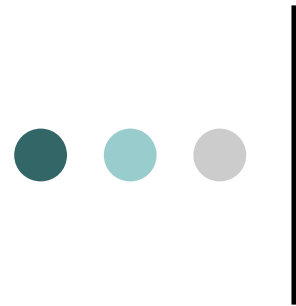




Session 2: Forecasting & Game Theory

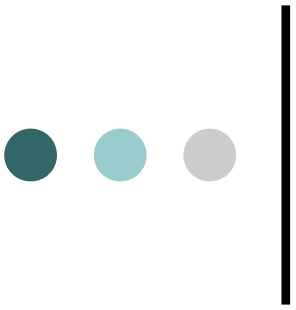


Introduction to Forecasting



Agenda

- Definition & Demand Patterns
- Simple Forecasting Methods
- Forecast Error



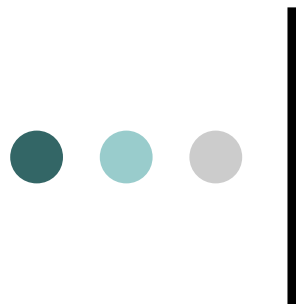
Definition

What is Forecasting?

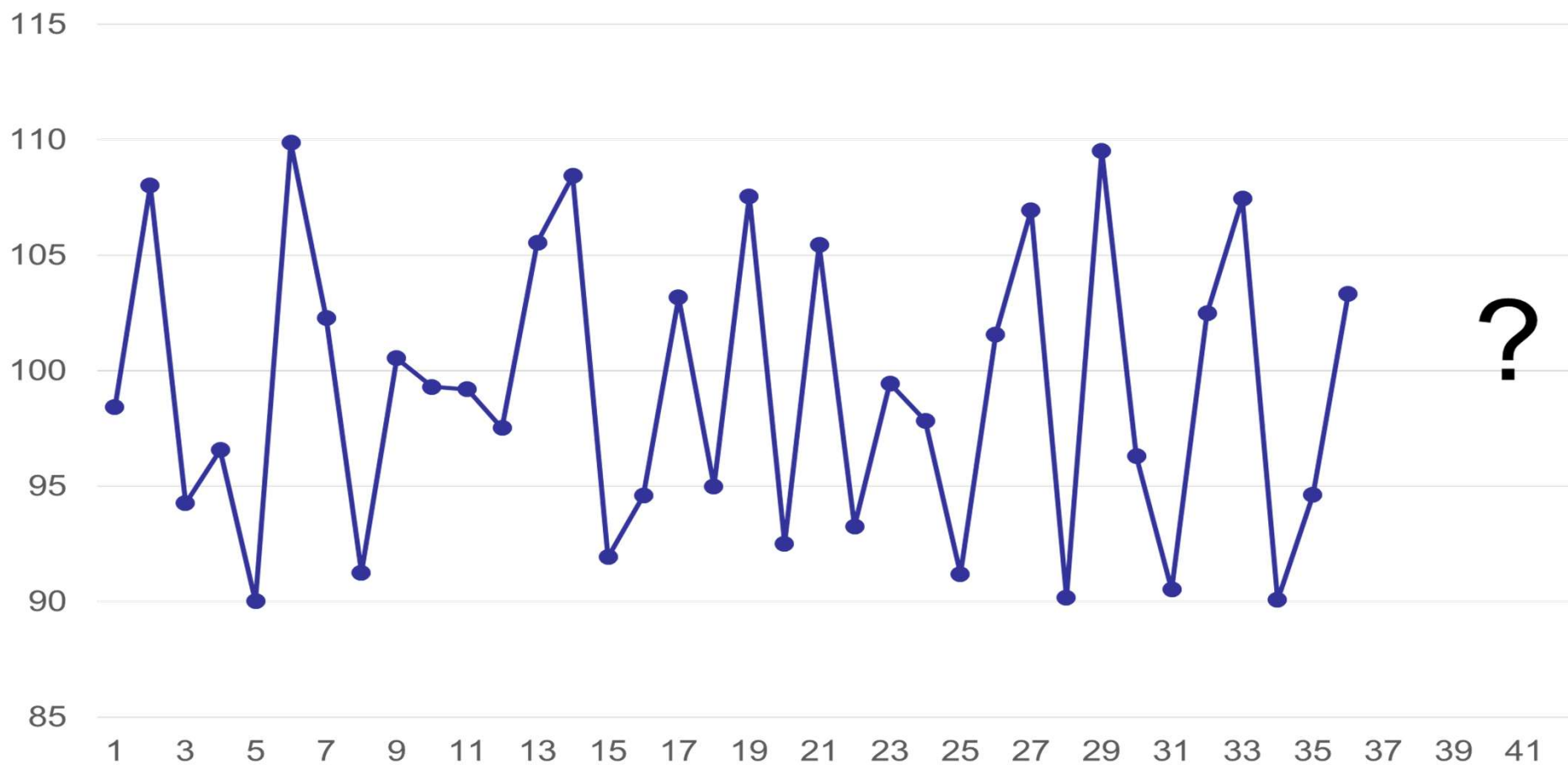
- It is the process of creating statements about outcomes of variables that presently are uncertain and will only be realized in the future

How?

- Mainly based on past and present data and analysis of trends



What is next?



What is next?

Market Summary > Bitcoin

20,684.08 EUR

+ Follow

+471.54 (2.33%) ↑ past 6 months

Mar 13, 12:55 PM UTC · [Disclaimer](#)

1D

5D

1M

6M

YTD

1Y

5Y

Max



What is next?

Market Summary > Bitcoin

61,918.15 EUR

+ Follow

+37,734.91 (156.04%) ↑ past 6 months

Mar 8, 12:04 PM UTC · [Disclaimer](#)

1D

5D

1M

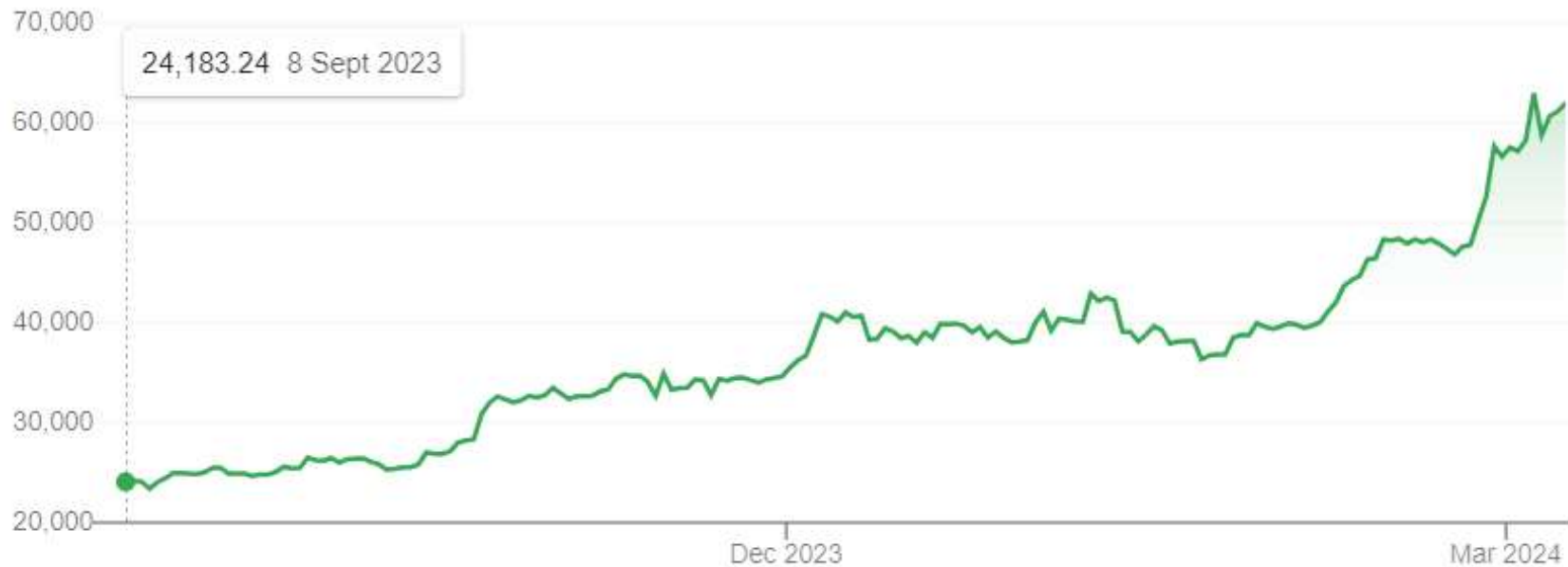
6M

YTD

1Y

5Y

Max



What is next?

Market Summary > Bitcoin

92,868.47 EUR

+36,213.14 (63.92%) ↑ past year

+ Follow

May 13, 1:51 PM UTC · [Disclaimer](#)

1D | 5D | 1M | 6M | YTD | 1Y | 5Y | Max



What is next?

Market Summary > Bitcoin

53,521.79 EUR

-42,259.10 (44.12%) ↓ past year

Jun 10, 2:40 PM UTC · [Disclaimer](#)



+ Follow

1D

5D

1M

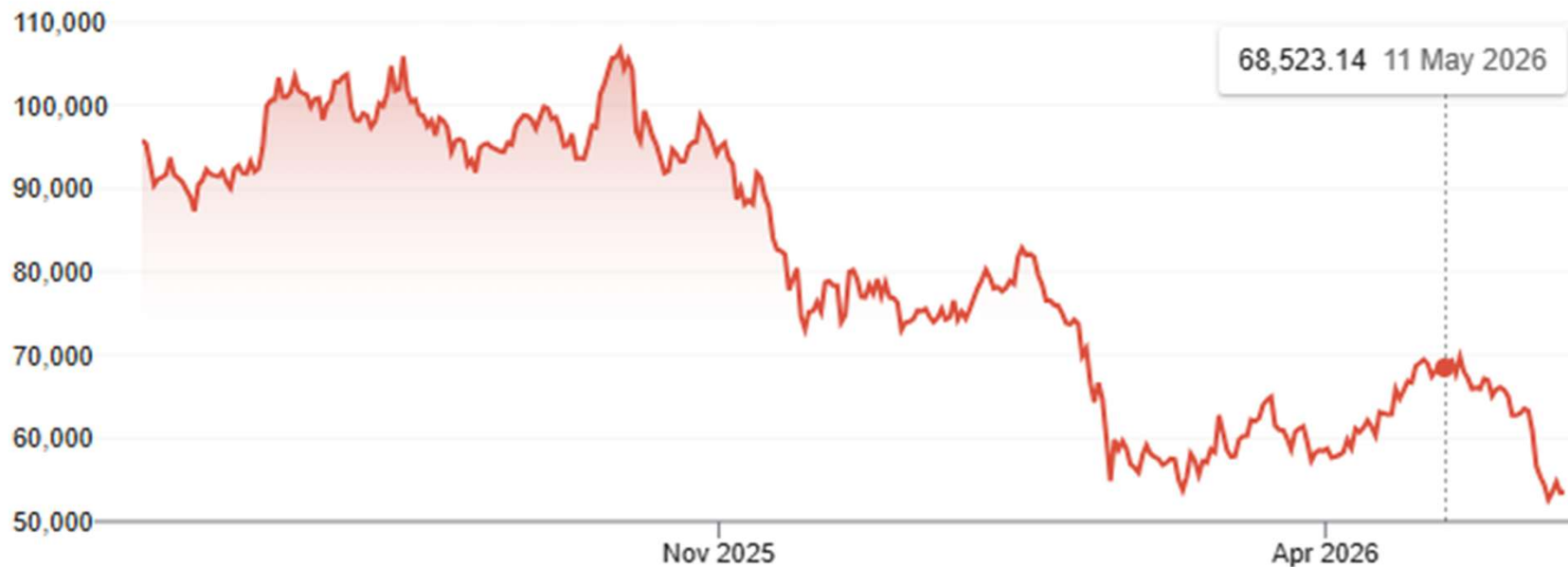
6M

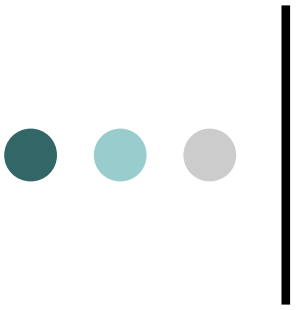
YTD

1Y

5Y

Max





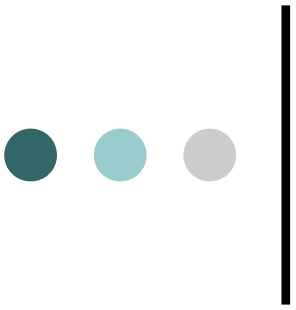
Definition

Advantages

- Reduce uncertainty and anticipate change(s) in the market

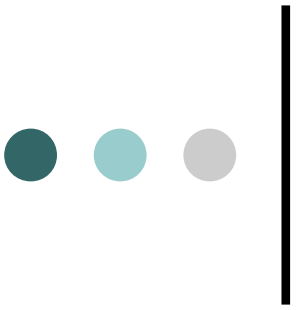
Disadvantages

- No one can be absolutely sure what the future holds
- *Silent assumption*: the future will be like the past; there is no room for human intelligence



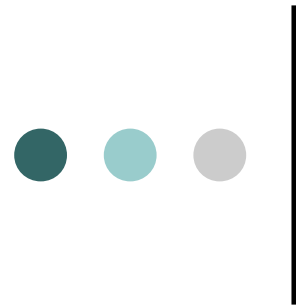
Example #1

- Thomas Watson (CEO of IBM), forecasted the demand for computers.
- He predicted that the world market demand for computers would be 5. Yes, you read correctly, not 5 million, just 5 computers. In his defense, he made this forecast in the 1950s.



Example #2

- In the 1960s, the managers at Decca Recording were offered the opportunity to publish the music of a Liverpool guitar band. Decca's forecast for sales of this band was pessimistic "guitar groups are on the way out" was the management consensus.
- Unfortunately for Decca, the band that they rejected was *the Beatles*, a band that subsequently went on to become one of the most successful music bands in history.

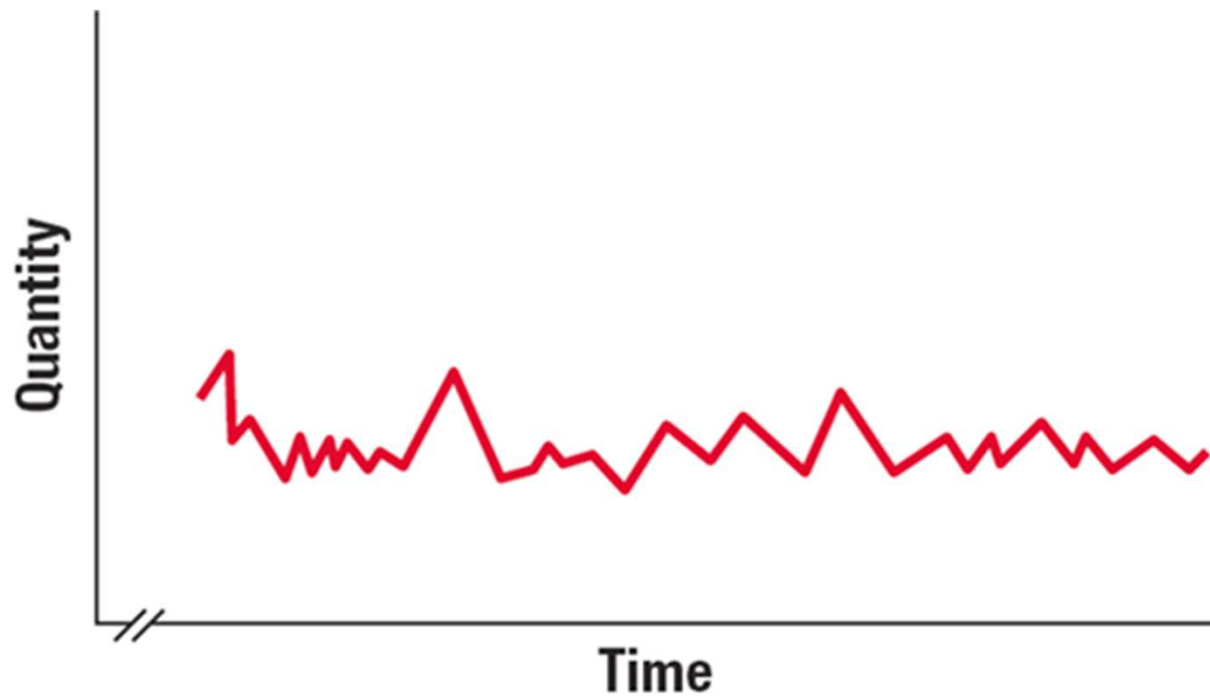


Patterns

- **Time series**
 - The repeated observations of data points in their order of occurrence (time order)
- **There are five basic time series patterns**
 1. Horizontal
 2. Trend
 3. Seasonal
 4. Cyclical
 5. Random

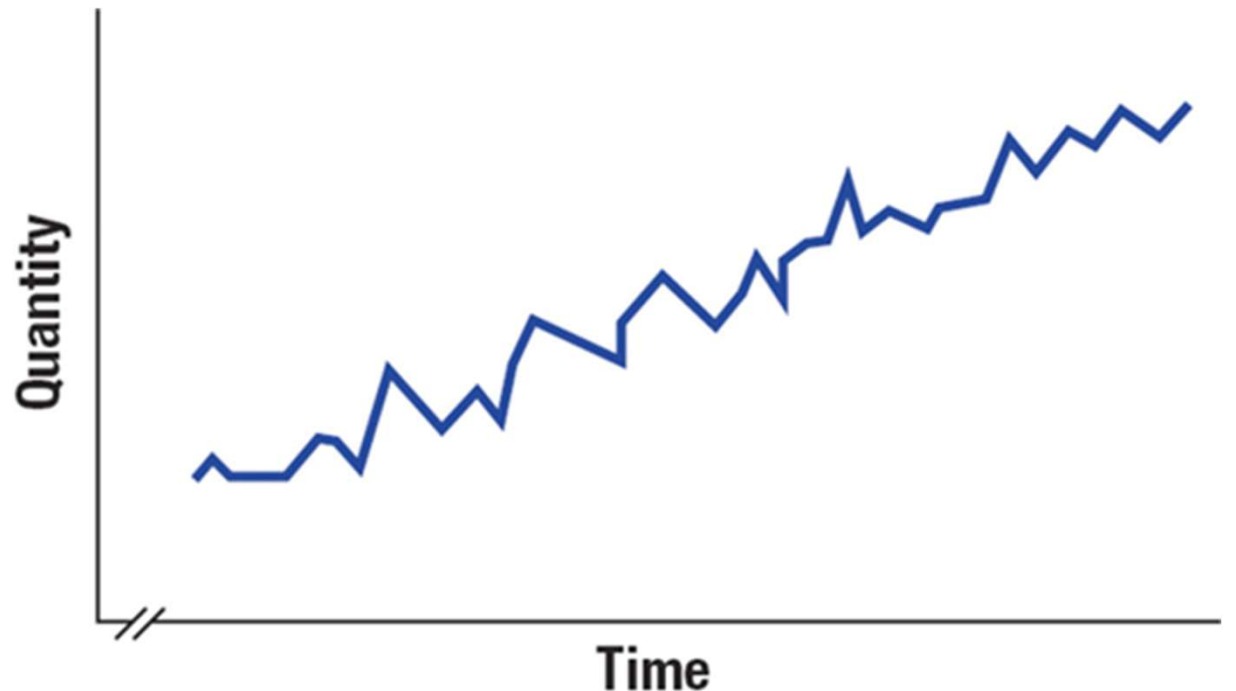
1. Horizontal

A horizontal pattern exists when data values fluctuate around a constant mean



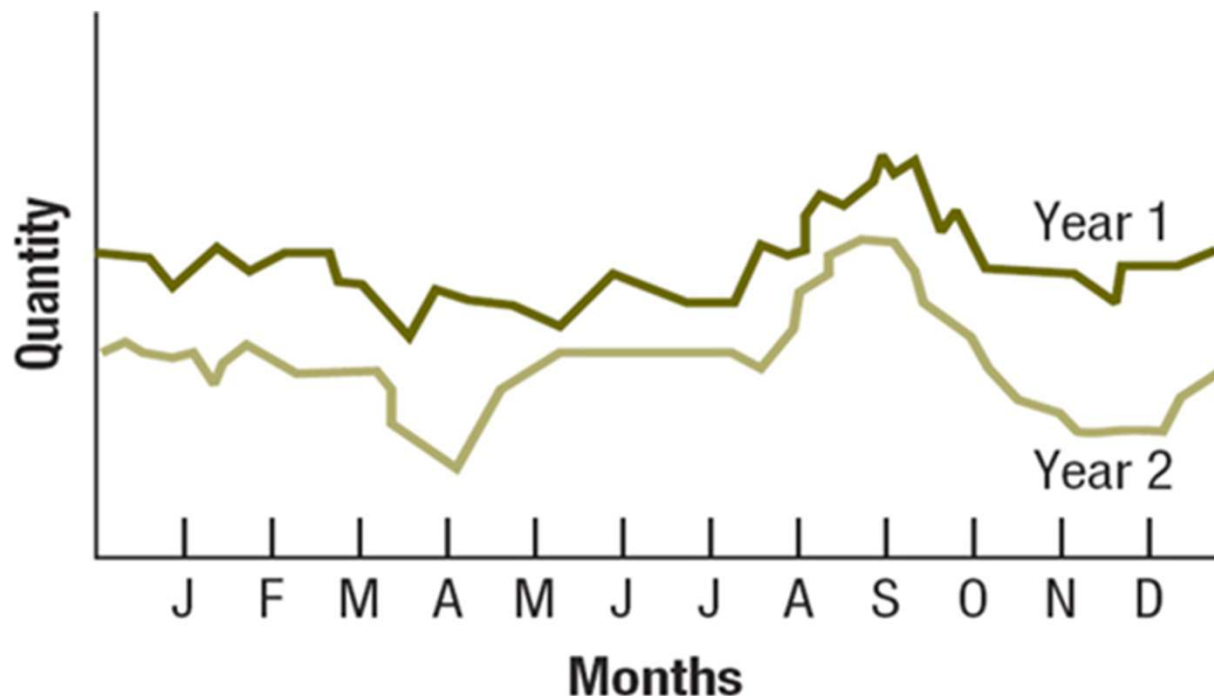
2. Trend

A trend exists when there is a long-term increase or decrease in the data. It does not have to be linear. Sometimes we will refer to a trend “changing direction” when it might go from an increasing trend to a decreasing trend



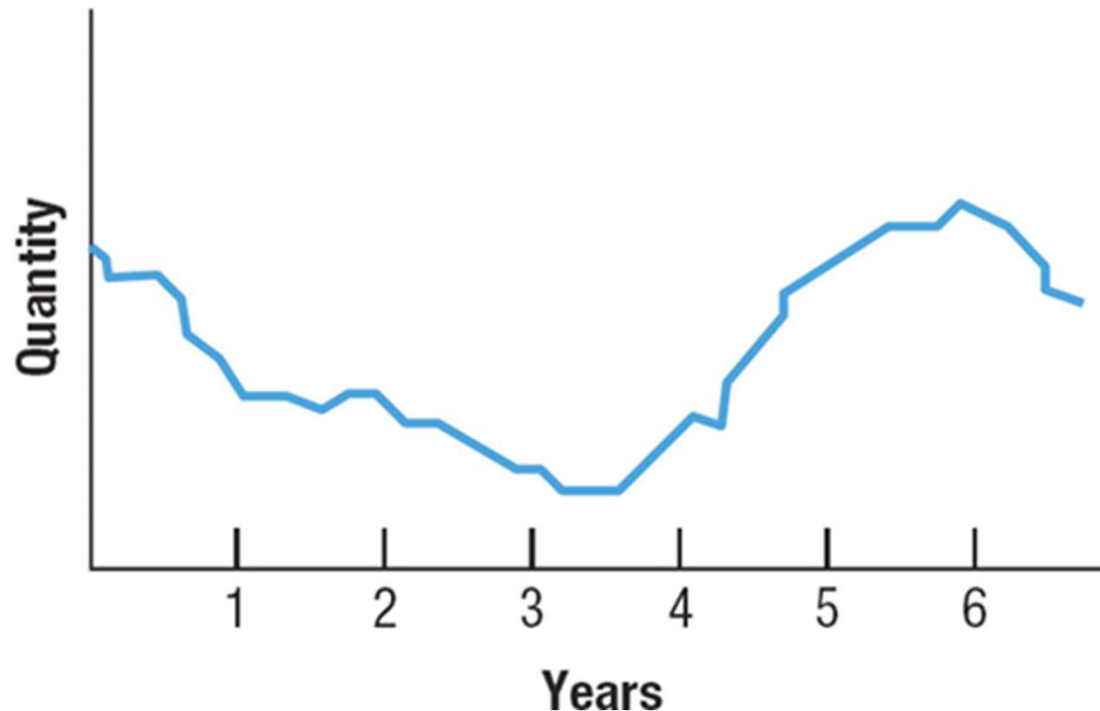
3. Seasonal

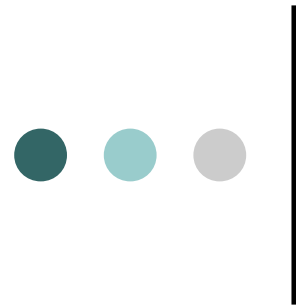
A seasonal pattern exists when a series is influenced by seasonal factors (e.g., the quarter of the year, the month, or day of the week). Seasonality is always of a fixed and known period



4. Cyclical

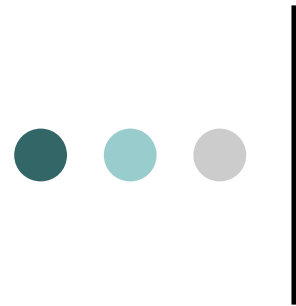
A cyclic pattern exists when data exhibit rises and falls that are not of fixed period. The duration of these fluctuations is usually of at least 2 years





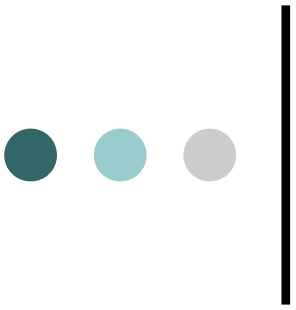
5. Random

No specific pattern can be identified



Forecasting Methods

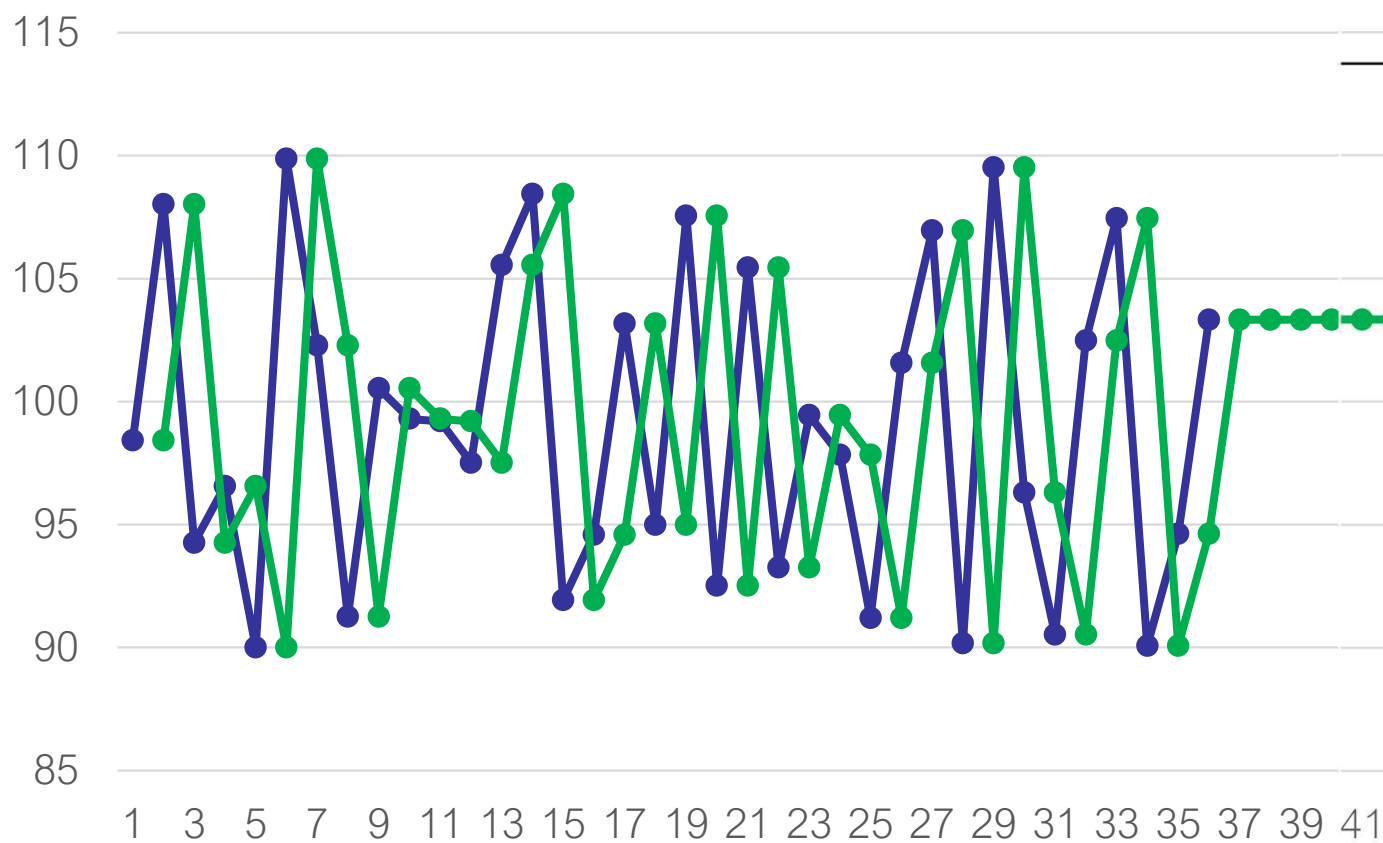
- Naïve method
- Global Average method
- Moving Average method
- Weighted Moving Average method



Naïve Method

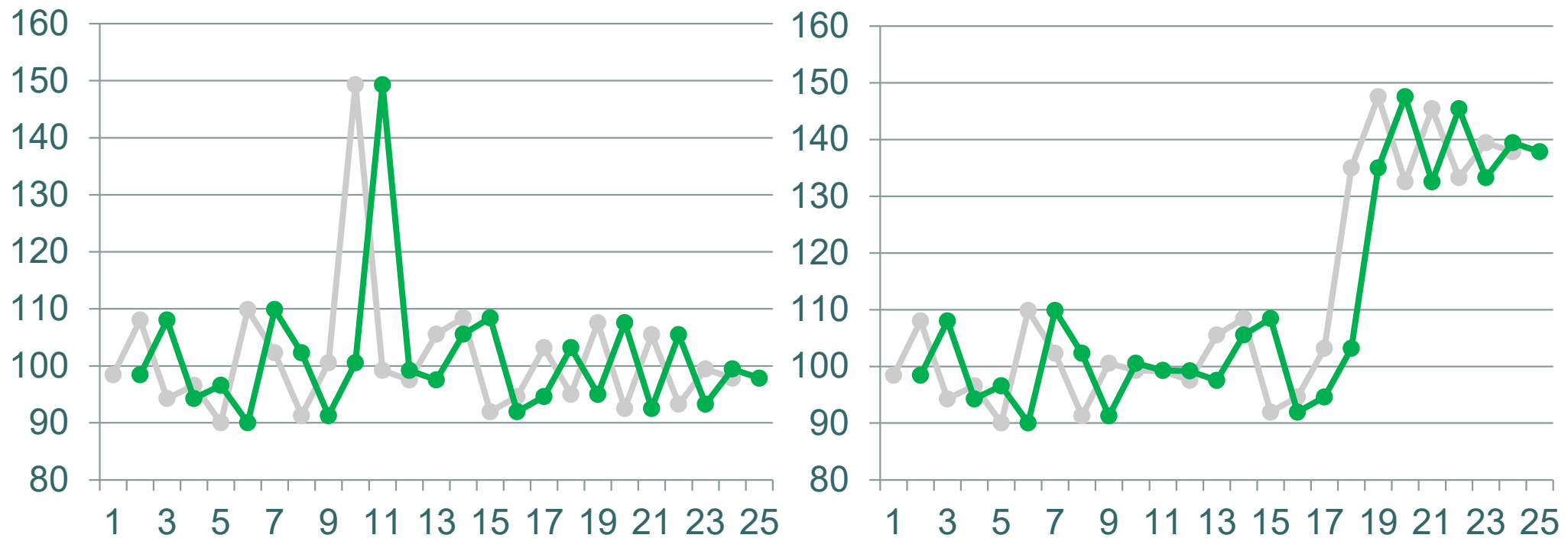
- The forecast for the next period equals the demand for the current period $\hat{y}_{t+1} = y_t$
- Comments:
 - Only the very last observation is considered
 - No smoothing or averaging is performed
 - Shortest memory possible

Naïve Method



$$\hat{y}_{t+h} = y_t$$

Naïve Method: pros and cons

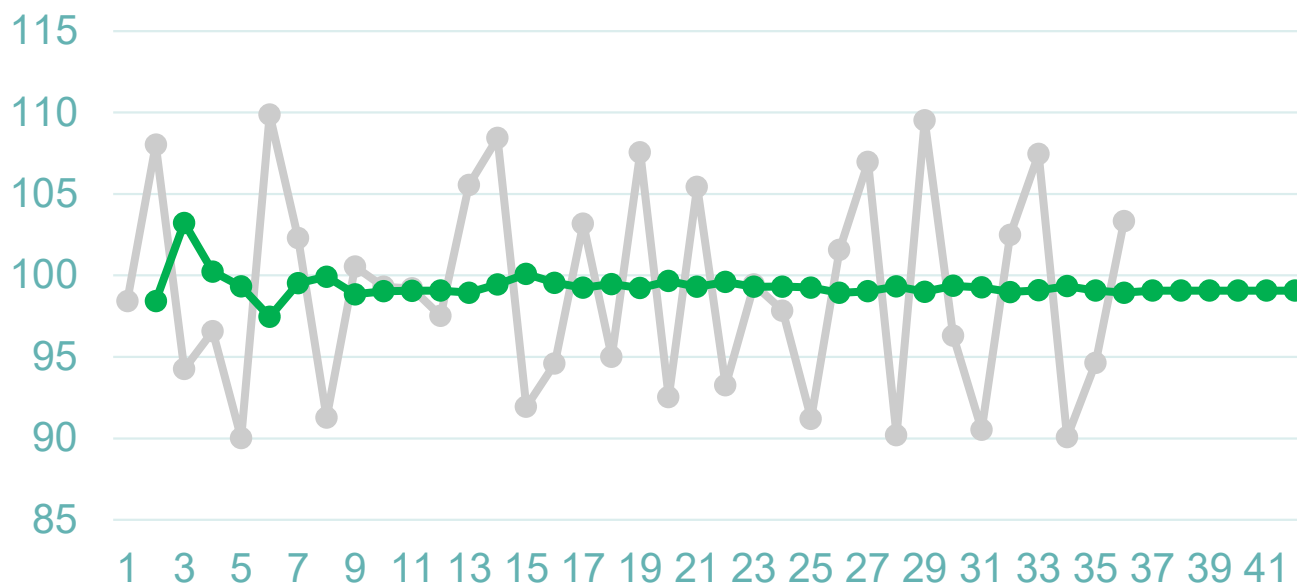


- Outliers are copied forward
- No smoothing
- Fast reaction to level changes

Global Average Method

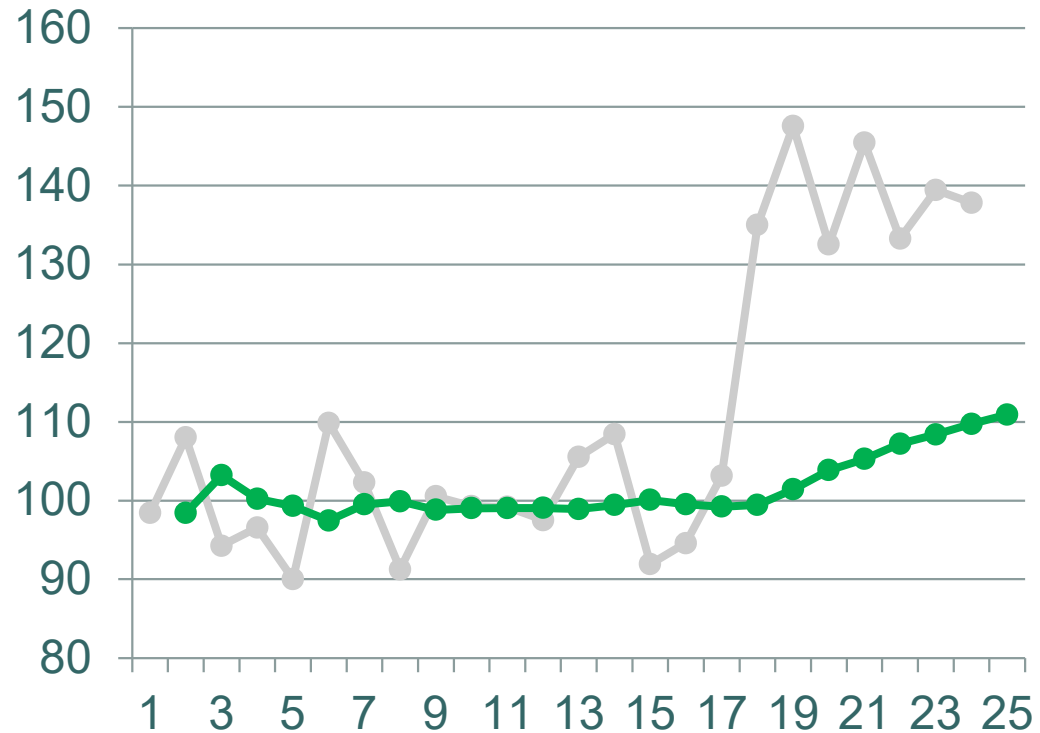
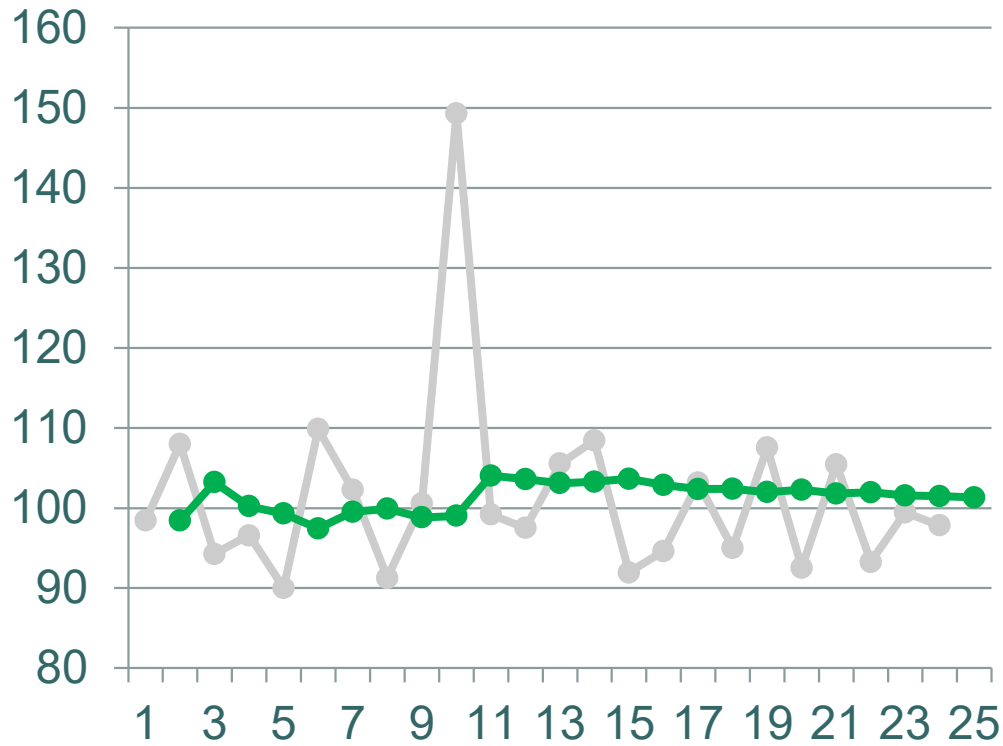
- No parameters, all values contribute equally
- The forecast is set as the mean of the observed sample
- Longest memory possible

$$\hat{y}_{t+h} = \frac{1}{n} \sum_{i=1}^n y_i = \bar{y}$$

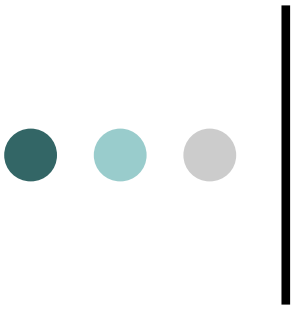


t	Y	Average
1	98.43	99.06
2	108.02	
3	94.26	
4	96.56	
...	...	...
34	90.07	99.34
35	94.62	99.07
36	103.33	98.94
37		99.06
38		99.06
39		99.06 ²³

Global Average Method: pros and cons



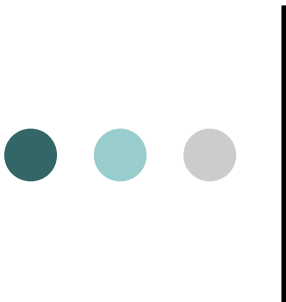
- Outliers are smoothed out
- Slow reaction to level changes



Moving Average Method

- Moving average: one parameter (k)
- The forecast is set as the average of the k-most-recent observations
- The value of k corresponds to the degree of smoothing and the length of the memory
- Selecting an appropriate value for k renders the model robust against outliers (high k values) or level changes (low k values)

$$\hat{y}_{t+h} = \frac{1}{k} \sum_{i=0}^{k-1} y_{t-i}$$



Moving Average Method: Examples

t	Y	MA(3)	MA(7)
1	98.43		
2	108.02		
3	94.26		
4	96.56	100.23	
5	90.01	99.61	
6	109.87	93.61	
7	102.29	98.81	
8	91.26	100.72	99.92
9	100.54	101.14	98.90
10	99.31	98.03	97.83
...	...	...	...
34	90.07	100.15	100.49
35	94.62	100.00	98.08
36	103.33	97.38	98.71
37		96.01	97.83
38		96.01	97.83
39		96.01	97.83

MA(3):

$$\hat{y}_4 = \frac{1}{3}(y_1 + y_2 + y_3)$$

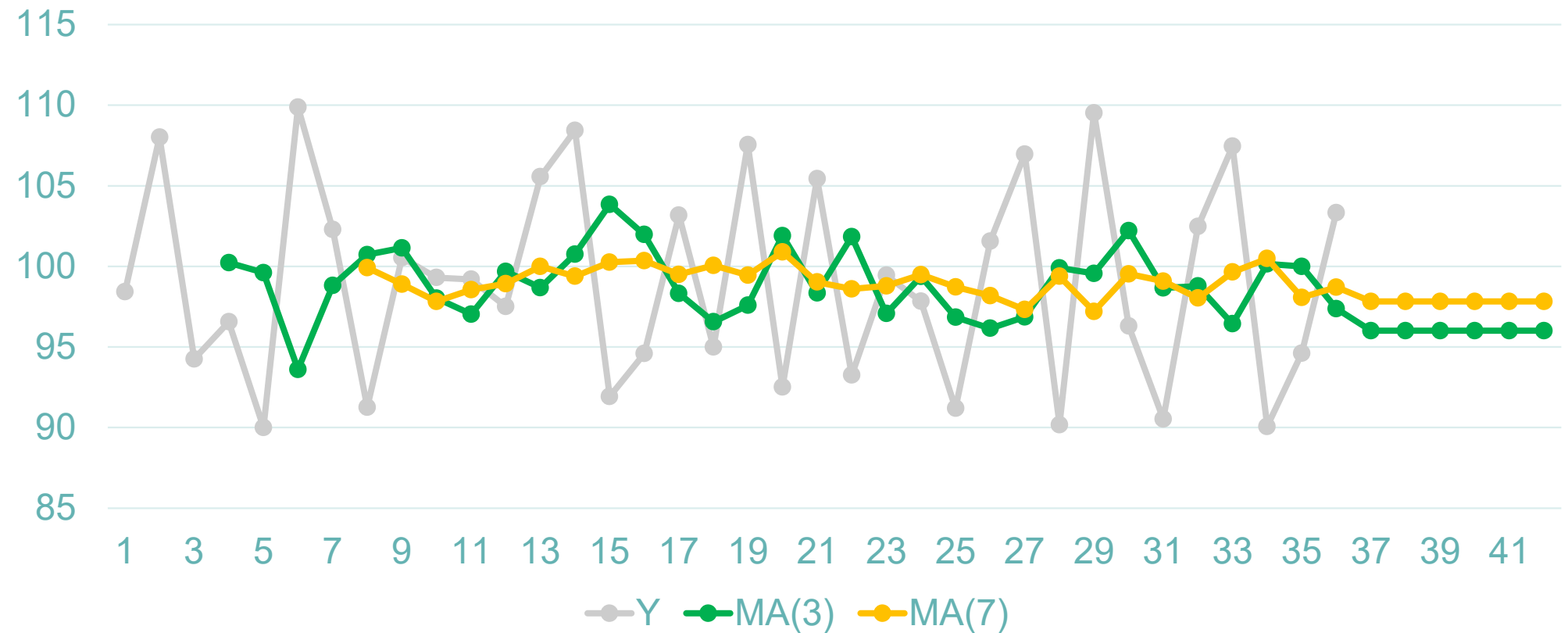
$$\hat{y}_{36} = \frac{1}{3}(y_{33} + y_{34} + y_{35})$$

MA(7):

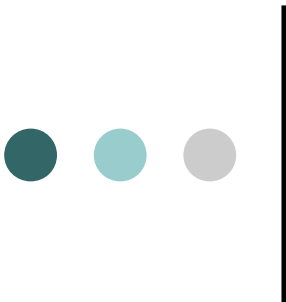
$$\hat{y}_8 = \frac{1}{7}(y_1 + y_2 + \dots + y_7)$$

$$\hat{y}_{36} = \frac{1}{7}(y_{29} + y_{30} + \dots + y_{35})$$

Moving Average Method: Examples



- What is the best value for k ?
- Does it make sense to give equal weight to all k recent observations?

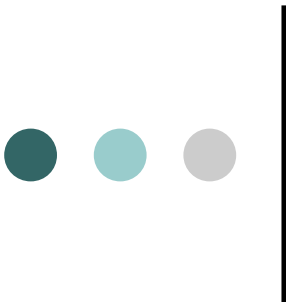


Moving Average Method: Examples

- Compute a three-week moving average forecast for the number of arrivals at Piraeus port in week 4. The numbers of arrivals for the past three weeks were as follows:

Week	Arrivals
1	400
2	380
3	411

- If the actual number of arrivals in week 4 is 415, what is the forecast error for week 4?
- What is the forecast for week 5?



Moving Average Method: Examples

The moving average forecast at the end of week 3 is:

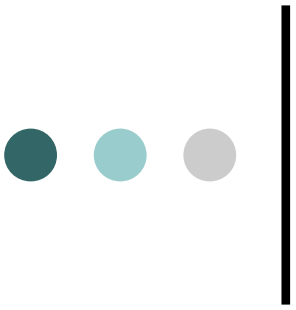
$$\hat{y}_4 = \frac{1}{3}(y_1 + y_2 + y_3) = \frac{1}{3}(400 + 380 + 411) = 397$$

The forecast error for week 4 is:

$$y_4 - \hat{y}_4 = 415 - 397 = 18$$

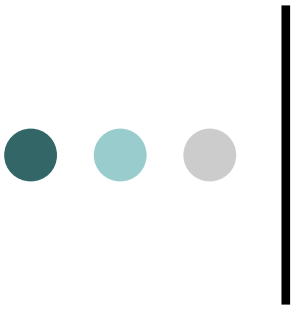
The forecast for week 5 requires the actual arrivals from weeks 2 through 4, the three most recent weeks of data

$$\hat{y}_5 = \frac{1}{3}(y_2 + y_3 + y_4) = \frac{1}{3}(380 + 411 + 415) = 402$$



Weighted Moving Average Method

- In the weighted moving average method, each historical data point in the average can have its **own weight**, provided that the sum of the weights equals one
- The average is obtained by multiplying the weight of each period by the actual data point for that period, and then adding the products together

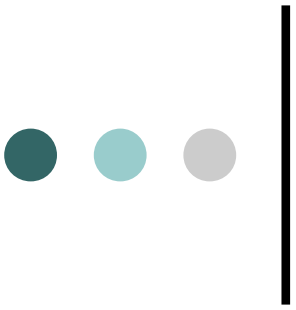


Forecasts

- There are four forecasts:

	#1	#2	#3	#4
Week 1	70	50	29	43
Week 2	55	32	52	44
Week 3	40	48	62	54
Week 4	80	60	47	49

- Which forecast is the best one?
- This cannot be answered **before** you observe the true data



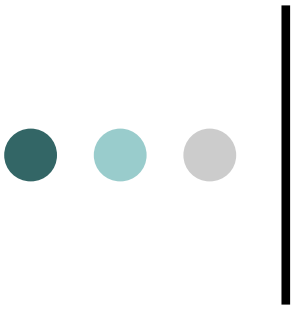
Forecast Error

- We define the **forecast error (FE)** for period t as the difference between the forecast for period t and the actual value for period t:

FE at t = Actual value at t – Forecasted value at t

	#1	#2	#3	#4	Actual
Week 1	70	50	29	43	38
Week 2	55	32	52	44	49
Week 3	40	48	62	54	59
Week 4	80	60	47	49	44

- Calculate the forecast error (FE) for #1 and #2



Forecast Error Calculations

- The FE for #1 is:

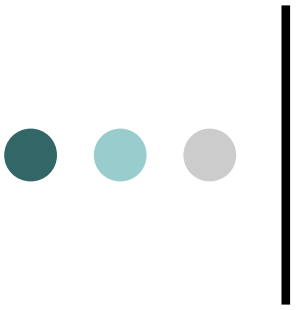
Week 1: $38 - 70 = -32$

Week 2: $49 - 55 = -6$

Week 3: $59 - 40 = 19$

Week 4: $44 - 80 = -36$

	#1	True	Error
Week 1	70	38	-32
Week 2	55	49	-6
Week 3	40	59	19
Week 4	80	44	-36



Cumulative Forecast Error

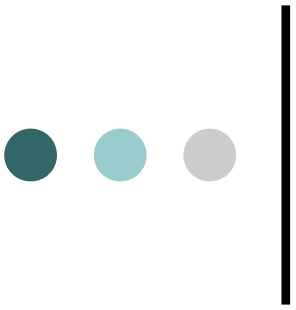
- The *Cumulative Forecast Error (CFE)* takes the sum of the forecast errors

$$CFE = \sum_{t=1}^N FE_t$$

- Then, we can calculate the *Average Forecast Error* as:

$$\frac{CFE}{N}$$

where N is the number of observations



Forecast Error Calculations

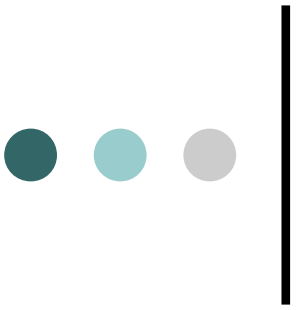
- The Cumulative Sum of Forecast Error (CFE) for #1 is:

$$\text{CFE} = (-32) + (-6) + 19 + (-36) = -55$$

$$\text{Average FE} = -55/4 = -13.75$$

	Error
Week 1	-32
Week 2	-6
Week 3	19
Week 4	-36

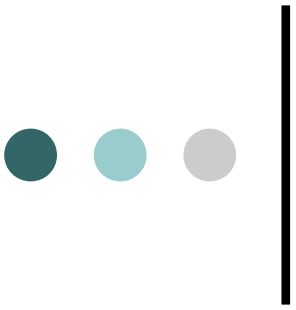
- What can we comment on the (average) forecast error?
- The FE for #2 is: -12, 17, 11, -16; i.e., the average forecast error for #2 equals with 0
- What can we comment on the #2?



Quality of a Forecast

- A first way to measure the quality of a forecast is to see if it is right, on average; i.e., having the average forecast error be 0
- **Calculate** the average forecast error for #3
- The average forecast error for #3 = 0
- Which forecast is the best one and why?
- Both are right, on average. Does this mean that they are equally good at forecasting?

	#3	True
Week 1	29	38
Week 2	52	49
Week 3	62	59
Week 4	47	44

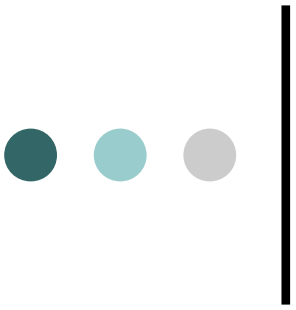


Mean Squared Error

- The ***Mean Squared Error (MSE)*** takes the average of the squared forecast errors

$$MSE = \frac{\sum_{t=1}^N FE_t^2}{N}$$

- The idea behind this is to first square the errors and then average them. A negative forecast error and a positive forecast error combined will no longer cancel each other out

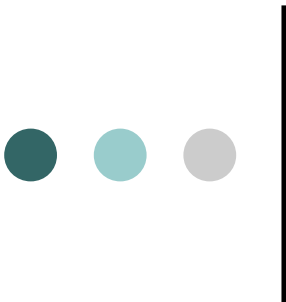


Mean Absolute Error

- An easier way is just to simply take the absolute values of the forecast errors and average those out
- We define the **Mean Absolute Error (MAE)** as the average of the absolute values of the forecast errors

$$MAE = \frac{\sum_{t=1}^N |FE_t|}{N}$$

- This is also referred to as the **Mean Absolute Deviation (MAD)**

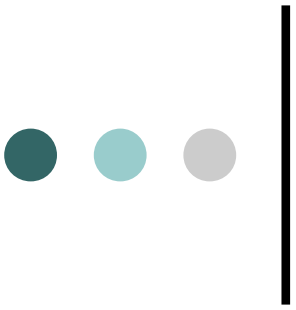


Mean Absolute Percentage Error

- The **Mean Absolute Percentage Error (MAPE)** is achieved by dividing the forecast errors by the actual value y_t

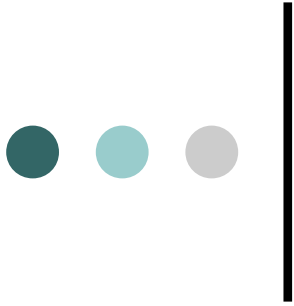
$$MAPE = \frac{\sum_{t=1}^N \left| \frac{FE_t}{y_t} \right| * 100}{N}$$

- This measure does not look at the forecast errors in absolute terms, but in relative terms



Key Takeaways

- Which measure of forecast quality you use is up to you
- Be careful when you report the forecast error and when you receive the forecast error
- Keep data from your old forecasts and assess the quality of those

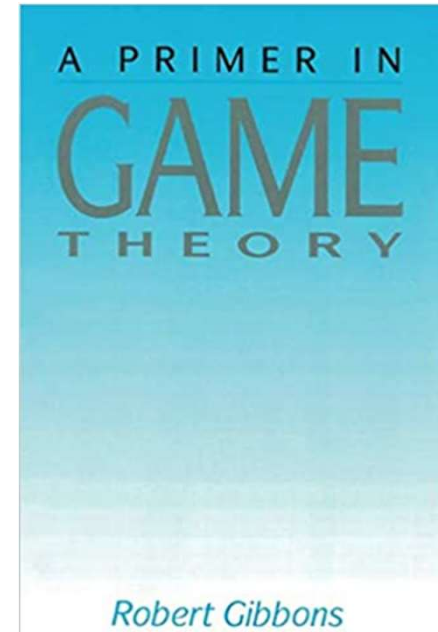




Game Theory

Agenda

- Game Theory
- Nash equilibrium
- Public Goods Game



R. Gibbons. A Primer in Game Theory
Paperback. Harlow:
Prentice Hall, 1992

Video

Game Theory Explained in One Minute

<https://www.youtube.com/watch?v=YueJukoFBMU>



Movie: A Beautiful Mind

Classification of Problems

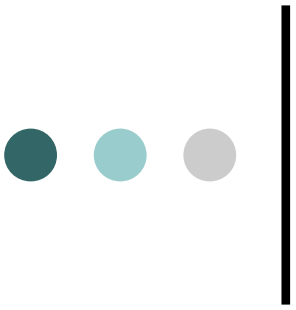
	A single decision maker	More than two decision makers
Deterministic	Optimisation	Game Theory
Stochastic	Decision Analysis	



Deterministic

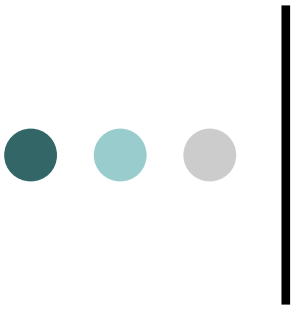


Stochastic



Many Decision Makers

- Game Theory: is the study of multiperson decision problems (Gibbons 1992)
- Eleven game-theorists have now won the economics Nobel Prize (2014, Jean Tirole)
- Categories:
 - Cooperative / Non-Cooperative games
 - Complete / Incomplete information
 - Time order: Simultaneous / Sequential
- Main Elements: Players, Strategies, Payoffs



Solution Concept

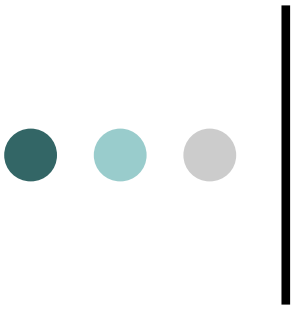
- In Game Theory, it is used the term *solution concept*
- Non-Cooperative games: Nash equilibrium
- Cooperative games: Core, Shapley value
- Nash equilibrium: If each player has chosen a strategy and no player can benefit by changing strategies while the other players keep theirs unchanged
- Rational players

Prisoner's Dilemma



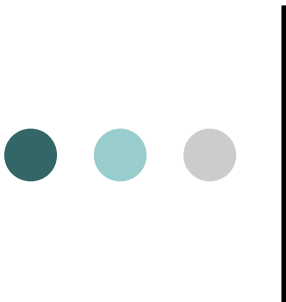
A FEW
MOMENTS LATER





Prisoner's Dilemma

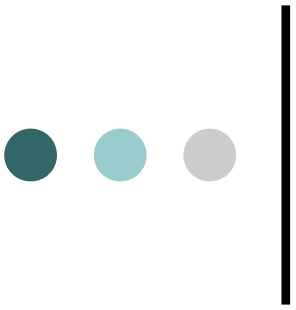
- Two friends had robbed a bank. The Police has arrested them for speeding without having not enough evidence to arrest them for the robbery
- In both friends are offered a deal by the Police and they have to decide what to do independently
- The deal is:
 - If both deny the robbery, they will be in prison for 1 year each
 - If both confess the robbery, they will be in prison for 6 years
 - If one confesses the robbery, then this guy will be free while the other will be in prison for 9 years



Prisoner's Dilemma: Main Elements

- Players: P1, P2
- Strategies: Deny, Confess
- Payoffs: a pair (x, y)

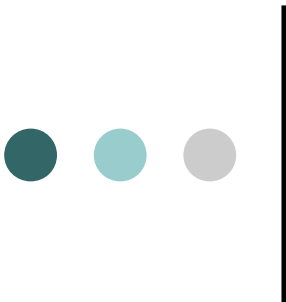
P1 \ P2	Deny	Confess
	Deny	Confess
Deny	(1,1)	(9,0)
Confess	(0,9)	(6,6)



Nash equilibrium

- Is Deny vs Deny (1,1) Nash equilibrium?
- Given that P2 remains on 'Deny'

P1 \ P2	Deny	Confess
	Deny	Confess
Deny	(1,1)	(9,0)
Confess	(0,9)	(6,6)



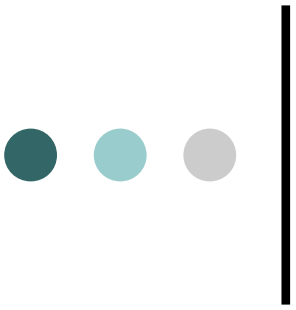
Banned Cigarette Advertisements

- On April 1, 1970, President Richard Nixon signed legislation officially banning cigarette ads on television and radio
- The ban took effect at midnight on Jan. 2, 1971
- What will be the impact of restriction rate in profitability of tobacco companies?
- All four major tobacco companies registered higher profits than before

Food for Thought

- Magic box that doubles the money
- Two players
- \$20 each
- How much should I put in the box?





Public Goods Game

- Four players (with the “same power”)
- Simultaneous game
- Box doubles the token/money
- “Public good” payoff is evenly divided among players
- Each subject also keeps the money they do not contribute
- Players are rational (i.e., to max their token/money)

How much should I put in the box?

