Lancaster University
Management School

Introduction to Operations Management

Lecture_ Forecasting

Slack and Brandon Jones (10th Ed) – pp. 358-368

Anas Iftikhar

Forecasting demand

Content

- Reasons to forecast
- Qualitative techniques
- Moving averages – Quantitative
- Seasonal adjustments – Quantitative
- Exponential smoothing – Quantitative
- Measuring error

Slack *et al*, pp. 358-368

Forecasting

- In wars, armies predict the number of enemies of the opponents.
- *"Art & Science of predicting future events for planning purposes" (Heizer & Render)*
- Can be subjective or objective
- Can use historical data and mathematical modeling

Used to:

- Determine resources needed, schedule existing resources & acquire additional resources
- Anticipate changes in prices/costs
- Prepare for new laws/regulations, competitors, and resource shortages

Reasons to forecast

- A purely reactive process is usually infeasible
  - Capacity cannot be modified instantaneously
    - Facilities take time to build
    - Equipment takes time to acquire
    - People take time to recruit & train
  - Forecasts are the basis for nearly all planning decisions in a supply chain.
  - Failure to meet demand or use capacity can be punitive
    - Loss of goodwill/future customers
    - Social unacceptability in vital services
    - Cost of funding unused capacity

Can you think of a mobile company that failed due to poor forecasting?

How to forecast?

Qualitative approaches

- Incorporates intuition, emotion, personal experiences, & value systems
- Human judgment based on heuristics (‘rules of thumb’)
- Used when adequate historical data is lacking
- Relies on managerial judgment/experience
- Can be used to modify forecasts generated by quantitative methods

How to forecast?

Qualitative approaches

- *Jury of executive opinion*
    - Pool opinions of high-level experts, sometimes augmented by statistical models.
    - Experts estimate demand by working together
    - 'Group think' disadvantage
- *Delphi method*
    - Panel of experts, queried iteratively, continues until consensus is reached.
    - 3 types of participants; decision-makers, staff, and respondents (experts).
    - Pharmaceutical firm can use doctors, researchers and industry experts.

How to forecast?

Qualitative approaches

- *Sales force composite*
    - Estimates from individual salespersons are reviewed for reasonableness, then aggregated.
    - Each salesperson projects his or her sales
    - Combined at district and national levels
    - Sales reps know customers' wants

How to forecast?

Why forecast *analytically*?

Problems of social context

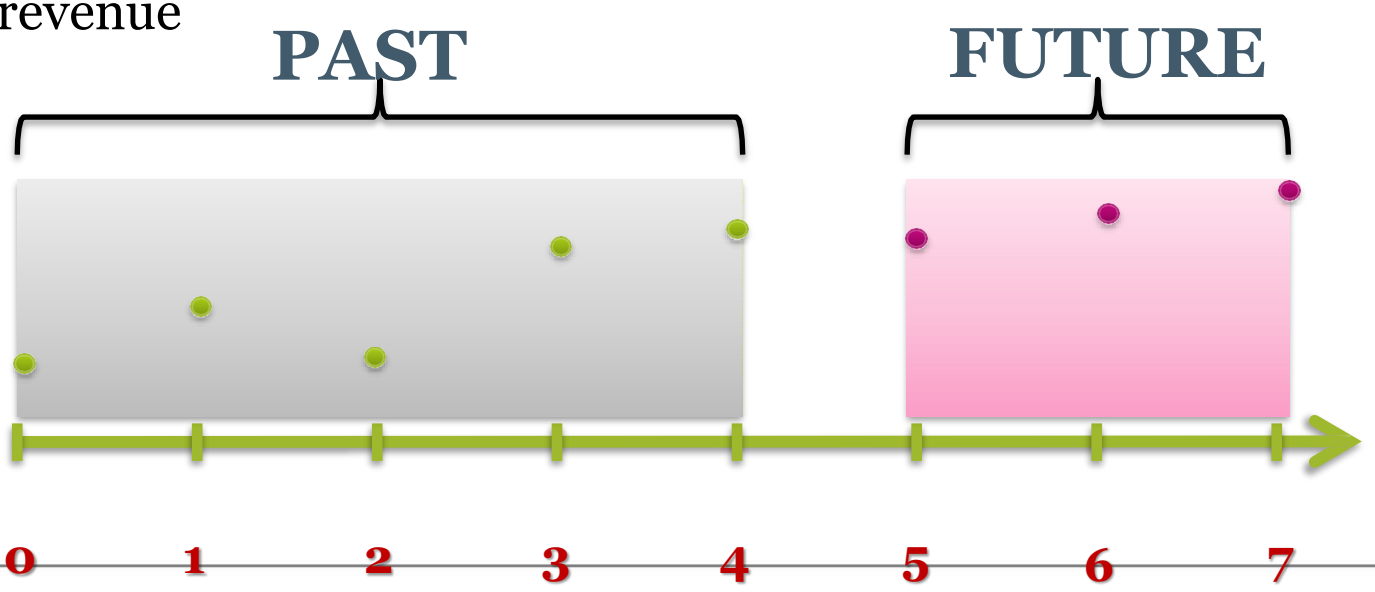
- Forecasts are not made in a social vacuum
- Groupthink & censorship: avoiding dissenting opinion

- So objective, quantitative approaches become important
- Used when the situation is ‘stable’ and historical data exist
- Involves mathematical techniques

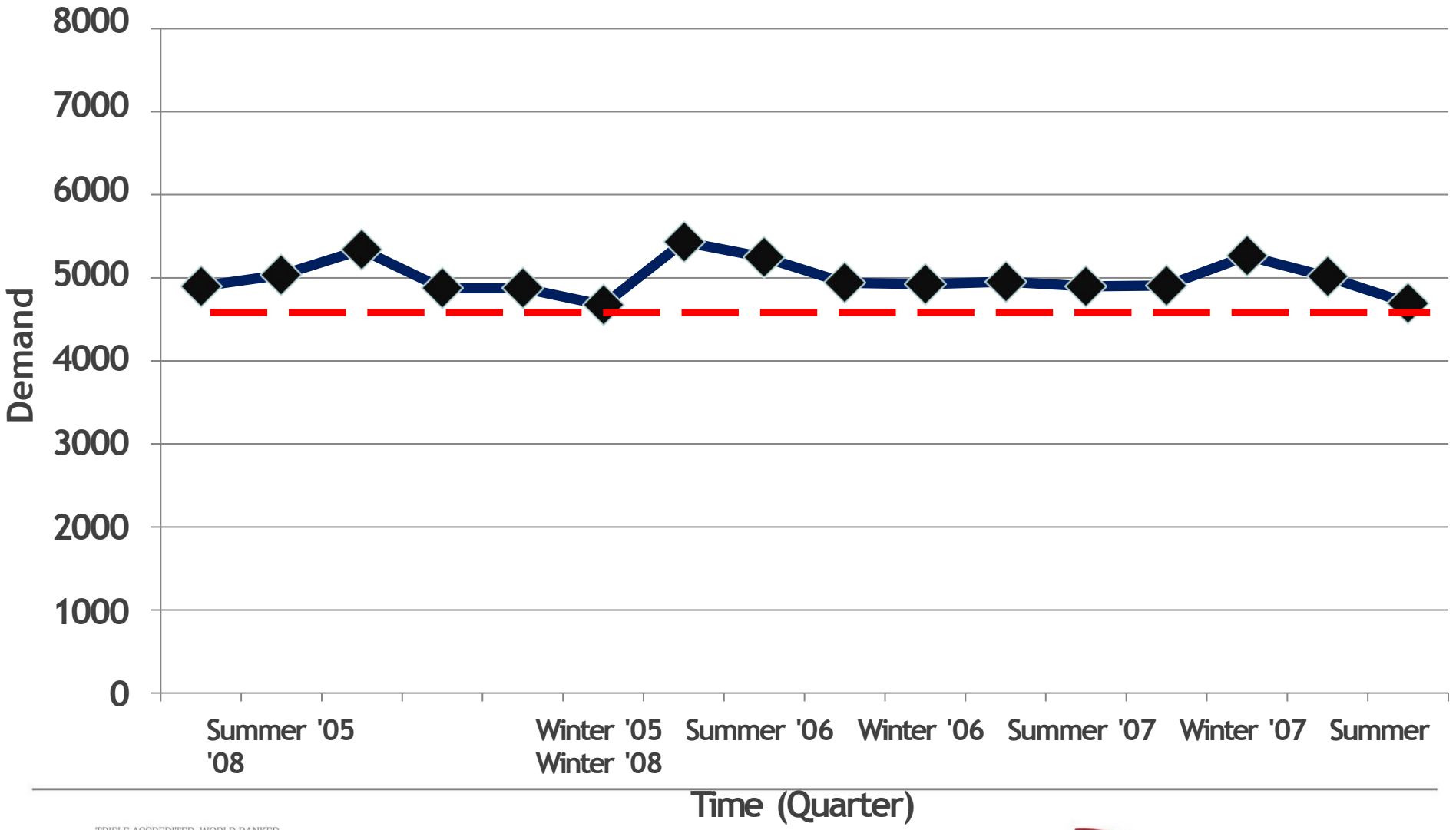
Time-Series Methods

- A time series is where the value of the same variable is recorded at regular time intervals.

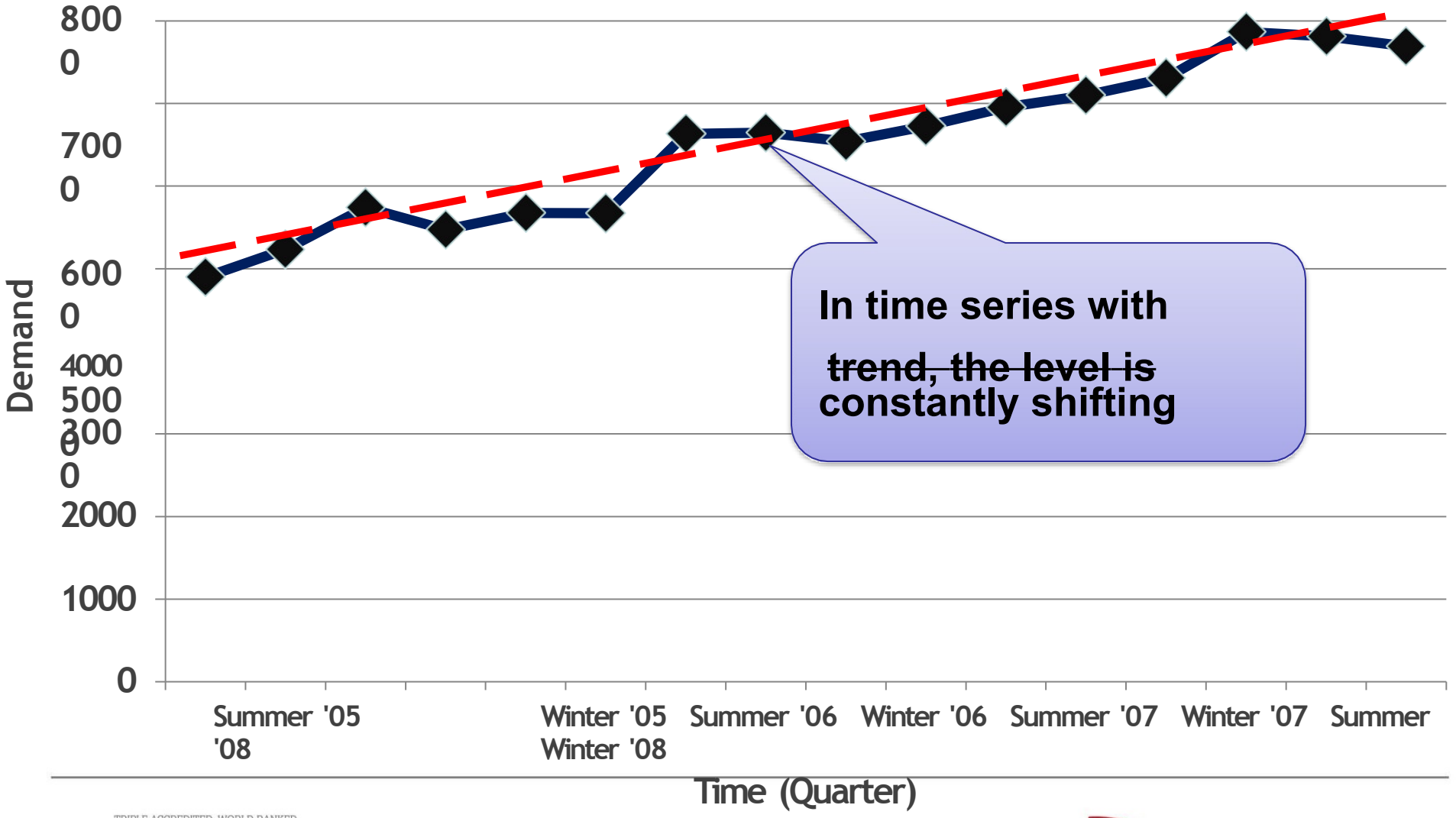
- Examples:
  - Daily stock price
  - Monthly customer demand
  - Annual revenue



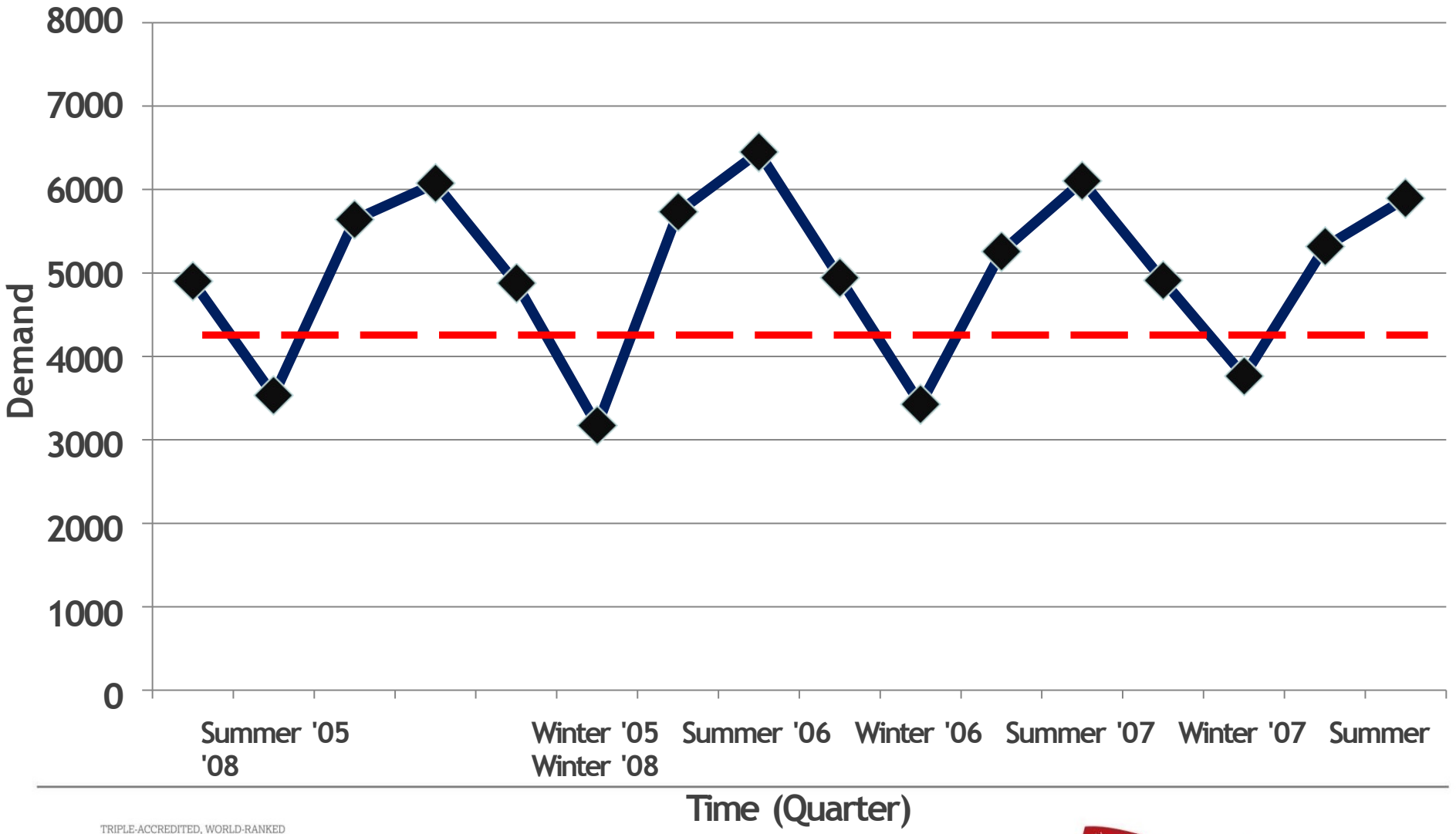
Time Series with No Trend or Seasonality



Time Series with Trend but No Seasonality



Time Series with Seasonality but No Trend



Time series and forecasts

What will the following year's demand be?

Student numbers on MSCI 000	Year
2014-15	198
2015-16	212
2016-17	219
2017-18	295
2018-19	273
2019-20	292
2020-21	328
2021-22	263
2022-23	316
2023-24	303
2024-25	312

Time series and forecasts

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Could look at just the most recent = 312
…but maybe this was influenced by a freak event

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Could look at all past values available
e.g. using past mean = (312 + 303 + … + 198)/11 = 273.7
…but why should the older values be relevant?

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More plausibly look only at recent values
E.g. mean of most recent 3 values =
(312 + 303 + 316) / 3 = 310

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More plausibly look only at recent values
E.g. mean of most recent 3 values =
(312 + 303 + 316) / 3 = 310

After this year then look at the updated most recent 3 values = (244 + 312 + 303) / 3 = 286.3

This is a 'moving average' forecast

Student numbers on MSCI 000	Year
2014-15	198
2015-16	212
2016-17	219
2017-18	295
2018-19	273
2019-20	292
2020-21	328
2021-22	263
2022-23	316
2023-24	303
2024-25	312
2025-26	244

Moving averages

For an 'n' point moving average

- Forecast = mean (demand in '*n*' previous periods)
- E.g. using 3-point moving average…

MA (period 6) = (67.2 + 66 + 67.7)/3 = 67.0

Period	Demand	3 PMA
1	63.3	
2	62.5	
3	67.7	
4	66	64.5
5	67.2	65.4
6		67

Moving averages

For an 'n' point moving average

- This gives equal weighting to all *n* periods
- Simple MA, cannot pick trends, they rely on averages.
- Lagging actual values.
- Requires extensive records of past data.

Period	Demand	3 PMA
1	63.3	
2	62.5	
3	67.7	
4	66	64.5
5	67.2	65.4
6		67

Moving averages

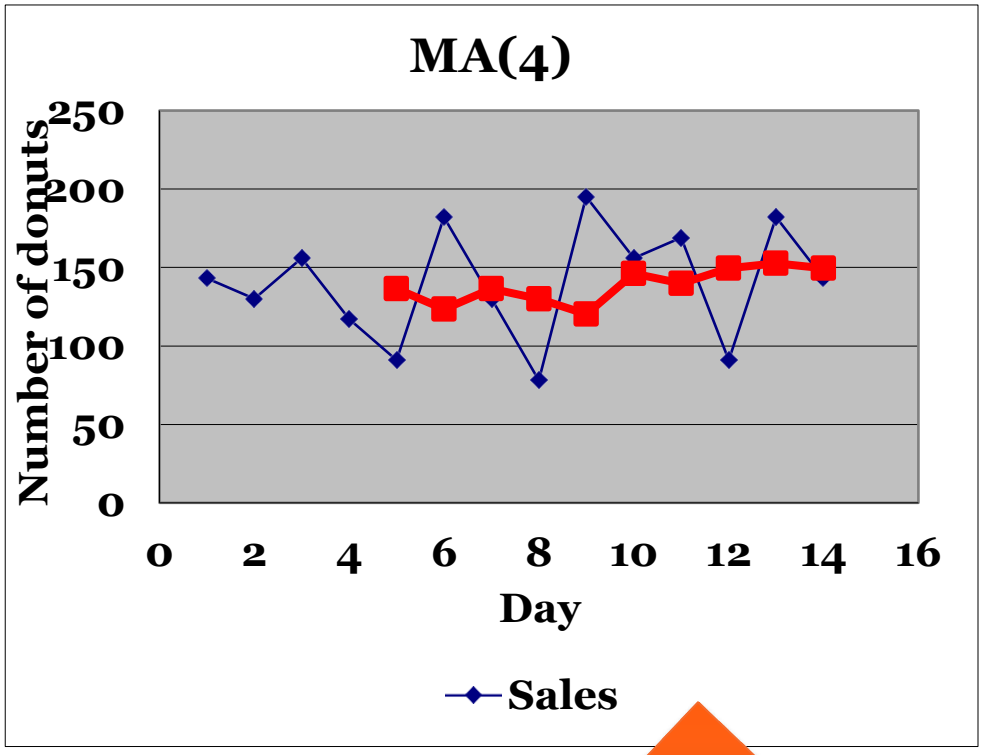
The following gives demand for an imaginary Lent term course, MSCI 282
Forecast the demand for 2024-25, using a 5-point moving average:

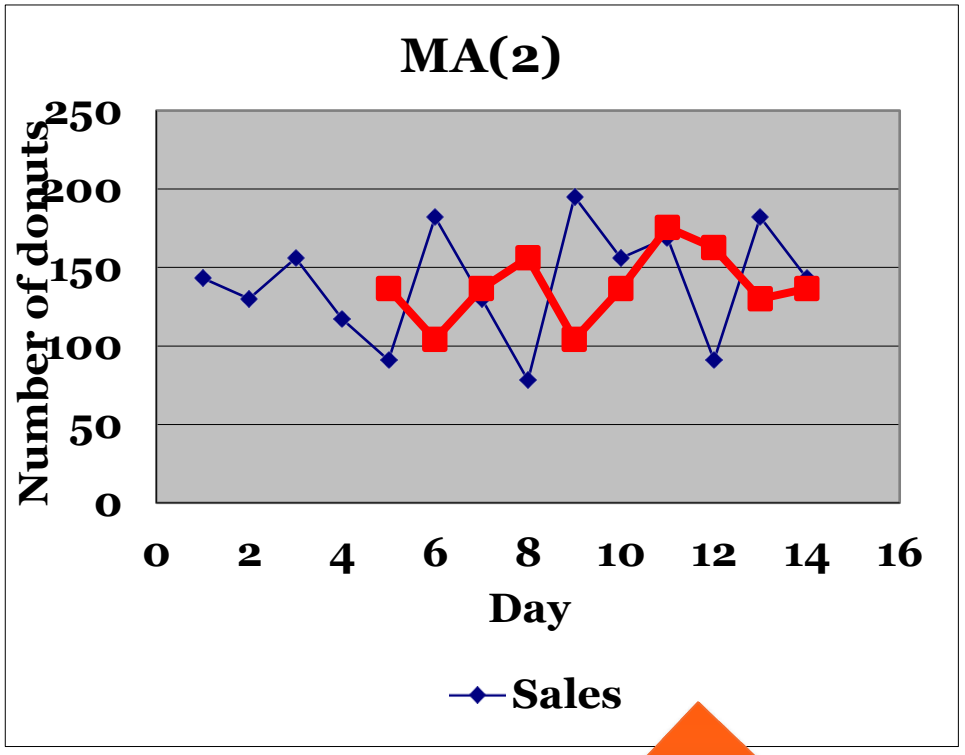
A. 232
B. 111
C. 98
D. 104

Period	Demand	5 PMA
2017-18	71	
2018-19	82	
2019-20	88	
2020-21	119	
2021-22	119	
2022-23	149	
2023-24	82	

How Does N Affect the Forecast?

How far back into the past should you look? (How large should N be?)





More smooth

More responsive and variable

Moving averages (with trend)

For an n point moving average ***with trend adjustment***

- Trend = difference between last 2 MAs
- Eg trend (period 6) = 67.0 – 65.4 = 1.6
- As 3 pt MA(period 6) is centred on period 4, not period 5:
  Forecast (period 6) = 3 pt MA + 2 x trend = 67.0 + (2 x1.6) = 70.1
- So generally forecast is ***N* pt MA + (*N* + 1)/2 x trend**

Period	Demand	3 PMA	Trend	Forecast
1	63.3			
2	62.5			
3	67.7			
4	66	64.5		
5	67.2	65.4	0.9	
6		67	1.6	70.2

Question

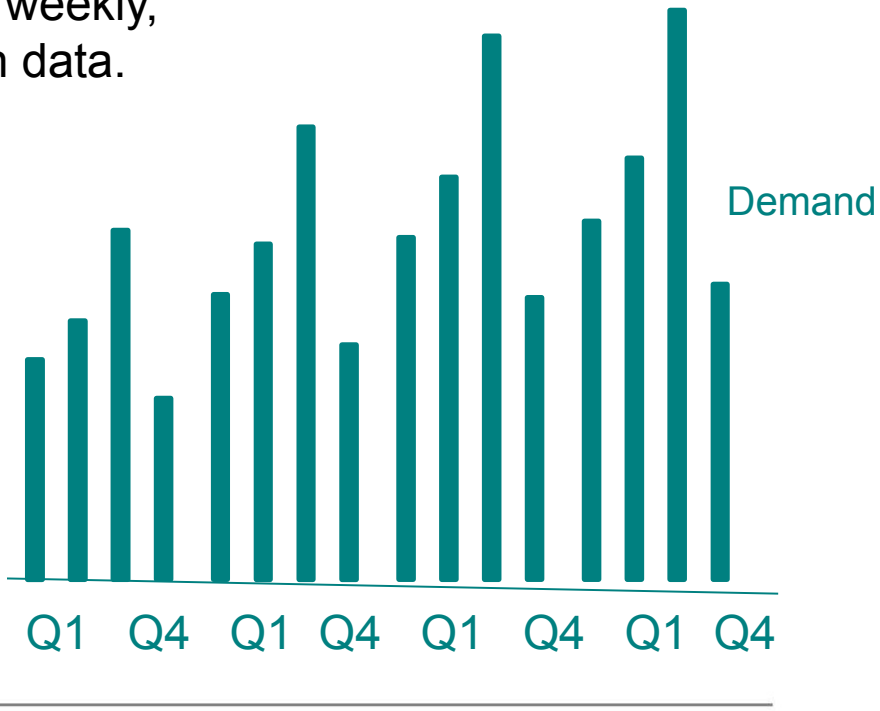
What is the **trend adjustment**, in this case, using a 5 point moving average?

A) -14
B) -2
C) 0
D) 7

Period	Demand	5 PMA	Trend	Forecast
2017-18	71			
2018-19	82			
2019-20	88			
2020-21	119			
2021-22	119			
2022-23	149			
2023-24	82			
2024-25				

Seasonal adjustment

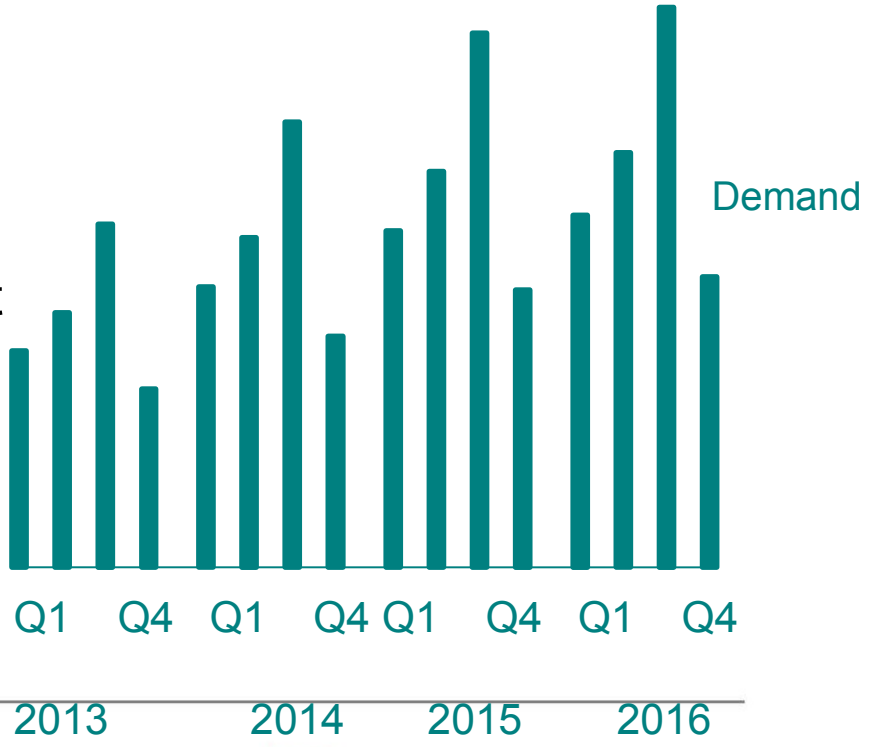
- Time series also tells us about seasonality
- Here there's a repeated cycle in values over a calendar year
- Seasonal variations are consistent and repeated upward or downward movements of data values.
- They can be traced to recurrent events – daily, weekly, quarterly or other regularly recurring patterns in data.



Seasonal adjustment

So to find a seasonal forecast:

1. Use the annual demand to produce annual forecasts, as before
2. Find each season's percentage or fractional contribution to the annual demand
3. Do this for each year of records and take an average
4. Multiply the annual forecast by the average percentage contribution of that season



Seasonal adjustment

Example

- Given demand data of electricity in MWh
- Find quarterly forecast for 2017
- Using 3 point MA with trend plus seasonal adjustment

Quarter	1	2	3	4	Total
2017	8.7	5.4	4.8	11.1	30
2018	16.5	8	7.5	18	50
2019	22.4	13.6	11.6	20.4	68
2020	22.9	2.8	24.5	23.8	74
2021	23.4	14.8	13.3	26.5	78
2022	27.2	17	12.8	28	85
2023					

Seasonal adjustment

- ***Step 1: find the trend-adjusted 3-point moving average for 2017***
  - The most recent moving average is (74 + 78 + 85)/3 = 79
  - The previous moving average is (68 + 74 + 78)/3 = 73.3
  - So the most recent trend = 79 – 73.3 = 5.7
  - So our forecast for 2017 = 79 + (2 x 5.7) = 90.3

Quarter	1	2	3	4	Total	3PMA	Trend	Forecast
2017	8.7	5.4	4.8	11.1	30			
2018	16.5	8	7.5	18	50			
2019	22.4	13.6	11.6	20.4	68			
2020	22.9	2.8	24.5	23.8	74			
2021	23.4	14.8	13.3	26.5	78			
2022	27.2	17	12.8	28	85	73.33		
2023						79	5.67	90.33

Seasonal adjustment

- ***Step 2: use quarterly data to find each quarter's fraction of the annual***

- E.g. in 2011 Q1 demand = 8.7/(8.7 + 5.4 + 4.8 + 11.1) = 0.29 or 29%
- E.g. in 2016 Q4 demand = 28/(27.2 + 17 + 12.8 + 28) = 0.33 or 33%

Quarter	1	2	3	4	Total
2017	8.7	5.4	4.8	11.1	30
2018	16.5	8	7.5	18	50
2019	22.4	13.6	11.6	20.4	68
2020	22.9	2.8	24.5	23.8	74
2021	23.4	14.8	13.3	26.5	78
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2023					

Quarter	1	2	3	4	Total
2017	0.29	0.18	0.16	0.37	1.00
2018	0.33	0.16	0.15	0.36	1.00
2019	0.33	0.20	0.17	0.30	1.00
2020	0.31	0.04	0.33	0.32	1.00
2021	0.30	0.19	0.17	0.34	1.00
2022	0.32	0.20	0.15	0.33	1.00
2023					

Seasonal adjustment

Example

- ***Step 3: for each quarter calculate average % of annual***
- Eg Q1 average (.29, .33, .33, .31, .32, .32) = 0.31

Quarter	1	2	3	4	Total
2017	8.7	5.4	4.8	11.1	30
2018	16.5	8	7.5	18	50
2019	22.4	13.6	11.6	20.4	68
2020	22.9	2.8	24.5	23.8	74
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2023					

Quarter	1	2	3	4	Total
2017	0.29	0.18	0.16	0.37	1.00
2018	0.33	0.16	0.15	0.36	1.00
2019	0.33	0.20	0.17	0.30	1.00
2020	0.31	0.04	0.33	0.32	1.00
2021	0.30	0.19	0.17	0.34	1.00
2022	0.32	0.20	0.15	0.33	1.00
Mean	0.31	0.16	0.19	0.34	1.00

Seasonal adjustment

Example

- ***Step 4: forecast quarter as annual x quarterly %***
- Eg 2017 Q1 = 90.3 x 31.3% = 28.3

Quarter	1	2	3	4	Total
Mean	0.31	0.16	0.19	0.34	1.00
3 PMA	90.33	90.33	90.33	90.33	
Forecast	28.29	14.57	17.05	30.42	90.33

Seasonal adjustment

May need to recognise specific events rather than 4 seasons:

E.g. Christmas at Amazon : UK Milton Keynes warehouse (@Slack et al)

- *40% annual sales in October-December*
- *50% online Christmas sales in last week November – first 2 weeks December*
- *Articles per day from 300,000 to 3.6 M on Cyber Monday*
- *Cyber Monday followed by Boomerang Thursday for returns (peaking at 19:00)*
- *So, depending on your operation, your approach to seasonality might be quite specific*

Eg: demand = *a* x population + *b* x GDP/head + *c* x temperature + …

Forecasting methods

Main types:

	NON-CAUSAL	CAUSAL
OBJECTIVE	Time series analysis eg: Moving averages Exponential smoothing	Regression Econometrics
SUBJECTIVE	Intuition	Expert opinion eg: Individual, Panel, Delphi