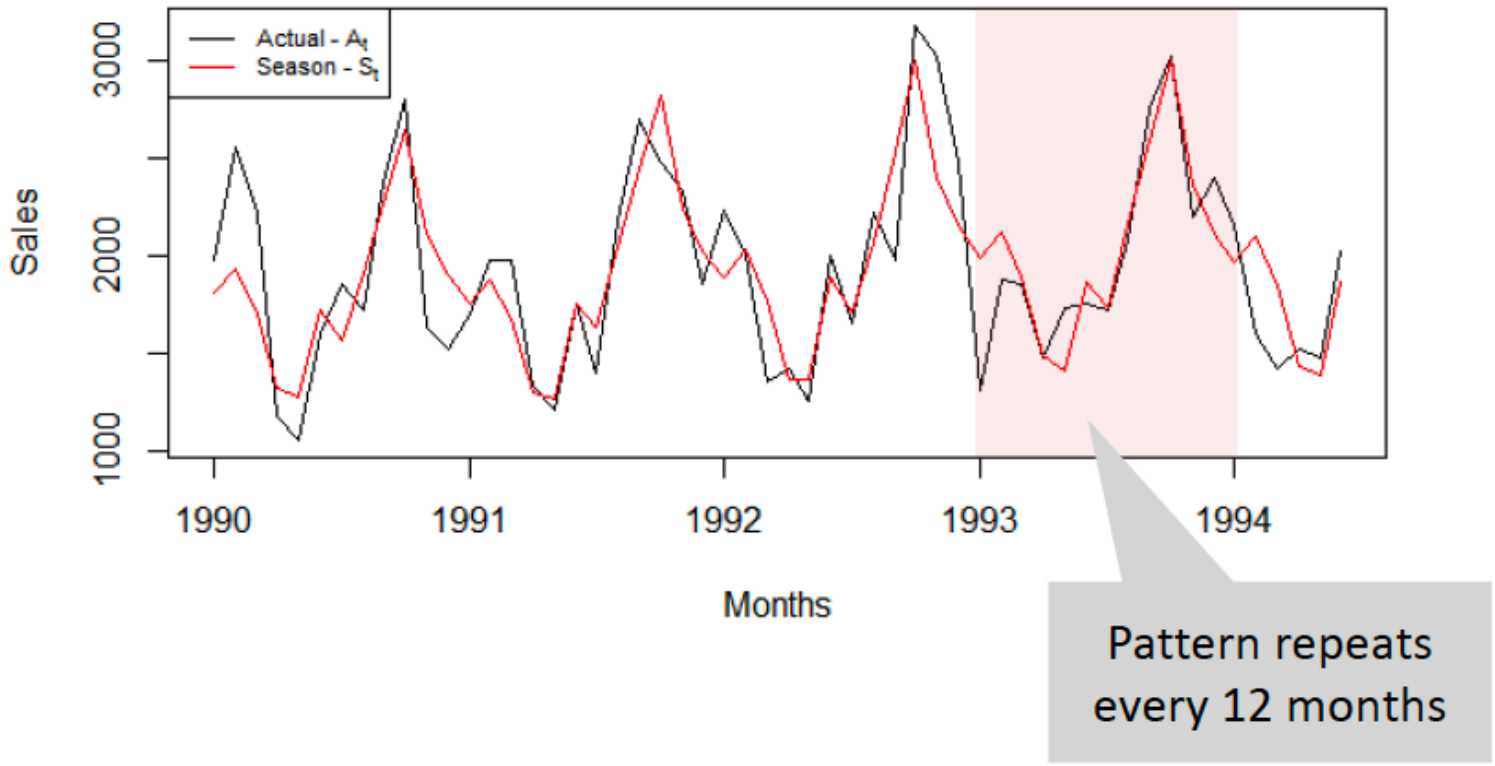
Time series components: Trend

Trend is the underlying long term changes in the level (increase or decrease).



Time series components: Season

Season is a repeating pattern of a fixed period.



Remember that the observed time series includes again **noise**, which explains (partially) why the pattern is not repeated perfectly every year.

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Forecasting Step by Step

1. Define the forecasting and planning **problem**, and decide the value of better forecasts
2. Determine the **resources** to be devoted to providing the forecasts;
3. Collect relevant **data** (e.g., from a survey, company records, online data etc.)
4. Conduct an **initial analysis** of the data
5. Select an appropriate **forecasting method**
6. **Generate forecasts**
7. **Validate** the forecasting exercise by checking forecasts against actual outcomes.

Forecasting Problem Structure

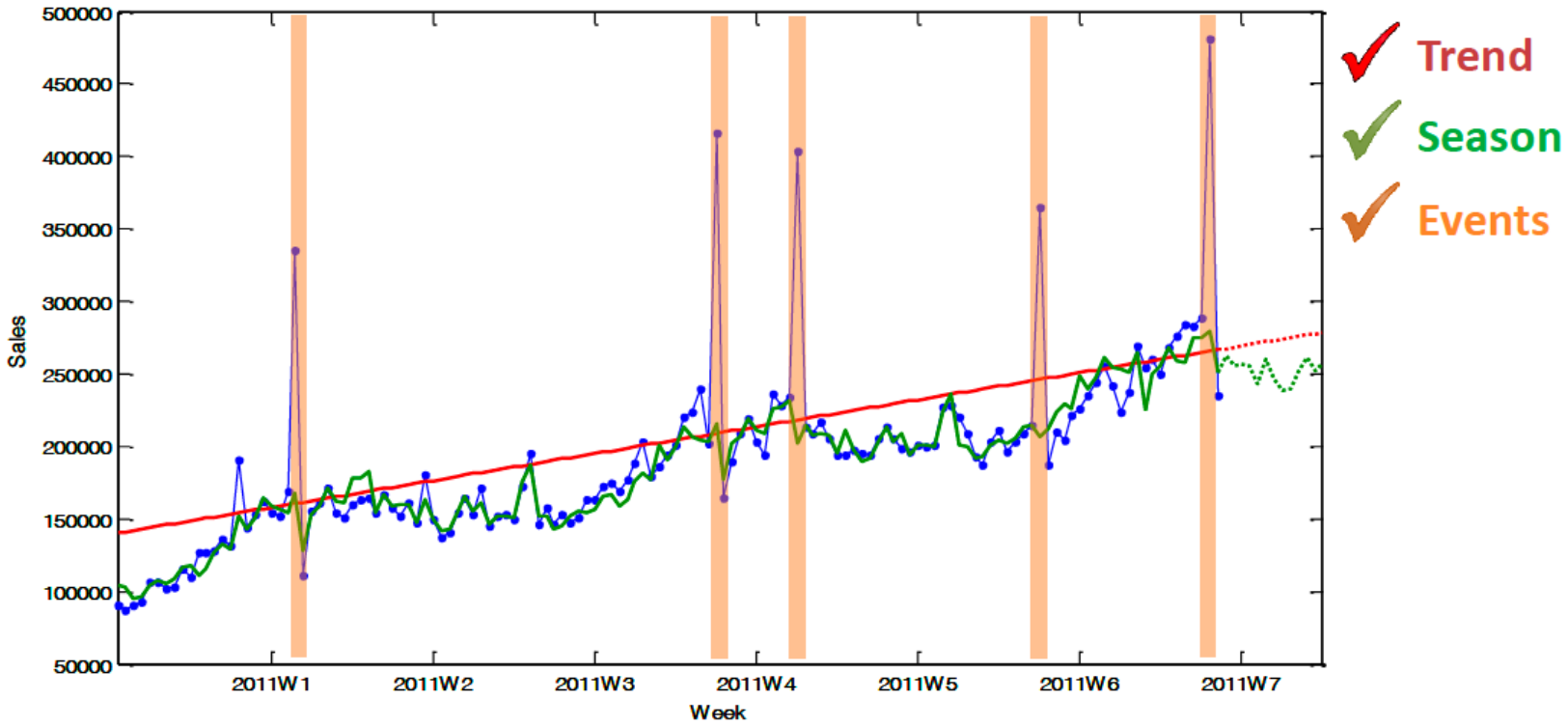
- Forecasting **object**
  - Level of aggregation
    - For a period,
    - Cumulative across periods,
    - growth rate
    - events
- Forecasting **horizon**
  How far into the future?
- Forecasting **frequency**
  Yearly / Monthly / Weekly/ Daily/ Hourly/ ...

Structure should be derived from decision-making process!

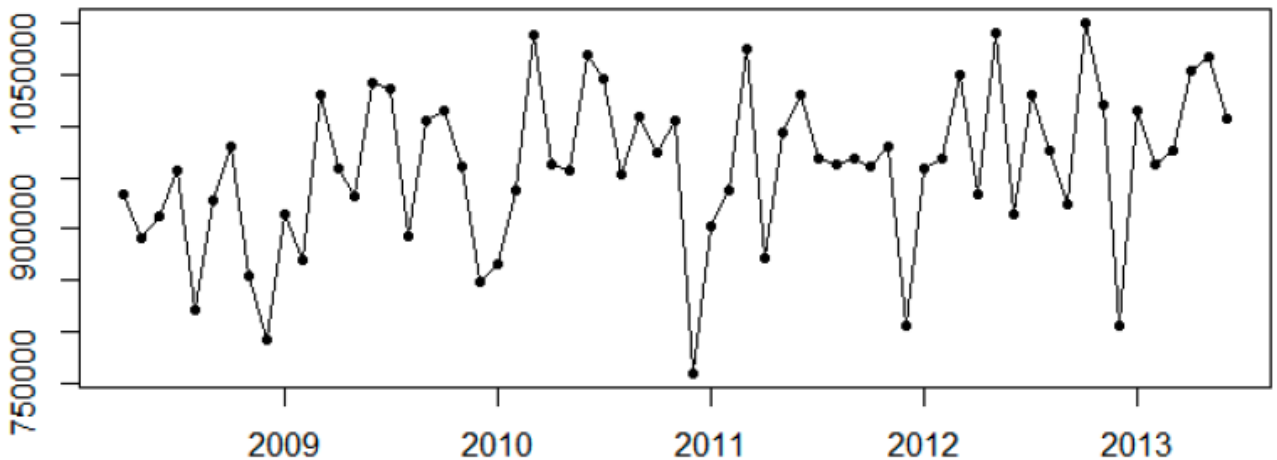
Objects of forecasting

Definition

A **time series** is a sequence of observations on a variable measured at successive points in time or over successive periods of time.



Time series notation



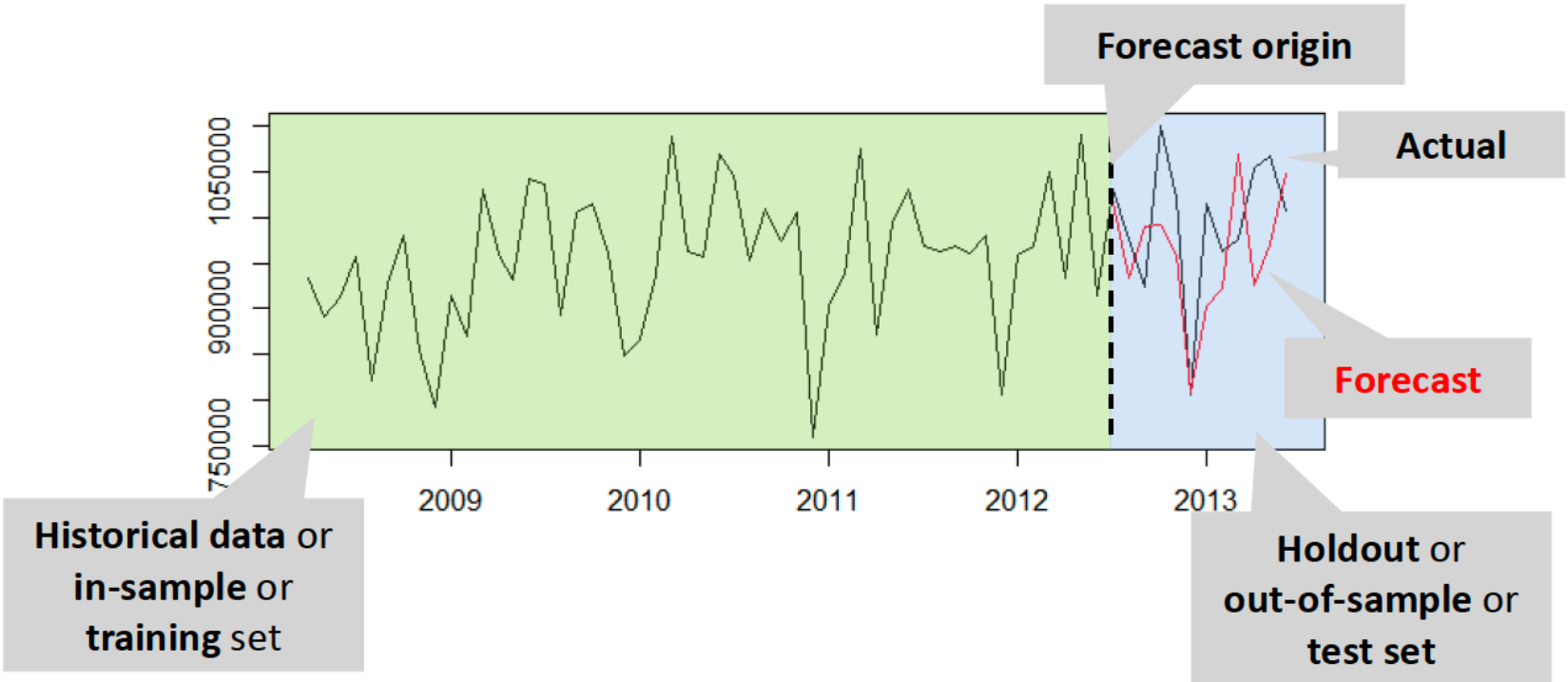
Actuals: A_t $\quad \cdots \; A_{t-2} \; A_{t-1} \; A_t \; A_{t+1} \; A_{t+2} \; \cdots$

Forecasts: F_t $\quad \cdots \; F_{t-2} \; F_{t-1} \; F_t \; F_{t+1} \; F_{t+2} \; \cdots$

Errors: $e_t = A_t - F_t$ $\quad \cdots \; e_{t-2} \; e_{t-1} \; e_t \; e_{t+1} \; e_{t+2} \; \cdots$

A common alternative notation is y_t for actuals and $\hat{y}_t$ for forecasts

Time series notation

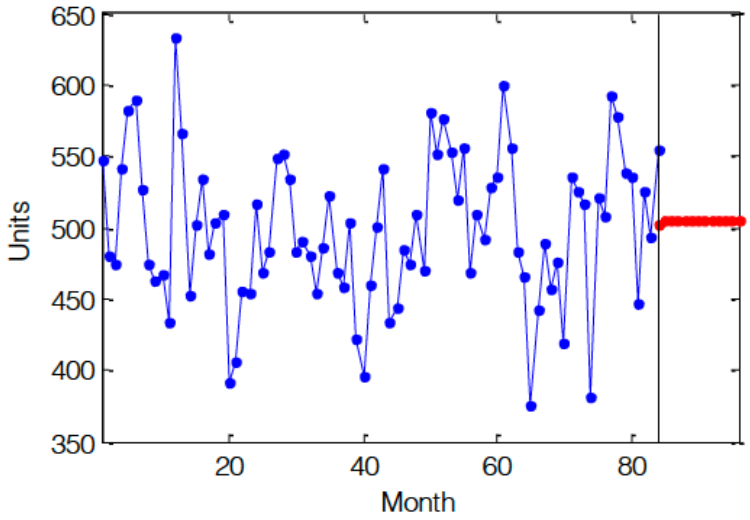


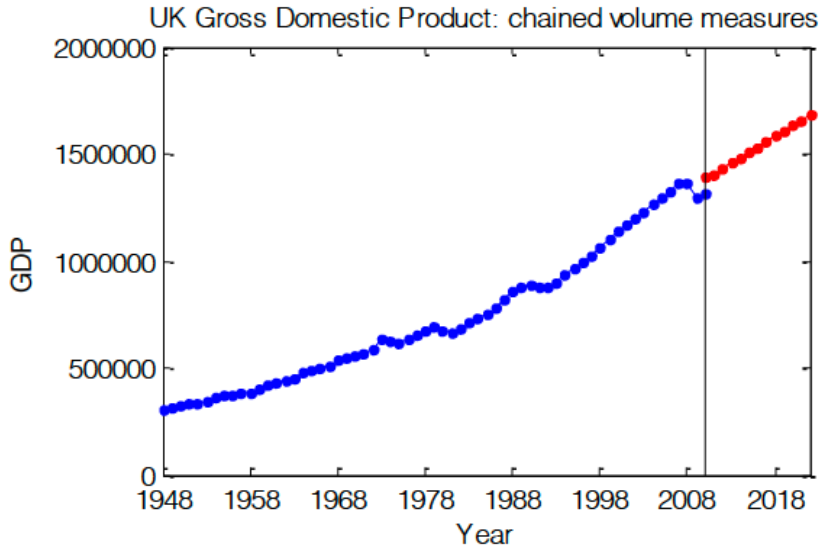
- You might need to predict not just one period ahead, so F_{t+h} means an h step ahead forecast from time t. For example, for the forecast 7 days ahead from today (t) we would write F_{t+7}
- It makes sense to use only part of the historical data to build the model and retain another part to evaluate how good we can forecast.

Objects of forecasting

Definition

Point forecast is our expectation of the most probable future value of a variable.



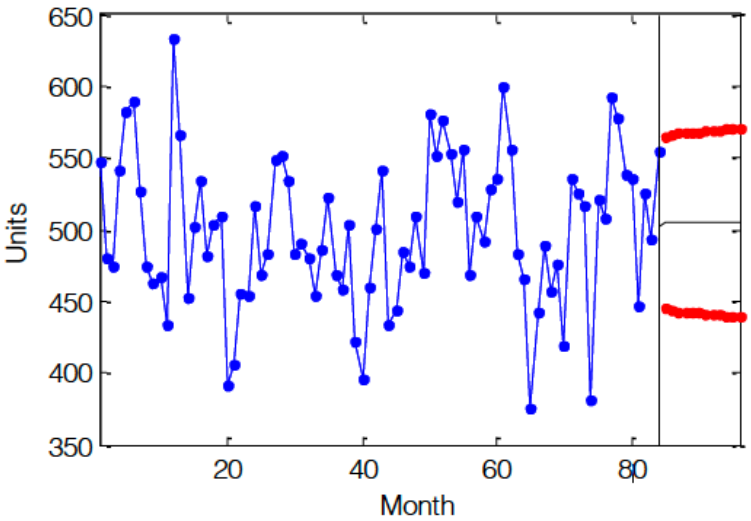


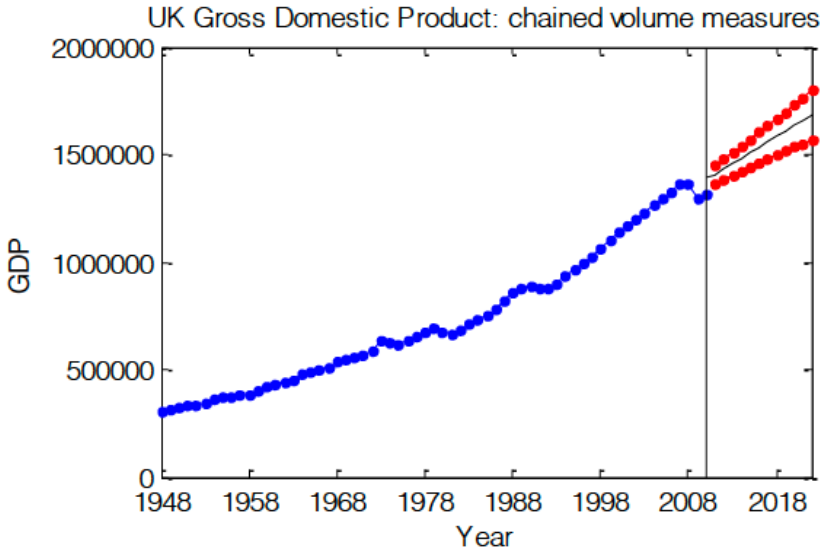
We are trying to estimate and extrapolate the most probable value (not the noise!), i.e. the expected value E(x).

Objects of forecasting

Definition

Prediction intervals show the bounds that the expected value should be in with a % chance.





We aim to capture uncertainty around point forecasts, we can call it *optimistic and pessimistic forecasts*.

When is it relevant?

Forecasting methods

Qualitative methods

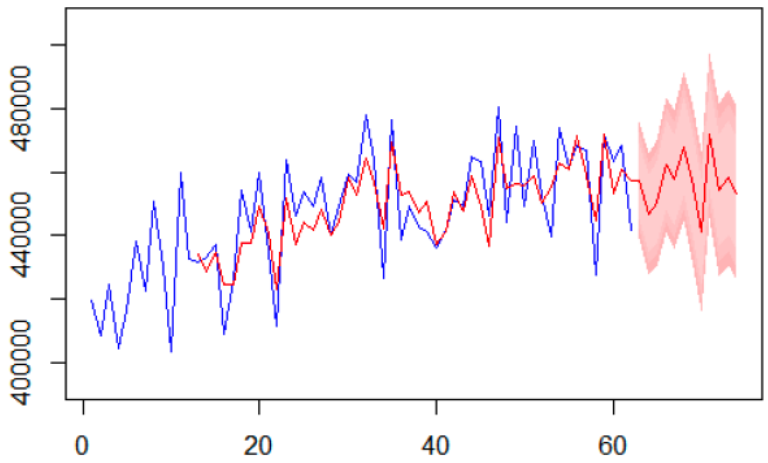
1. involve the use of expert judgment to develop forecasts;
2. are appropriate when historical data are either unavailable or not applicable;
3. typically informal, implicit human extrapolations without systematic instructions how to generate a forecast;
4. are subjective based upon personal experience and knowledge;
5. can incorporate new, unstructured information
6. The results of forecast are not replicable by other experts, or same expert at another time.

Quantitative methods

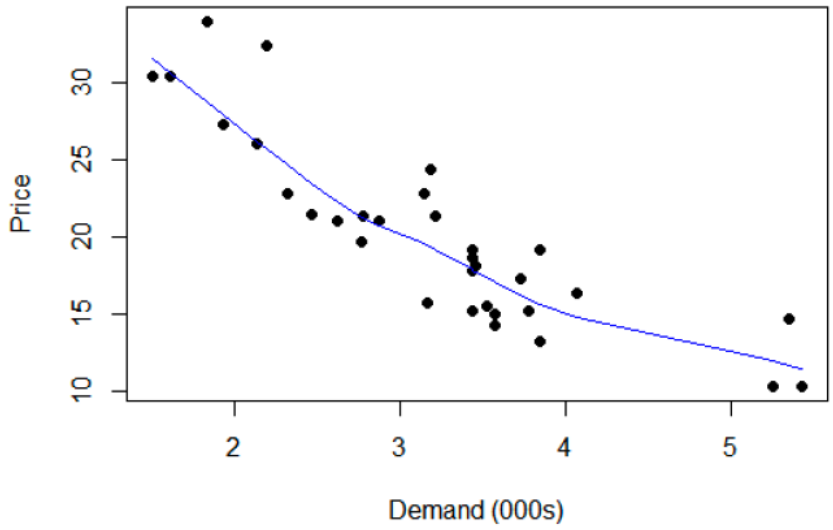
1. use formal mathematical models
2. can be used when past information is available and can be quantified
3. are based on the application of a prescribed explicit analysis of numerically coded data
4. are not based on subjective experience of human experts
5. can be replicated: when used on identical data, it will always lead to the same forecasts (any exceptions?)
6. quicker to obtain the results for many time series using many observations/variables

Quantitative forecasting methods

Time series extrapolative methods



Causal methods



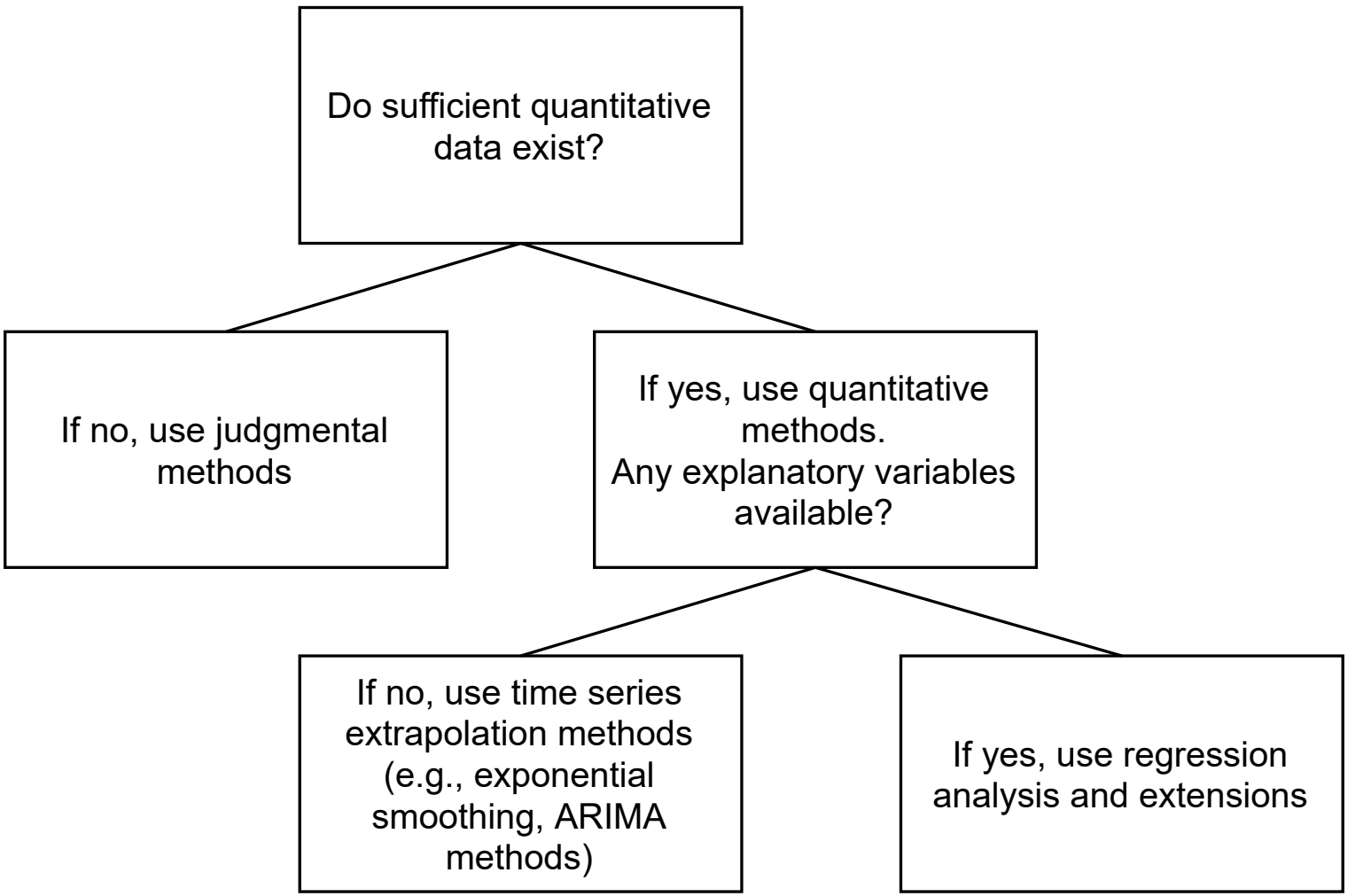
Use only past historical information to identify and capture patterns and extrapolate them into the future

Capture relationships between variables, predict variables first and use a "mechanistic" approach to produce forecasts

Each approach (or their combination) is fitting to different forecasting challenges.

Forecasting methods

A simplified methodology tree for forecasting:



Forecasting Accuracy

Performance Metric:

- Accuracy metric
  - Forecast Error:

$$Error_t = Actual_t - Forecast_t \tag{1}$$

  - Percentage Error:

$$PE_t = 100 \left(\frac{Actual_t - Forecast_t}{Actual_t} \right) \tag{2}$$

- Key Performance Indicator (KPI), e.g., service level (95%) or stock indicators

Error measures

Mean Squared Error

$$MSE = \frac{1}{m}\sum_{j=1}^{m}(Actual_{t+j} - Forecast_{t+j})^2 \tag{3}$$

Penalises larger errors though squared-function.

Mean Absolute Error

$$MAE = \frac{1}{m}\sum_{j=1}^{m}\left|Actual_{t+j} - Forecast_{t+j}\right| \tag{4}$$

Also ignores signs of error but penalises larger errors less strongly than MSE.

Note: FE, PE, MSE and MAE are all **scale-dependent**, meaning that we should not compare accuracy across multiple series, varying in scale.

Error measures

Mean Absolute Percentage Error

$$MAPE = \frac{100}{m}\sum_{j=1}^{m}\left|\frac{Actual_{t+j} - Forecast_{t+j}}{Actual_{t+j}}\right| \tag{5}$$

- Intuitive to explain to practitioners (e.g. "on average the forecast is out by 10%").
- Some organisations use (100% - MAPE) as a measure of "forecast accuracy".
- MAPE is a **scale-independent** measure. So, it may be used for comparisons across multiple series.
- MAPE puts a heavier penalty on negative errors than positive errors (www.robjhyndman.com/hyndsight/smape)

Error measure exercise

Try to calculate the errors for this example:

Week	Actuals	Forecasts	FE	AE	SE	APE (%)
1	17					
2	21	17.00				
3	19	19.00				
4	23	19.00				
5	18	20.00				
6	16	19.60				
7	20	19.00				
8	18	19.14				
9	22	19.00				
10	20	19.33				
11	15	19.40				
12	22	19.00				

Error measure exercise (continued)

Check your calculations:

Week	Actuals	Forecasts	FE	AE	SE	APE (%)
1	17					
2	21	17.00	4.00	4.00	16.00	19.05
3	19	19.00	0.00	0.00	0.00	0.00
4	23	19.00	4.00	4.00	16.00	17.39
5	18	20.00	-2.00	2.00	4.00	11.11
6	16	19.60	-3.60	3.60	12.96	22.50
7	20	19.00	1.00	1.00	1.00	5.00
8	18	19.14	-1.14	1.14	1.30	6.33
9	22	19.00	3.00	3.00	9.00	13.64
10	20	19.33	0.67	0.67	0.45	3.35
11	15	19.40	-4.40	4.40	19.36	29.33
12	22	19.00	3.00	3.00	9.00	13.64

How would you calculate MFE, MAE, MSE and MAPE?

Wrap up

Here we:

- Discussed time-series data;
- Introduced time series analysis and forecasting;

Next time:

- **Forecasting 2**