



MSci 523.1 – Forecasting

Lecture 1.1 **Introduction to Forecasting**

Dr. Sven F. Crone
Director & Assistant Professor





Research Centre for Forecasting @ Lancaster Uni Management School

HALIFAX Always giving you extra

HAGEMEYER

AstraZeneca

LANCORD SYSTEMS All things cloud™

THE LOTUS GROUP

BDF Beiersdorf

The co-operative bank

swatch BOX

BUNZI

OHMV top dog for music-dvd-games

wilkinson

Waitrose

Littlewoods even more

Dixons

shop direct group

AEA Technology

ovum

GJ Druckerei-Jahr AG & Co. KG Druck- und Verlagshaus Hamburg

itv Burton's Foods

vodafone

Ministry of DEFENCE

AOL BDF Beiersdorf

Interbrew

Nestle PHILIPS sense and simplicity

British Gypsum

Hapag-Lloyd

Codelco

tobaccoland Automaten

Cow & Gate DALER ROWNEY

sanofi aventis Because health matters

NHS

BAYER

LONDON ELECTRICITY

Caminus Energy Consultancy Ltd

National Grid Transco plc

premierline direct just business insurance

DLO Defence Logistics Organisation

Celanese

INFOR

→Active engagement with companies in consultancy & training



Research Centre for Forecasting

Lecturer Sven F. Crone



- ▶ **Dr Sven F. Crone** is an Assistant Professor in Management Science at Lancaster University, UK, with a main research focus on business forecasting with neural networks – mostly in FMCG, Pharma and CPG forecasting applications.
- ▶ Sven has a PhD thesis plus 85 research papers published on neural networks in forecasting, with 2000+ citations. Google scholar currently ranks him 17th in Forecasting and 19th in Neural Networks in the UK, and 102nd and 255th worldwide by citations.
- ▶ Sven frequently provides in-house industry training courses on forecasting and analytics for companies, IBF and IEEE, and has been a regular speaker at international conferences.
- ▶ He is also CEO and founder of iqast.de, a university spin-off company pioneering artificial intelligence and machine learning algorithms in forecasting and time series analytics.



- ▶ **Office Hours:**
Wed afternoon 16:00 – 17:00
& after email s.crone@lancaster.ac.uk

- ▶ **Dr Sasan Barack** is a PhD student in Management Science at Lancaster University, UK, with a main research focus on forecasting model selection with meta learning and artificial intelligence.
- ▶ **Carlos Rodrigues** is a PhD student in Management Science at Lancaster University, UK, with a main research focus on forecasting with k-nearest Neighbours machine learning methods.



Course Outline

Lectures

wk11 - Free -

wk12 **Introduction to Forecasting in Organisations** SC

Workshop 1: Introduction to R SB/CR/SC

wk13 **Data Exploration** SC

Workshop 2: Data Exploration SB/CR/SC

wk14 **Exponential Smoothing Methods** SC

Workshop 3: Exponential Smoothing SB/CR/SC

wk15 **ARIMA** SC

Workshop 4: ARIMA SB/CR/SC

wk16 **Time Series Regression** RF

Workshop 5: Regression SB/CR

wk17 - Free -

Workshop 6: Catchup & prep for coursework SB/CR

wk18 - Free -

Workshop 7: Catchup & prep for coursework SB/CR

wk19 **Artificial Intelligence and Machine Learning** SC

Workshop 8: Evaluation SB/CR/SC

wk20 - Optional : Forecasting Systems & Expert Judgment RF

- Optional -

Practicals @ A001c

1 Thu 13:00 – 14:00

2 Thu 14:00 – 15:00

3 Thu 16:00 – 17:00

ex **DROP IN CLINIC**

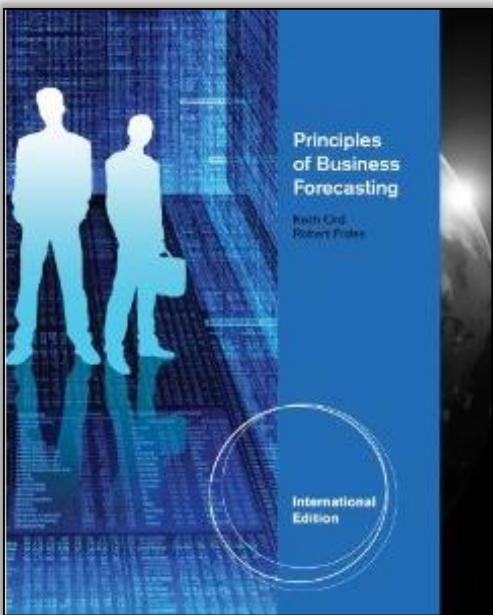
tra Thu 17:00 – 18:00

Group 1 & 2 & 3: tbd Wed

If possible bring your own laptop!
(to install R & iqast and extensions!)

Material

1. Lecture notes
2. Papers & other resources that will be put online
→ MUST READ UP AHEAD OF COURSE!!!



Forecasting: Principles and Practice
(Hyndman & Athanasopoulos)
<https://www.otexts.org/book/fpp>



Principles of Business Forecasting 2nd edition
[Paperback]
or 1st edition Keith Ord, Robert Fildes GPB 45.-
2012 ISBN-10: 1133584403, ISBN-13: 978-
1133584407 | Edition: International

Forecasting: methods and applications
Makridakis, Wheelwright and
Hyndman, 1998, Wiley, 3rd edition

- **Use discussion forums in MOODLE!**

→ You are not the only one with the same question

→ Discussing with your classmates helps to solve
your problems better and faster! (more minds!)

→ I will try to respond to questions asap



Assessment

The course will be assessed through one assignment

- Individual task on forecasting a set of real time series with methods from time series extrapolation and causal regression
- Hand-out: week 17 (25-27.02.)
- Due: tbd → approx. 6 weeks to complete
- Hand-in: online to MOODLE
AND in print in to coursework box

The coursework is weighted 100%. For the cwa, standard departmental penalties will apply for late work unless you have been given an extension by the relevant lecturer for exceptional reasons.



International Institute of Forecasters

Leading academic and professional body dedicated to the discipline of forecasting.

Award of Certificate of Forecasting Practice

- Completion of MSCI 523 with a mark of 60% or higher
- Completion of a practical forecasting-based MSc project, supervised by a member of the Lancaster Centre for Forecasting, with a mark of 60% or higher
- Payment of small fee (\$50), matched by the department



Agenda

Introduction to Forecasting

1. Introduction

- Why forecast?
- What are Time Series?
- Forecasting problems in SCM, Marketing & Finance
- What is good Forecasting? Why use Statistics?

2. Forecasting Models & Methods

- A Short history of Forecasting
- Objective vs. Subjective & Time Series vs. Causal
- Forecasting Methods

3. The Forecasting Process

- Exploration → Method Selection → Parameterisation
→ Calculation → Evaluation → ...

BRAINSTORM: Why do we need to forecast?

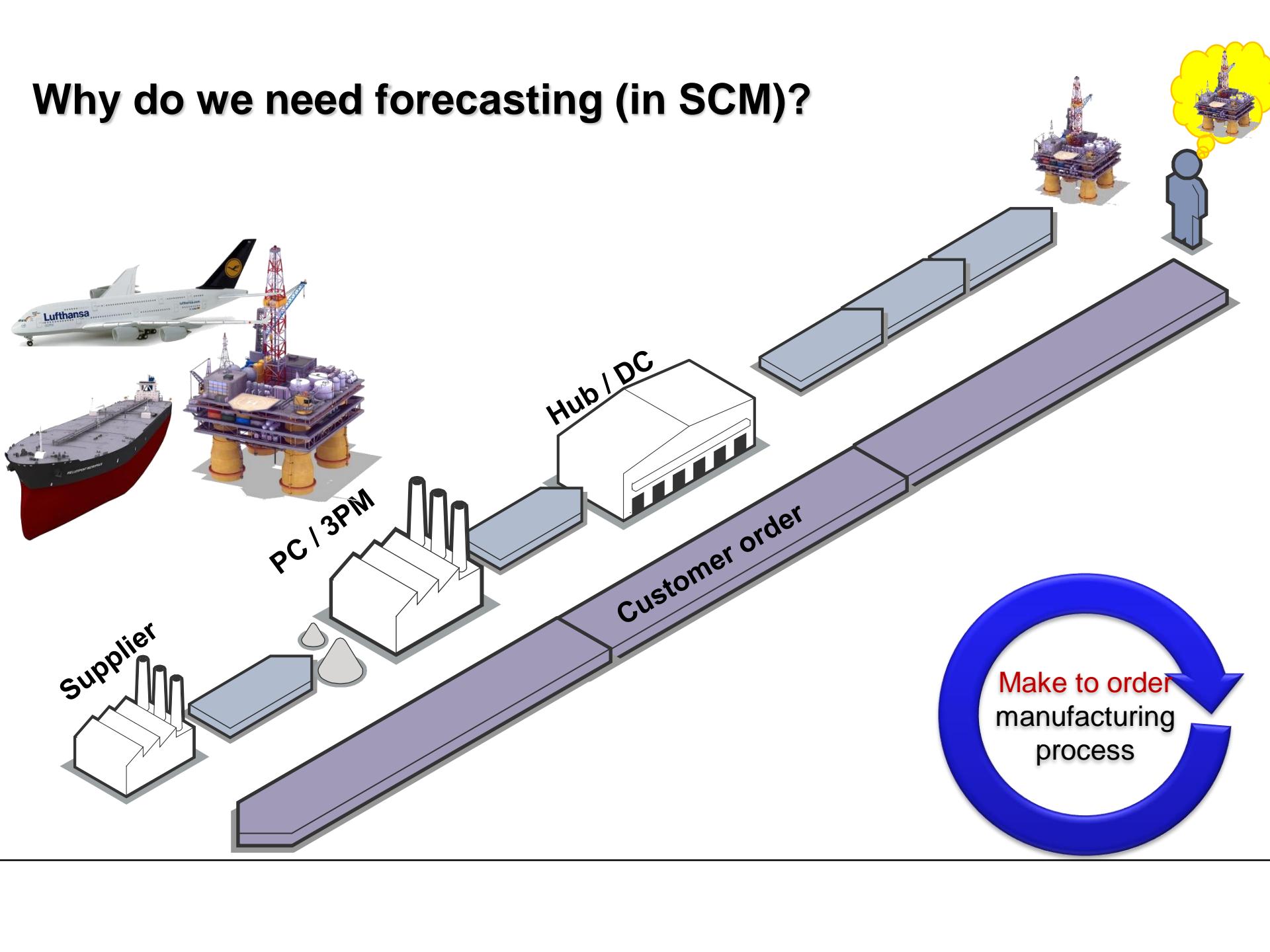
Why do we need to forecast?

What do we need to forecast?

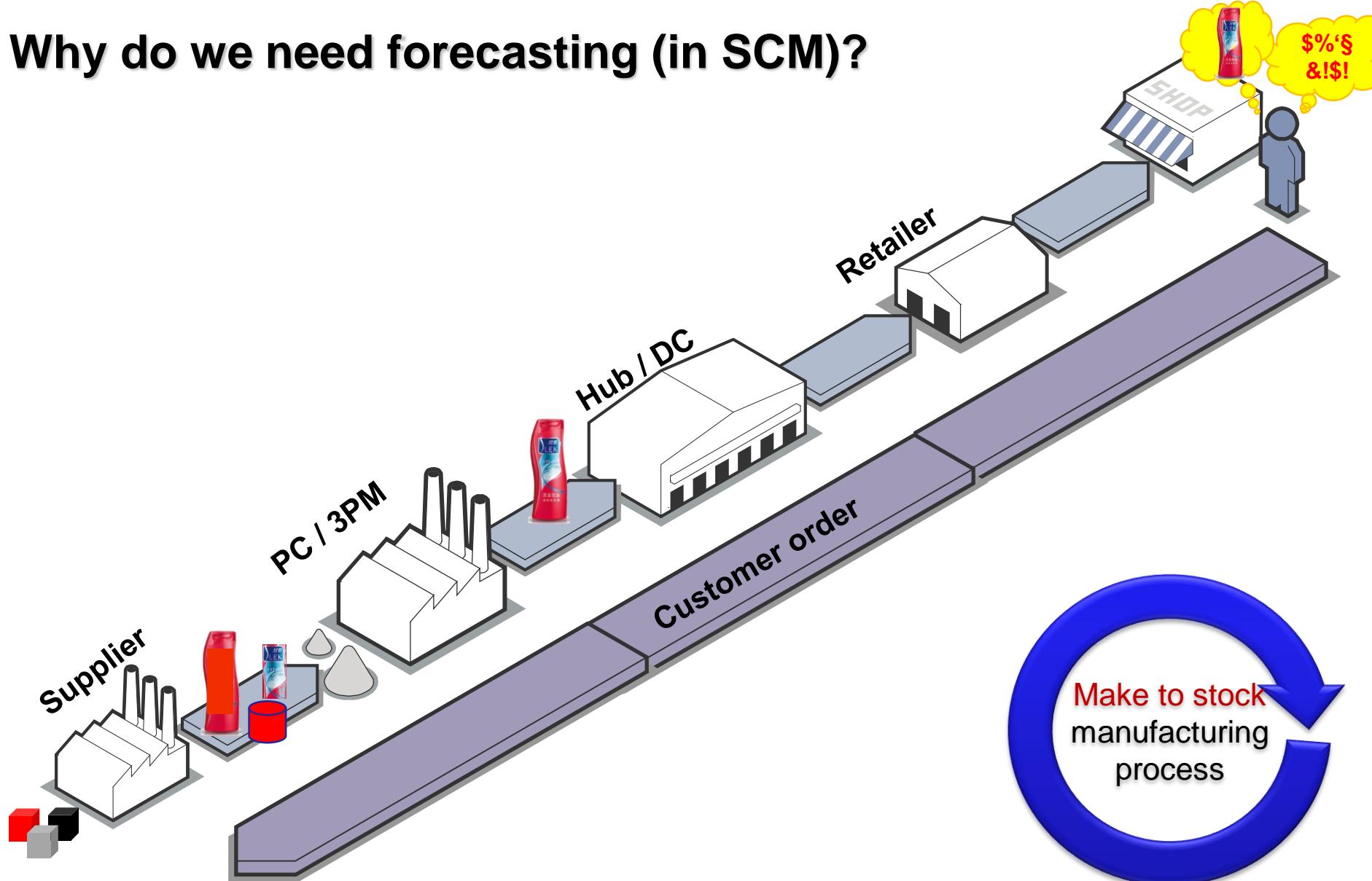
What decisions depend on it?



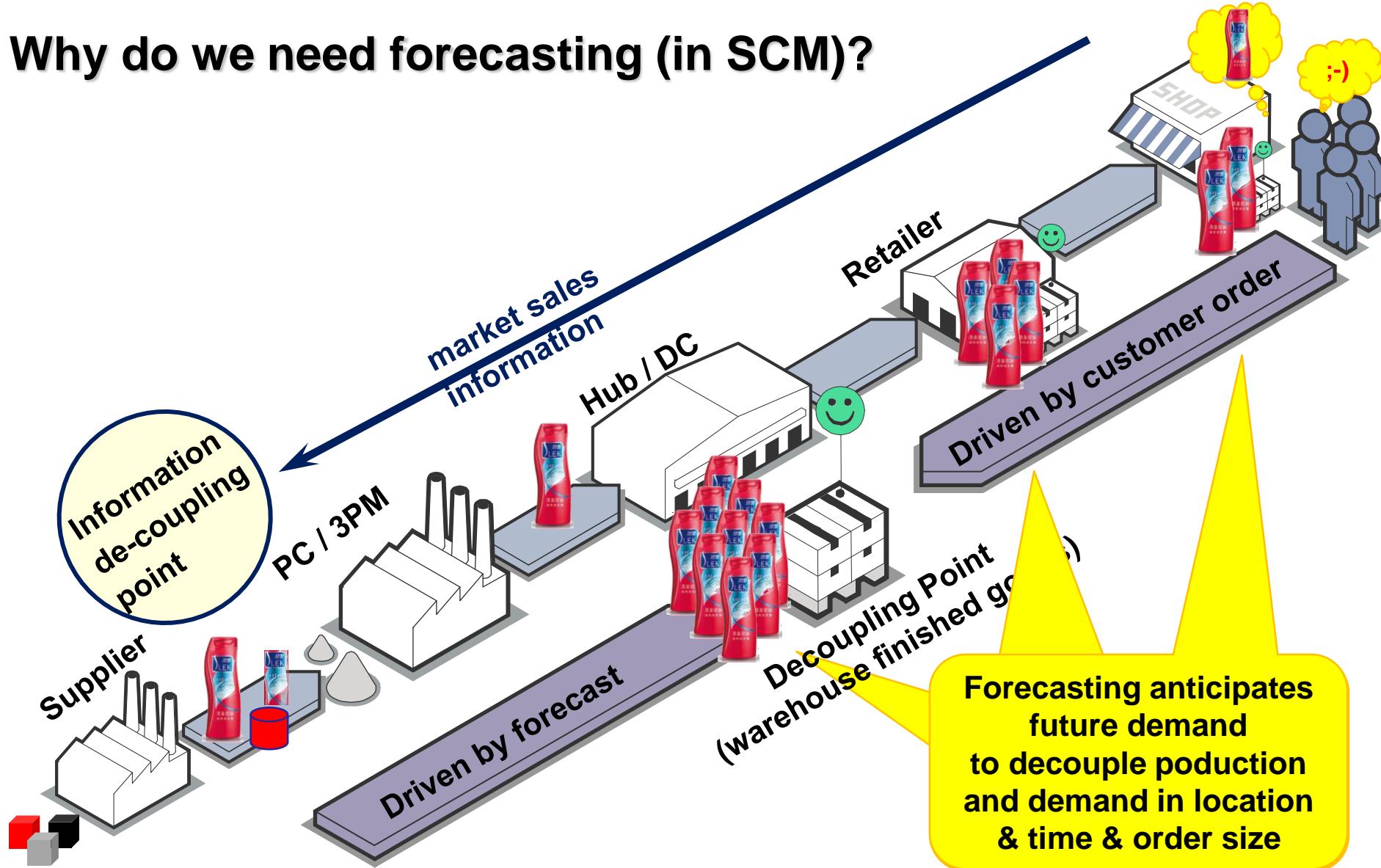
Why do we need forecasting (in SCM)?



Why do we need forecasting (in SCM)?



Why do we need forecasting (in SCM)?



What happens if we forecast wrong?

What happens if we forecast too high?

What happens if we forecast too low?

What is then forecasting „just right“?



What happens if we forecast wrong

At the distribution centre / 3PL / wholesaler / retailer:



Too low: out-of-stocks!

- Lost profit
- Lost sales (market share)
- Angry customers
- Penalization from retailers
- Increases competitor share



Just right!
What is the right service level?

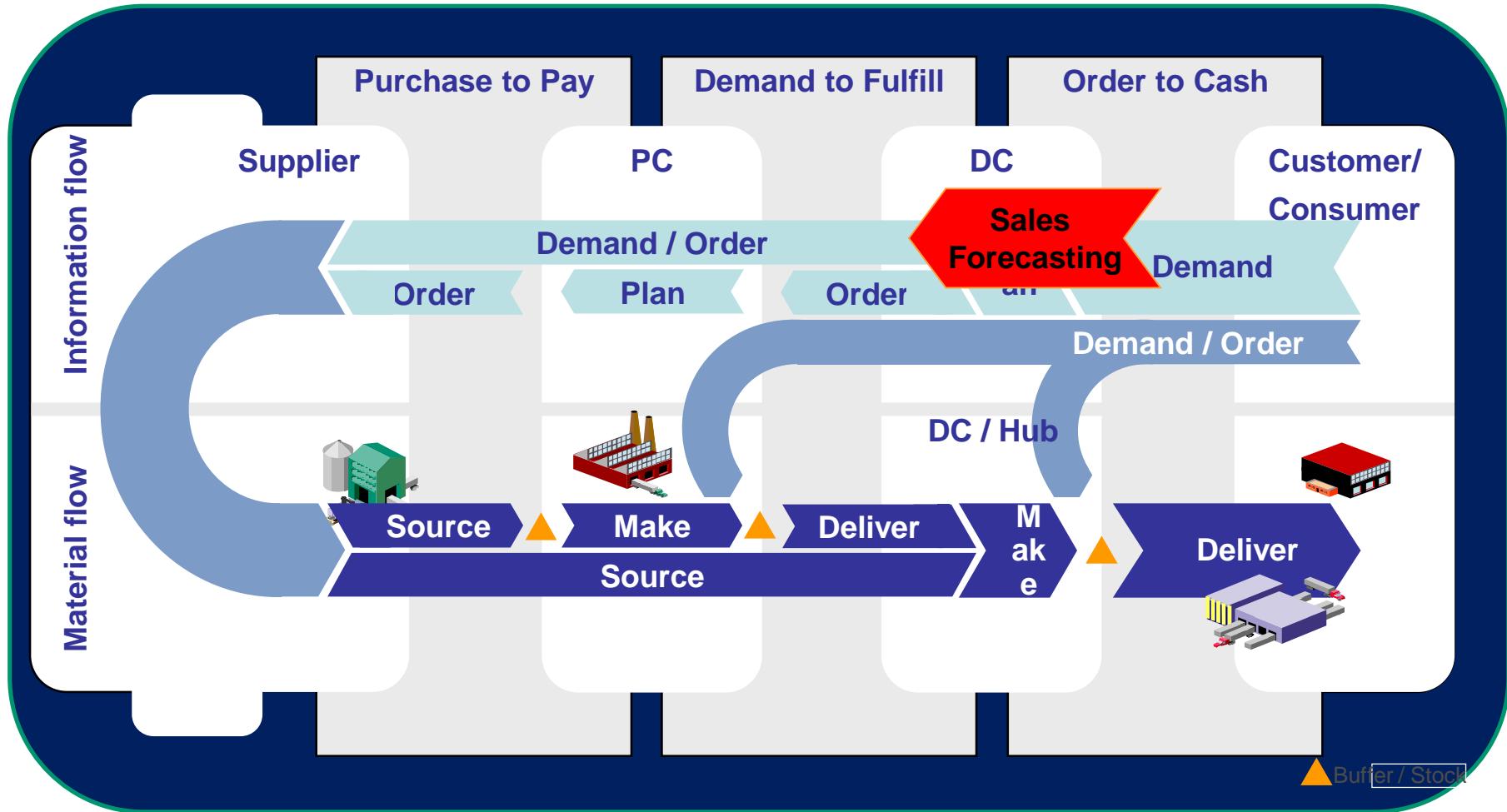


Too high: overstocks!

- Lost money in inventory (assets tied up in stock)
- Risk of damage, wastage etc.

...

What happens if we forecast wrong

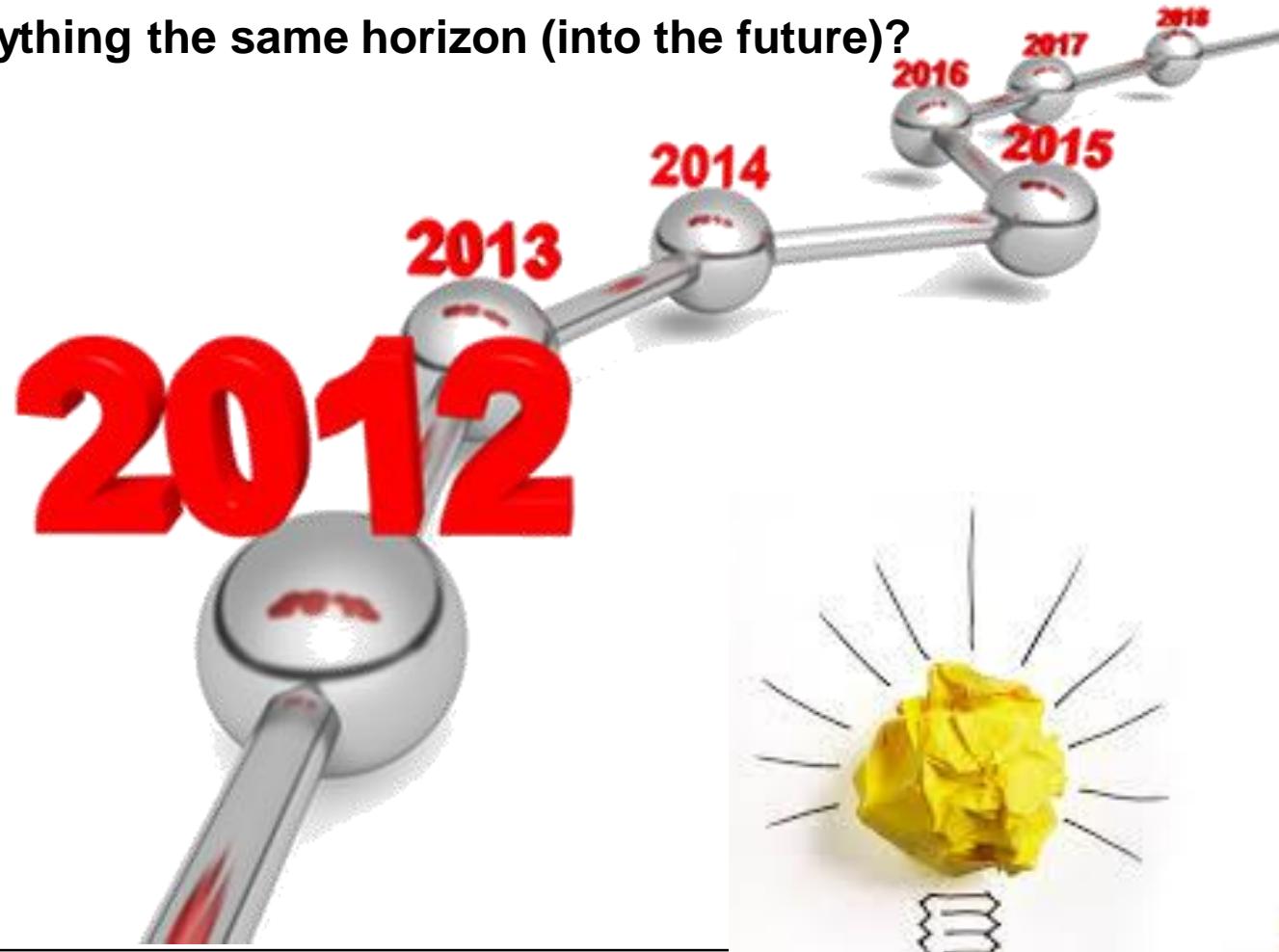


→DCs ensures with high forecast quality → high service levels & moderate SC costs
→DCs important in SCM → Perfect Process execution as critical success factor

How far do we need to forecast?

How far into the future do we need to forecast?

Is everything the same horizon (into the future)?

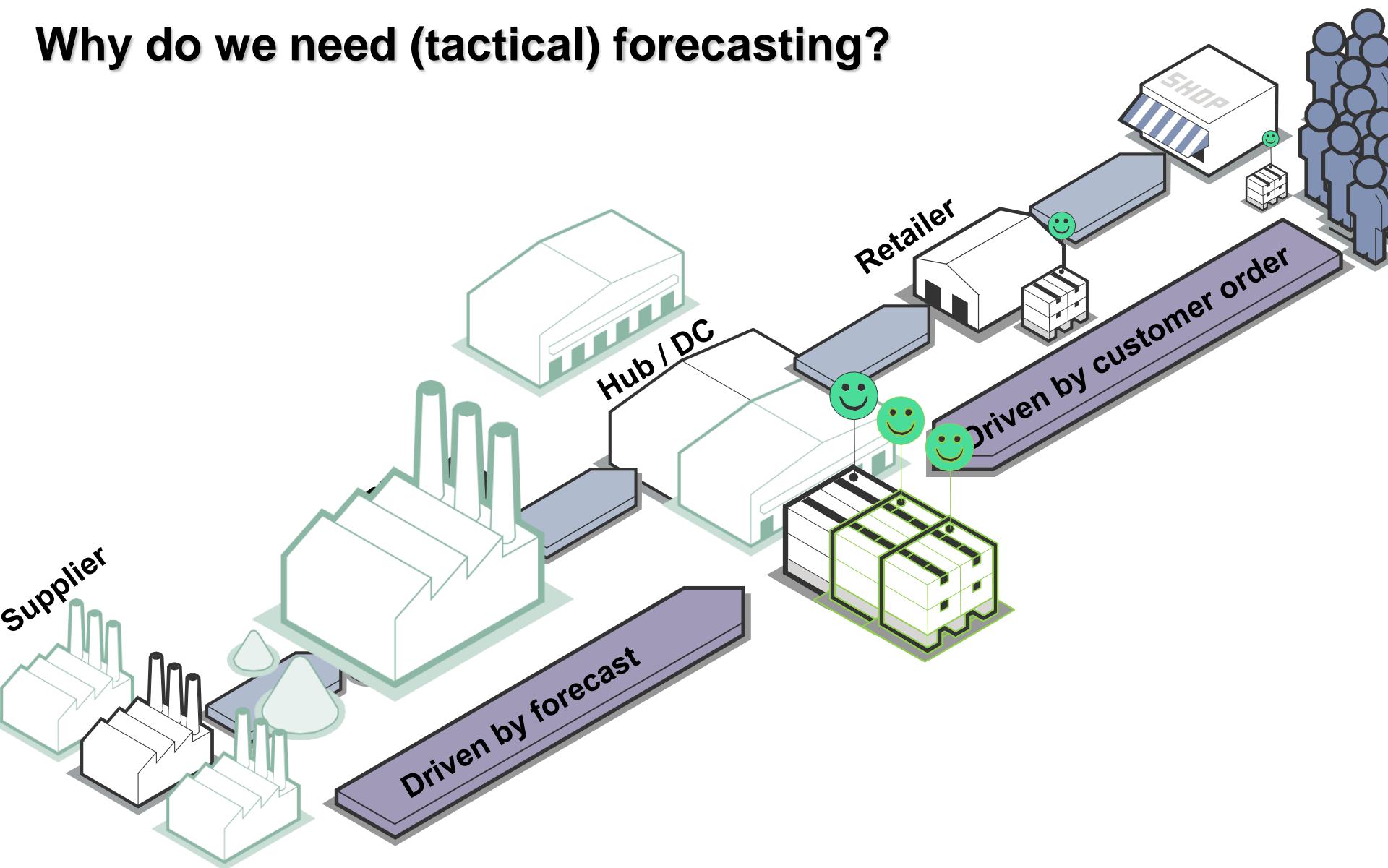


Forecasting for operational → tactical → strategic Planning



Strategic	At this level, company management will be looking to high level strategic decisions concerning the whole organization, such as the size and location of manufacturing sites, partnerships with suppliers, products to be manufactured and sales markets.
Tactical	Tactical decisions focus on adopting measures that will produce cost benefits such as using industry best practices, developing a purchasing strategy with favored suppliers, working with logistics companies to develop cost effect transportation and developing warehouse strategies to reduce the cost of storing inventory.
Operational	Decisions at this level are made each day in businesses that affect how the products move along the supply chain. Operational decisions involve making schedule changes to production, purchasing agreements with suppliers, taking orders from customers and moving products in the warehouse.

Why do we need (tactical) forecasting?





What is Forecasting

What do organisations need to forecast?

✓ Costs

- raw materials
- semi-finished goods
- wage rates & overheads
- interest rates

✓ Demand / Sales/ Activities

- by industry
- by region
- by market/product (market share)
- by product category, by wholesaler, by retailer
- new product sales
- competitive position - e.g. prices, exchange rates
- competitive behaviour
- customer service
- prices
- competitor activities

✓ Technology

- new products
- new processes
- diffusion rates

✓ Social and Political trends

- demographics
- wealth profile
- welfare and health provisions
- impact of technology

✓ Projects

- duration
- costs
- life cycle maintenance

✓ ...

→Forecasting (formal / informal) is the foundation for ALL managerial decision making (and many personal decisions!)



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What are Time Series?

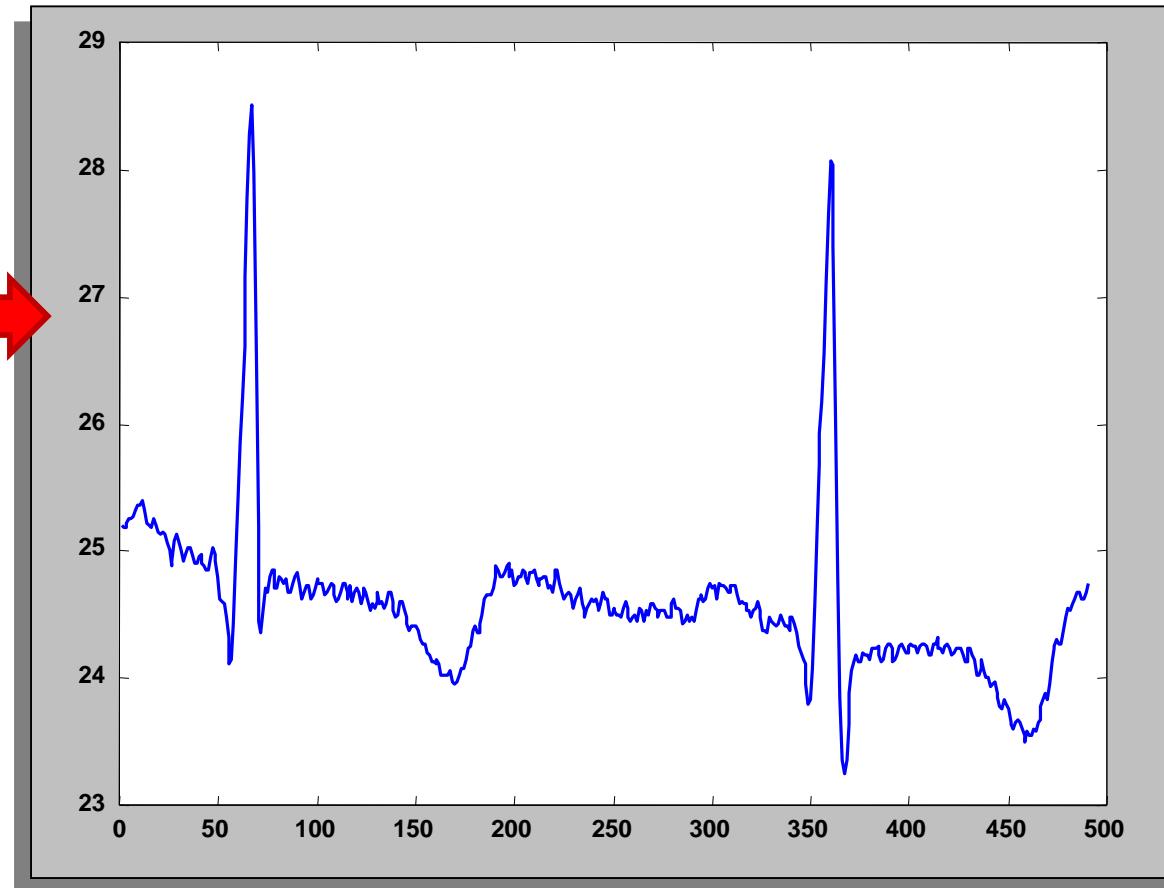
→ collection of observations made sequentially in time

25.1750
25.2250
25.2500
25.2500
25.2750
25.3250
25.3500
25.3500
25.4000
25.4000
25.3250
25.2250
25.2000
25.1750

..

..

24.6250
24.6750
24.6750
24.6250
24.6250
24.6250
24.6250
24.6750
24.7500



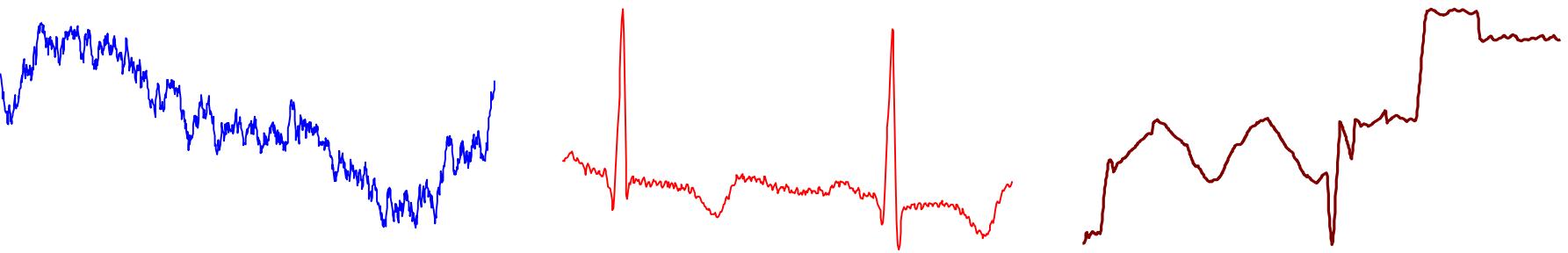
→ time series occur in virtually every domain
medical, scientific and business (Supply Chain, Finance,...)

Time Series are Ubiquitous!

People measure things...

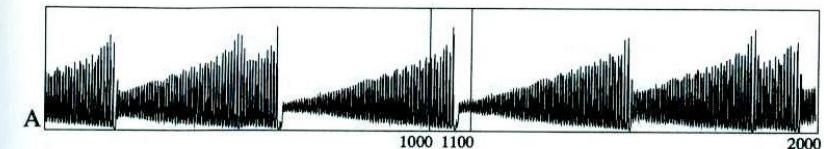
- *Schwarzeneggers popularity rating.*
- *Their blood pressure.*
- *The annual rainfall in New Zealand.*
- *The value of their Yahoo stock.*
- *The number of web hits per second.*

... and things change over time.

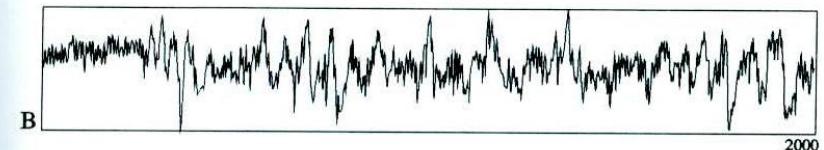


→ time series occur in **virtually every domain**
medical, scientific and business (Supply Chain, Finance,...)

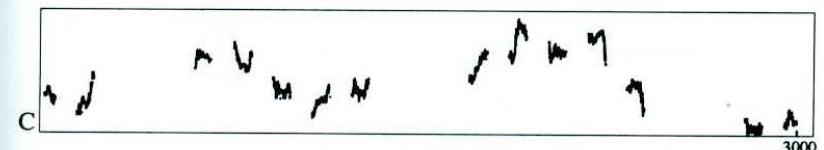
A. Far-infrared laser excitation



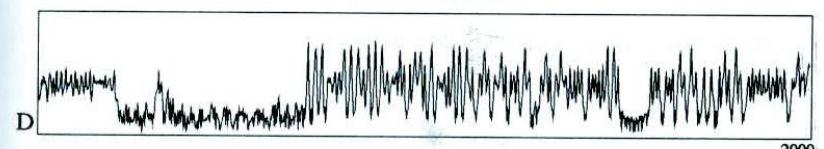
A. Currency exchange rates



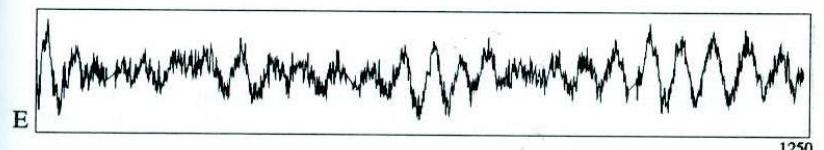
B. Sleep Apnea



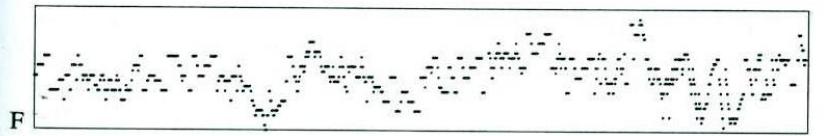
c. Particle driven in nonlinear
multiple well potentials



D. Variable star data



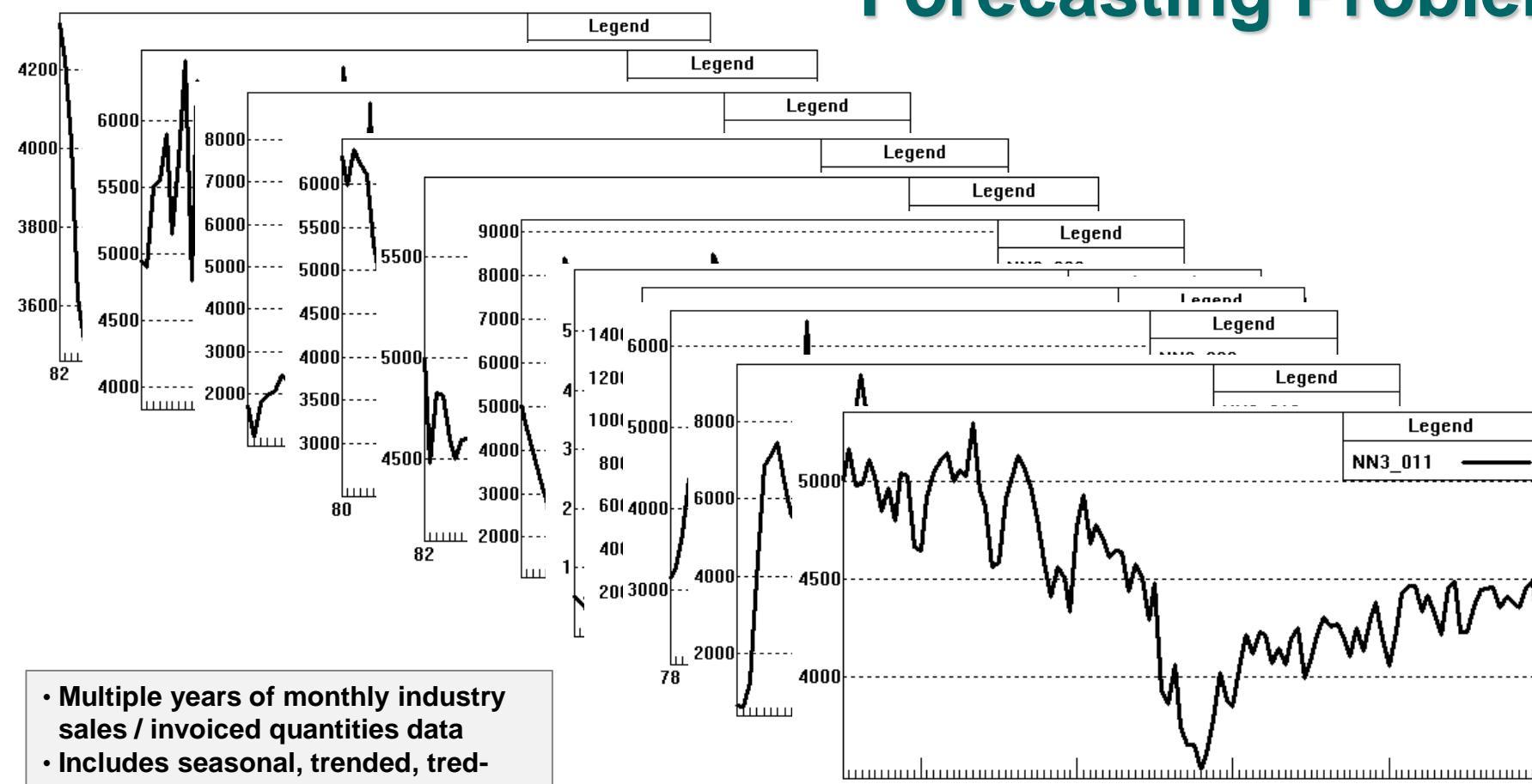
E. J. S. Bach fugue notes



→ Focus on **business time series** which change over time

→ OR/MS context → time series properties from logistics etc.

Forecasting Problems

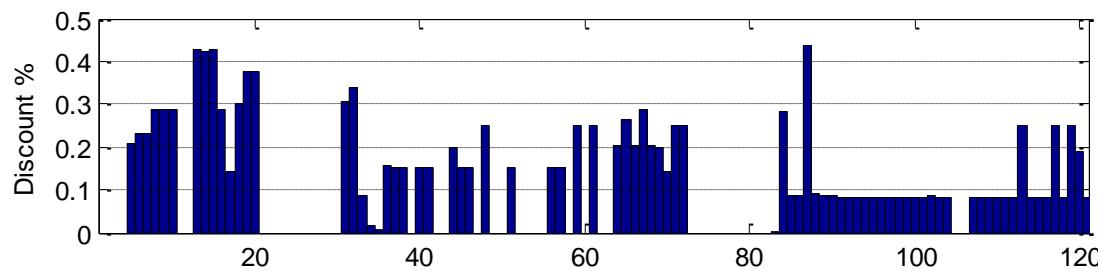
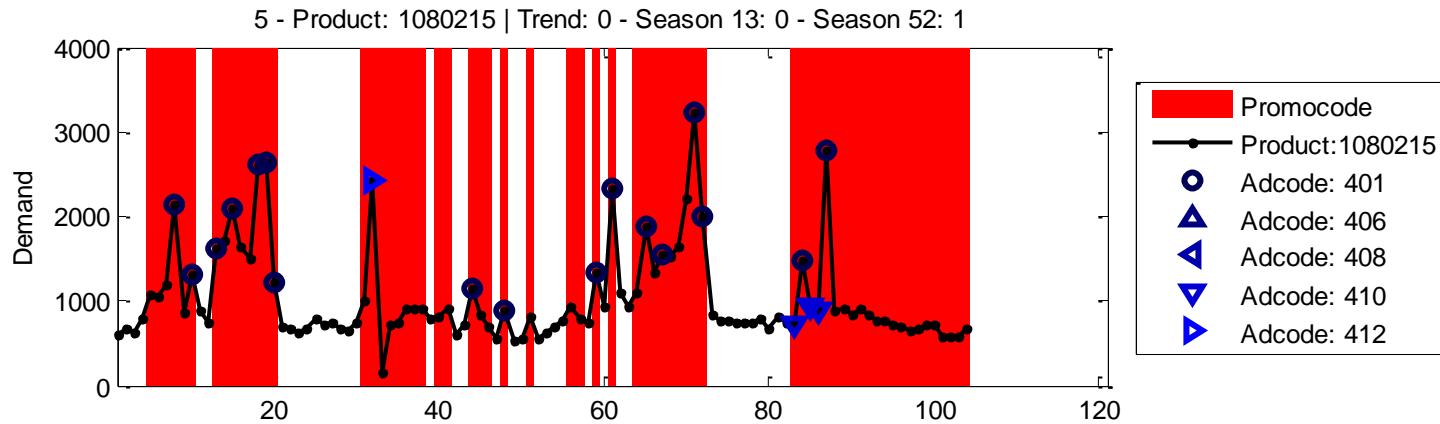


- Multiple years of monthly industry sales / invoiced quantities data
- Includes seasonal, trended, trend-seasonal, level, intermittent etc. time series
- Includes external shocks through level shifts and outliers from unknown causal forces



→**SUPPLY CHAIN FORECASTING:** industry sales → for production planning
→Automating forecasting of many different time series patterns

Forecasting Problems



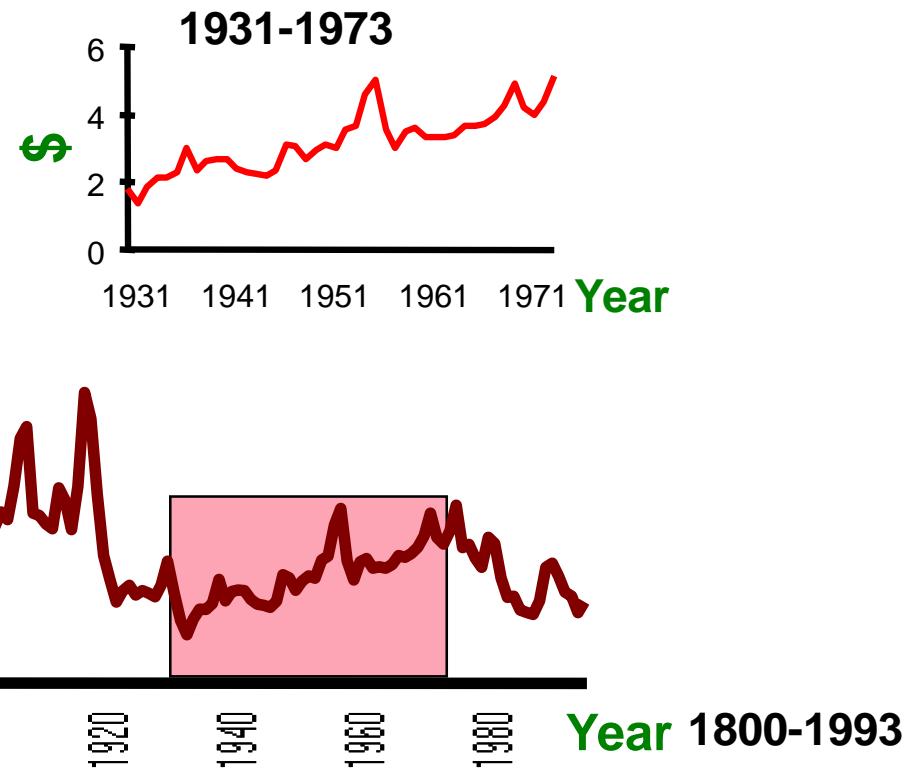
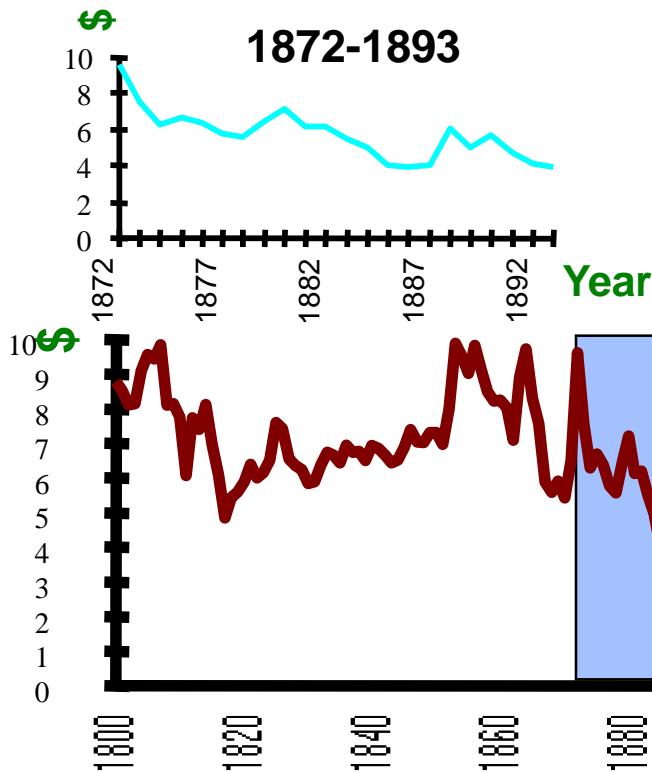
- Multiple years of daily or weekly retail sales
- Includes seasonal, trended, trend-seasonal, level, intermittent etc. time series & external shocks through level shifts and outliers from unknown causal forces
- Strong influence from Price Promotions (BOGOF, BOGTF, on packs, extra volume) and Advertising (TV, newspaper, cooupons, ins-troe)

→ MARKETING ANYLTICS: retail sales with promotions

→ Automating forecasting of many series with different causal influences



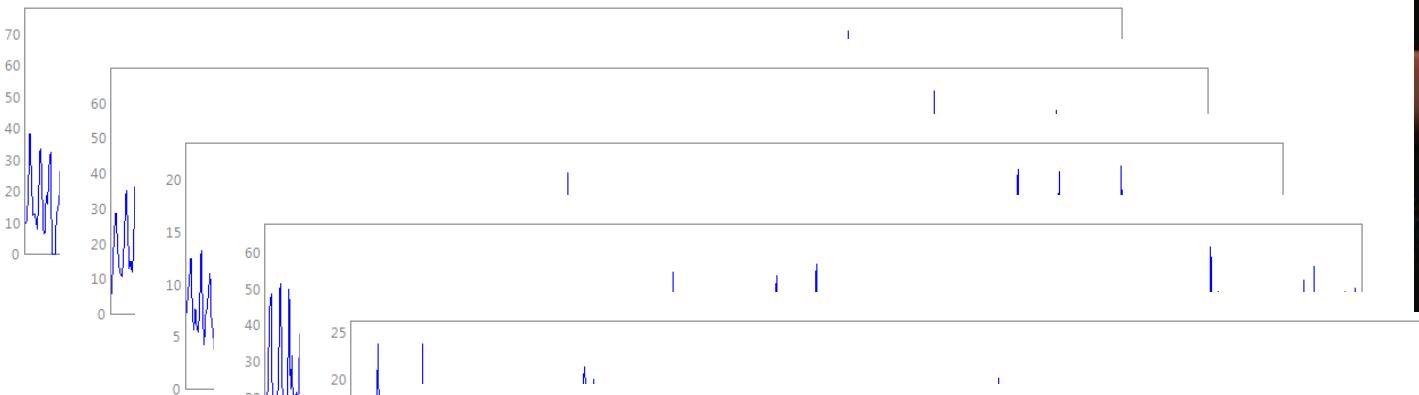
Forecasting Problems



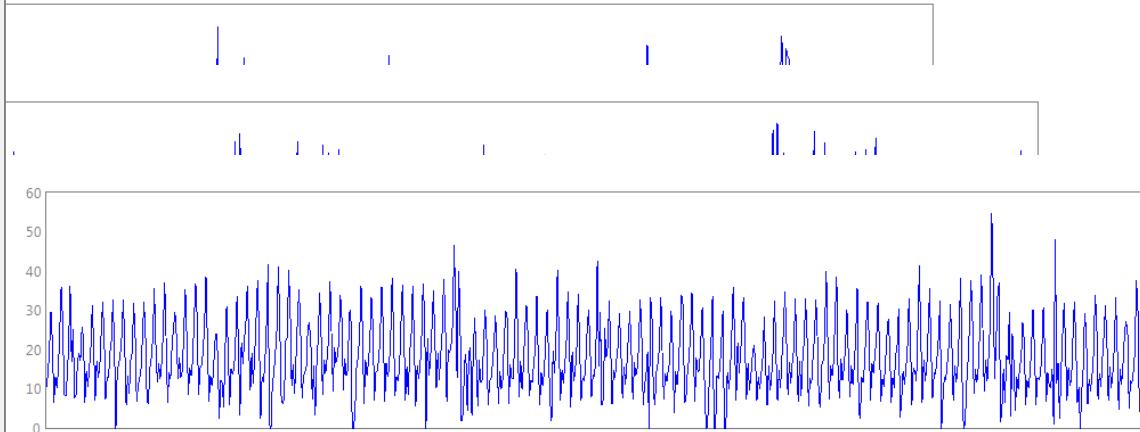
→ Real Copper Prices in \$ per KG



Forecasting Problems



- 2 years of daily cash money demand at cash machines (ATMs) at different locations in England
- Cash machines operate as miniature “retail outlets” and provide cash money to customers.
- The data may contain a number of time series patterns including multiple overlying seasonality, local trends, structural breaks, outliers, zero and missing values etc.
- Plus causal forces driven by the underlying yearly calendar, such as reoccurring seasonal periods, bank holidays, or special events of different length and magnitude of impact, with different lead & lag effects.



created with BISlabIF



Forecasting Competition for
Artificial Neural Networks &
Computational Intelligence

→**FINANCIAL FORECASTING:** Forecasting daily cash withdrawals at ATMs
→Problem of Multiple overlying time series patterns



Where is Forecasting used?





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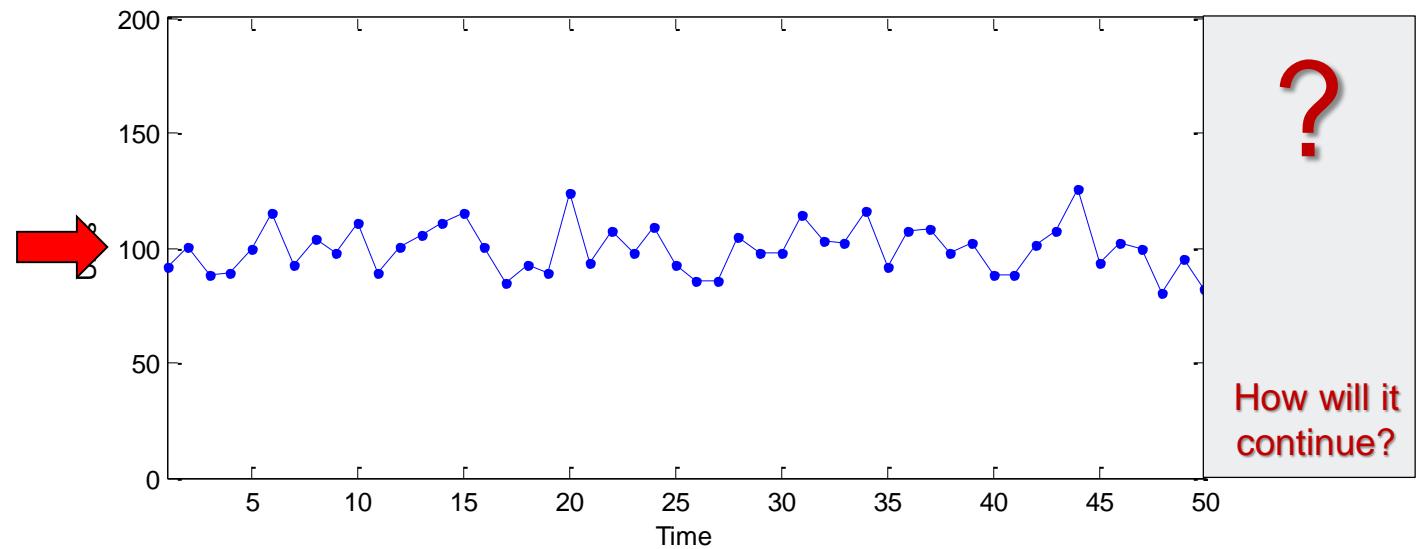
What is Forecasting?

This is a time series ...

(a collection of observations
made sequentially in time)

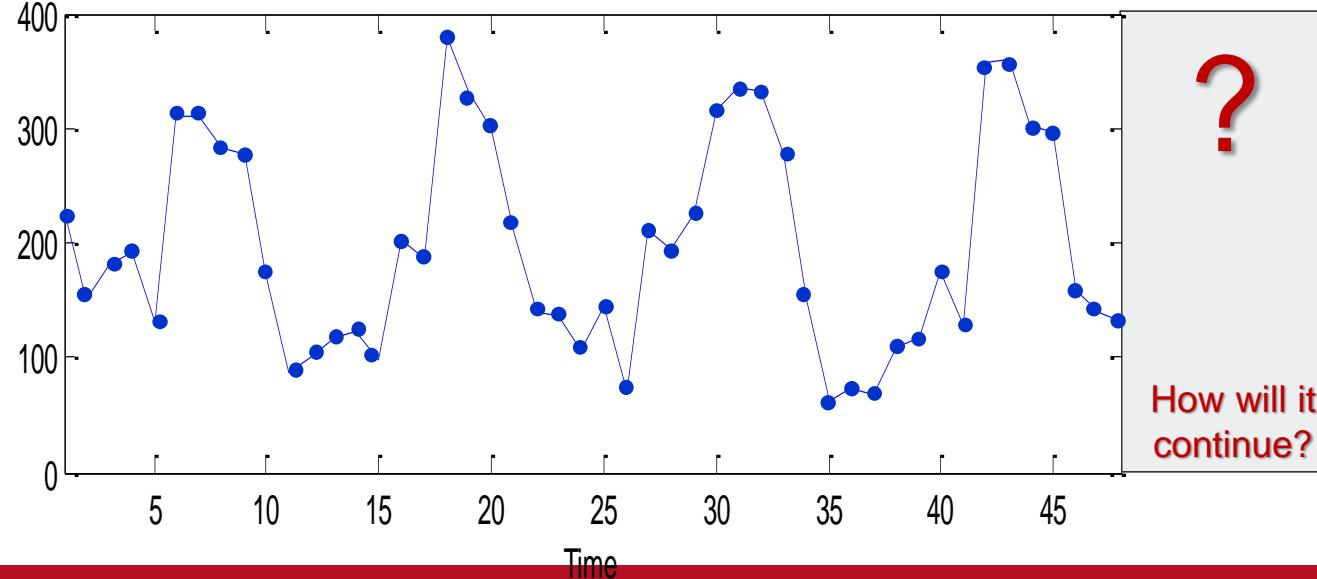
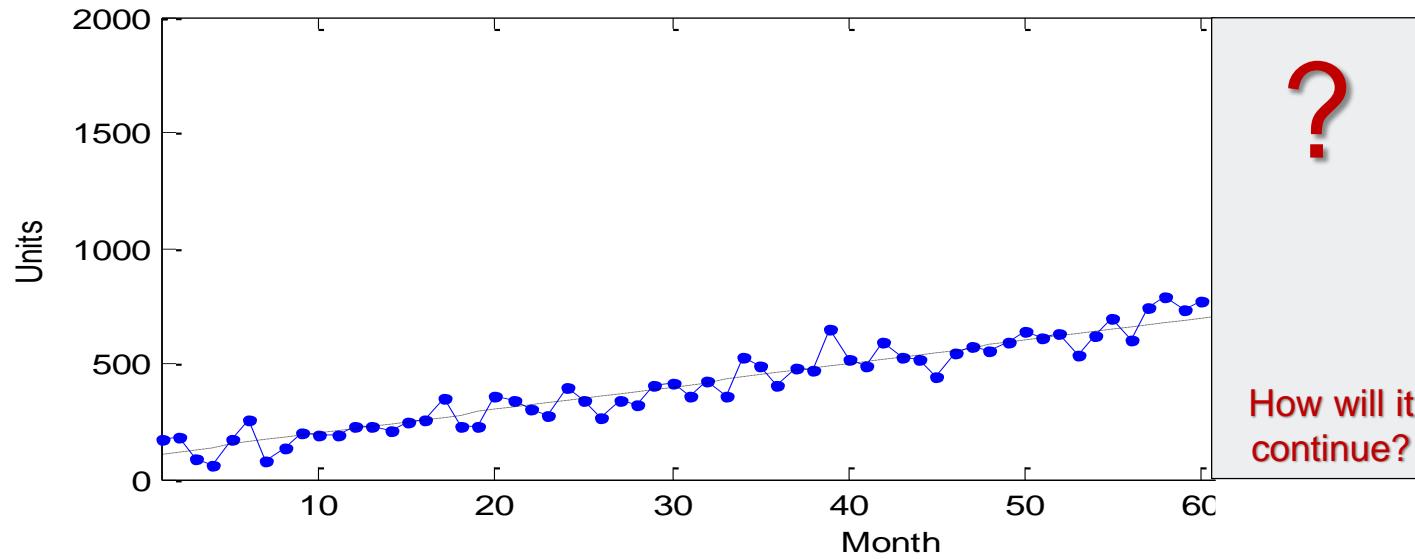
Jan 2016	91.36
Feb 2016	100.77
Mar 2016	87.85
Apr 2016	88.86
May 2016	99.93
Jun 2016	115.32
July 2016	92.30
Aug 2016	103.71
Sep 2016	97.74
Oct 2016	111.17
...	...
Dec 2016	89.26

... how will it continue?

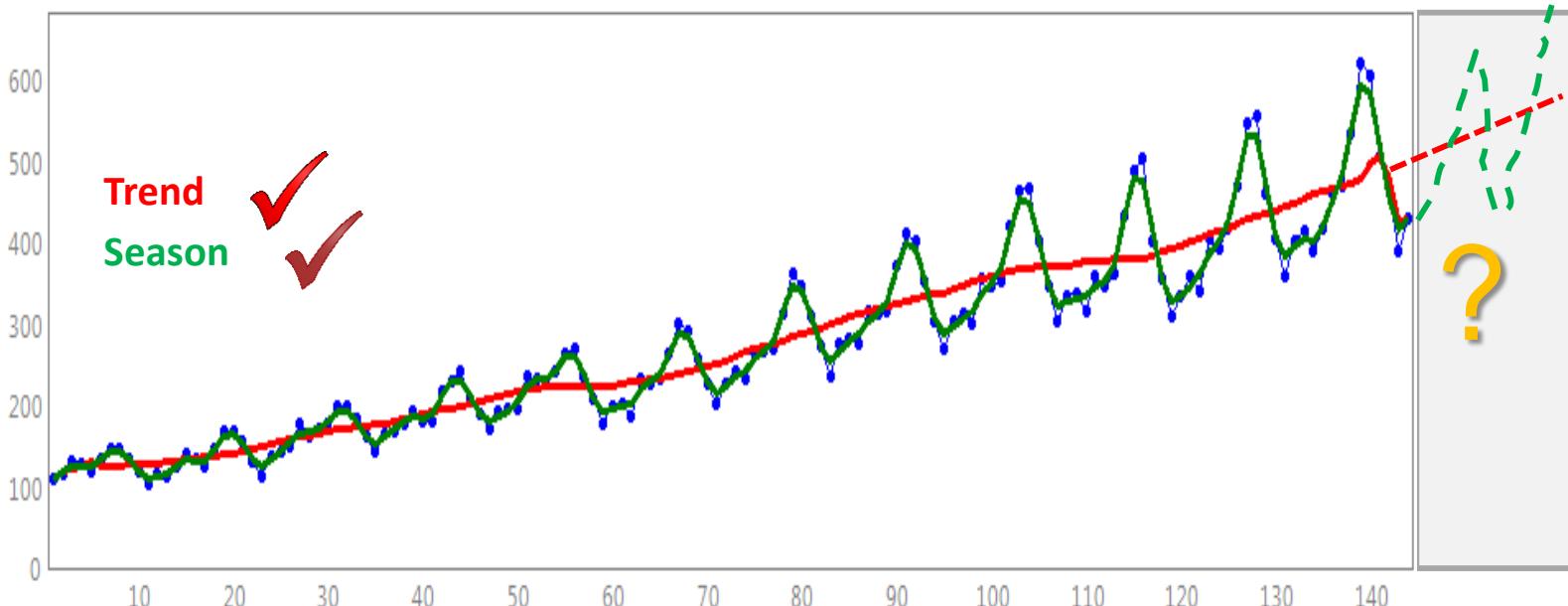


"Estimation how the sequence of observations
observed in the past will continue into the future"
[Makridakis, Wheelwright, Hyndman, 1998]

What is Forecasting?



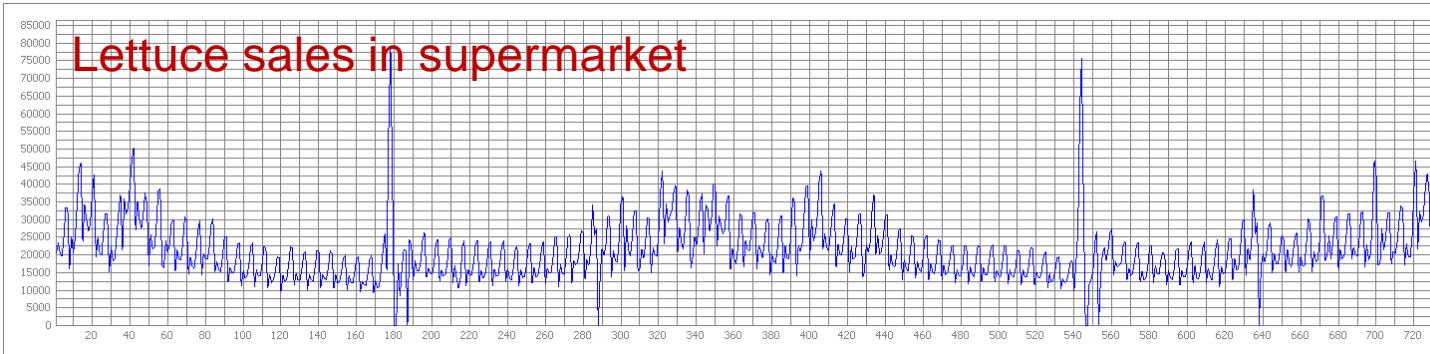
What is Forecasting?



What is forecasting? → A process perspective

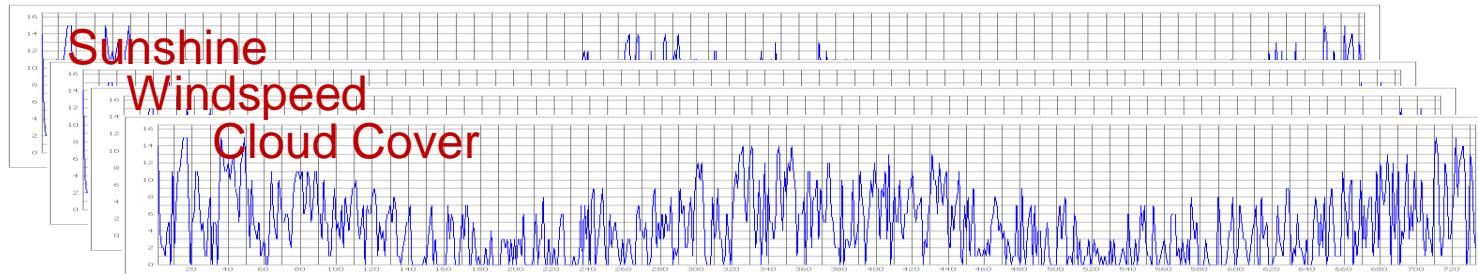
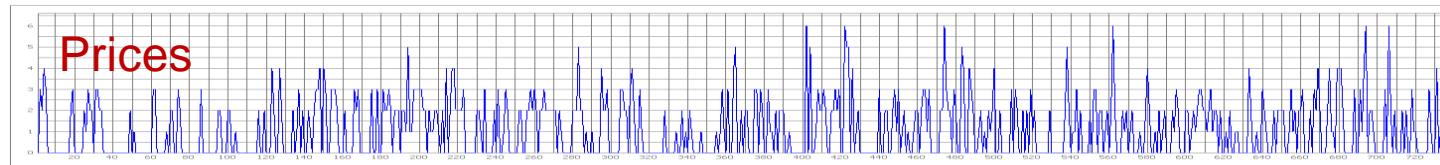
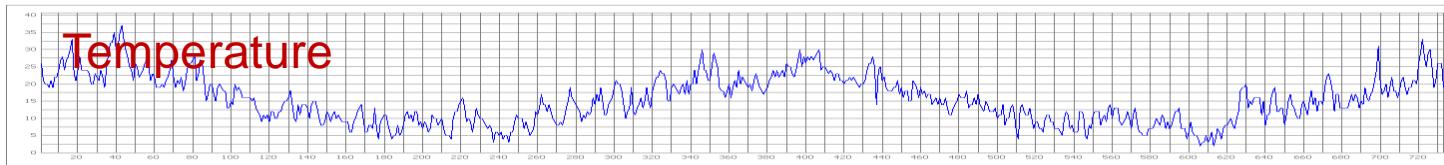
1. Identify systematic pattern in past historical data
2. Select & Parameterise an adequate model(-set)
3. Execute forecasting model → extrapolate structure into future
4. Assess the accuracy of the model(s in set), select model etc.

What is Forecasting



?

How will it continue?





What is Forecasting

Past sales

Period 10	91.36
Period 9	100.77
Period 8	87.85
Period 7	88.86
Period 6	99.93
Period 5	115.32
Period 4	92.30
Period 3	103.71
Period 2	97.74
Period 1	111.17

Interval or nominal scaled independent variable(s)

In statistical terms?



Future sales

Period 11	100.00
Period 12	100.00
Period 13	100.00
Period 14	100.00

Interval scaled variable(s)

From Wikipedia, the free encyclopedia

In statistics, regression analysis is a statistical technique for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. Most commonly, regression analysis estimates the conditional expectation of the dependent variable given the independent variables — that is, the average value of the dependent variable when the independent variables are fixed. Less commonly, the focus is on a quantile, or other location parameter of the conditional distribution of the dependent variable given the independent variables. In all cases, the estimation target is a function of the independent variables called the regression function. In regression analysis, it is also of interest to characterize the variation of the dependent variable around the regression function, which can be described by a probability distribution.

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used

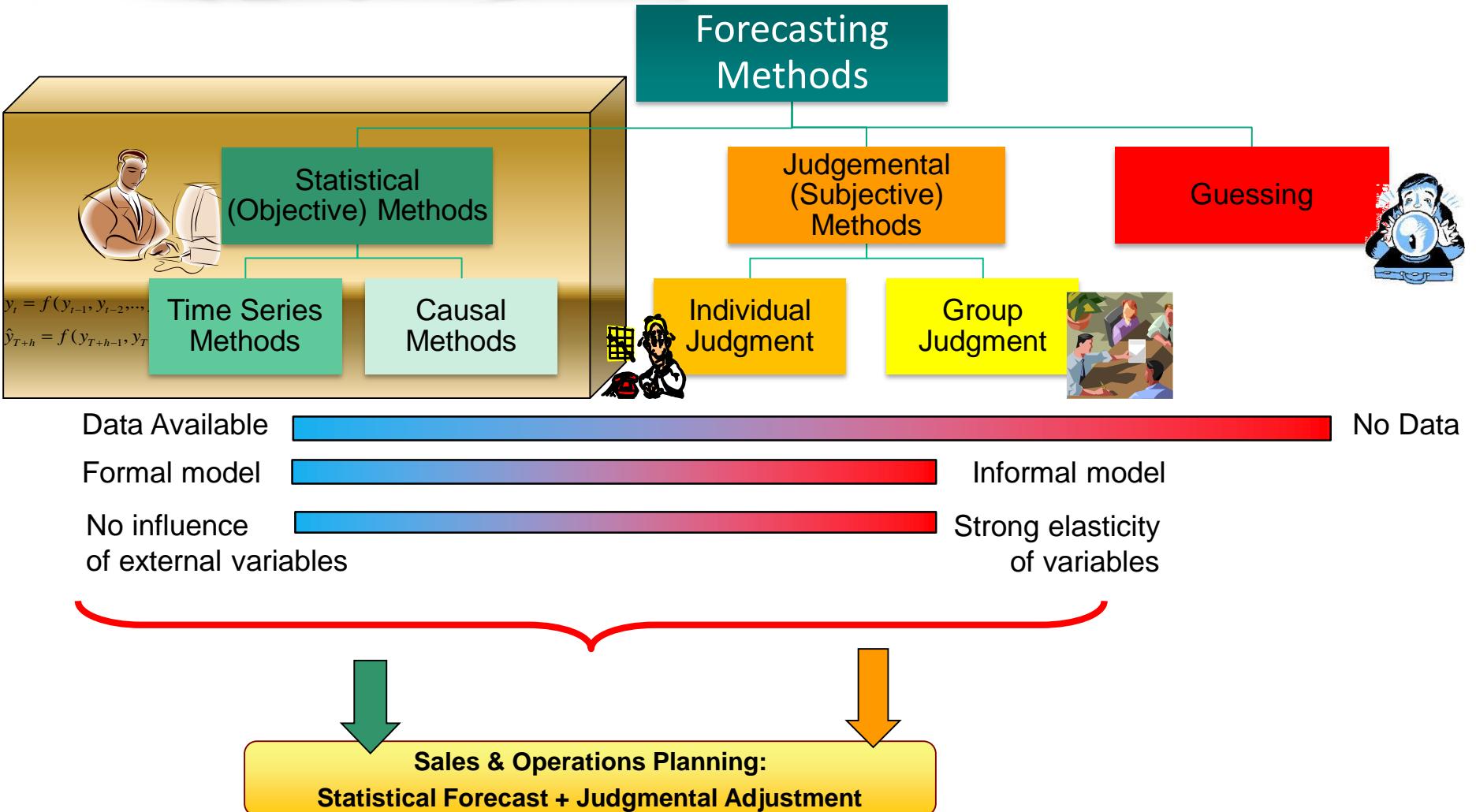
→Estimate (future realisations) of an interval scaled variable
→regardless of time-lagged observations → Regression !



Love Regression?



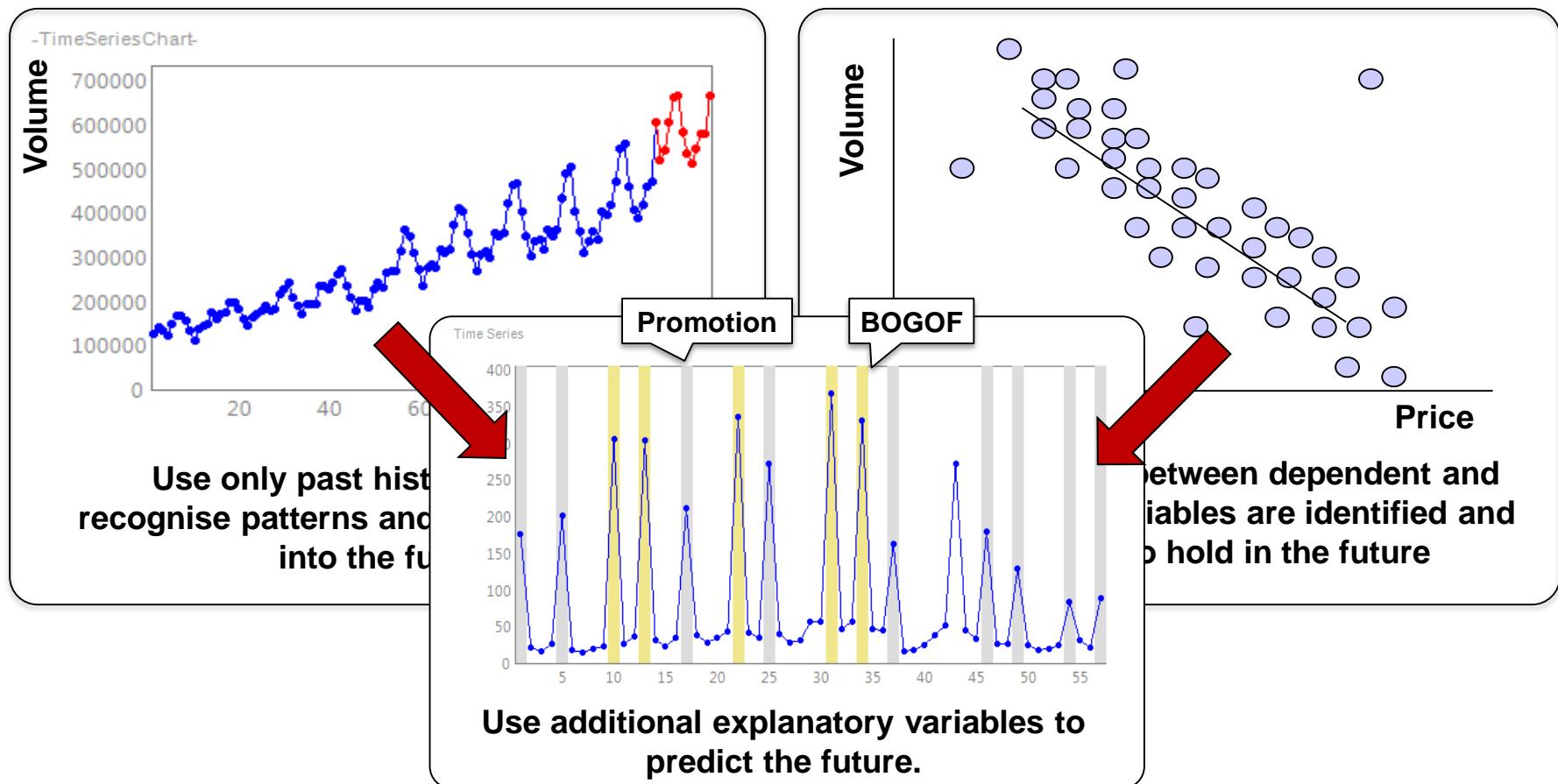
Forecasting Methods





How? Forecasting Methods

Time Series (Extrapolative) vs. Causal (Explanatory) Methods

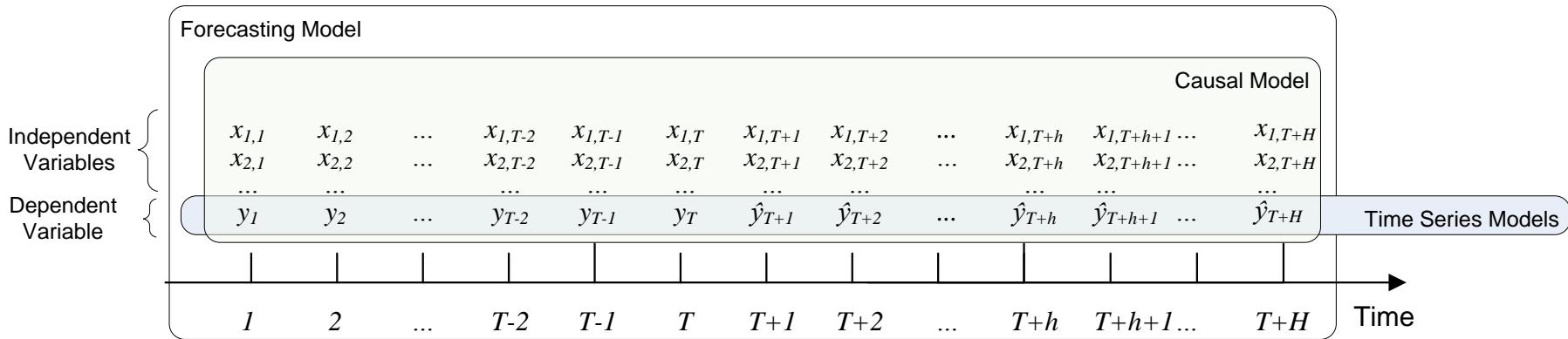


- No a-priori superiority of either approach – depends on problem & data
 - how is this different to “regression” you know?

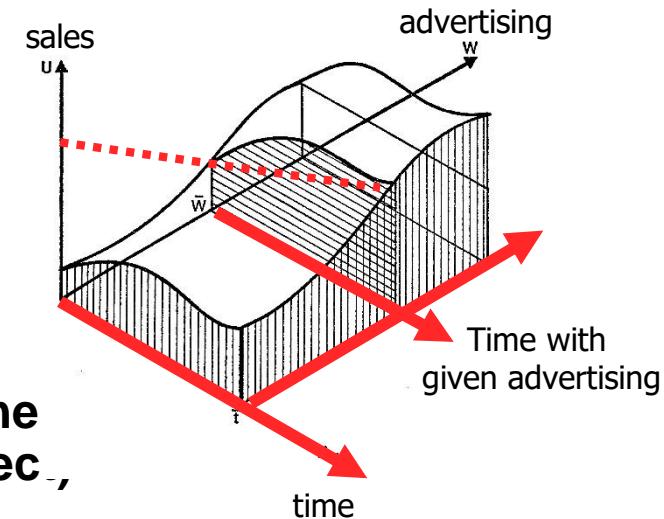


Statistical Methods

Time series analysis vs. causal modelling

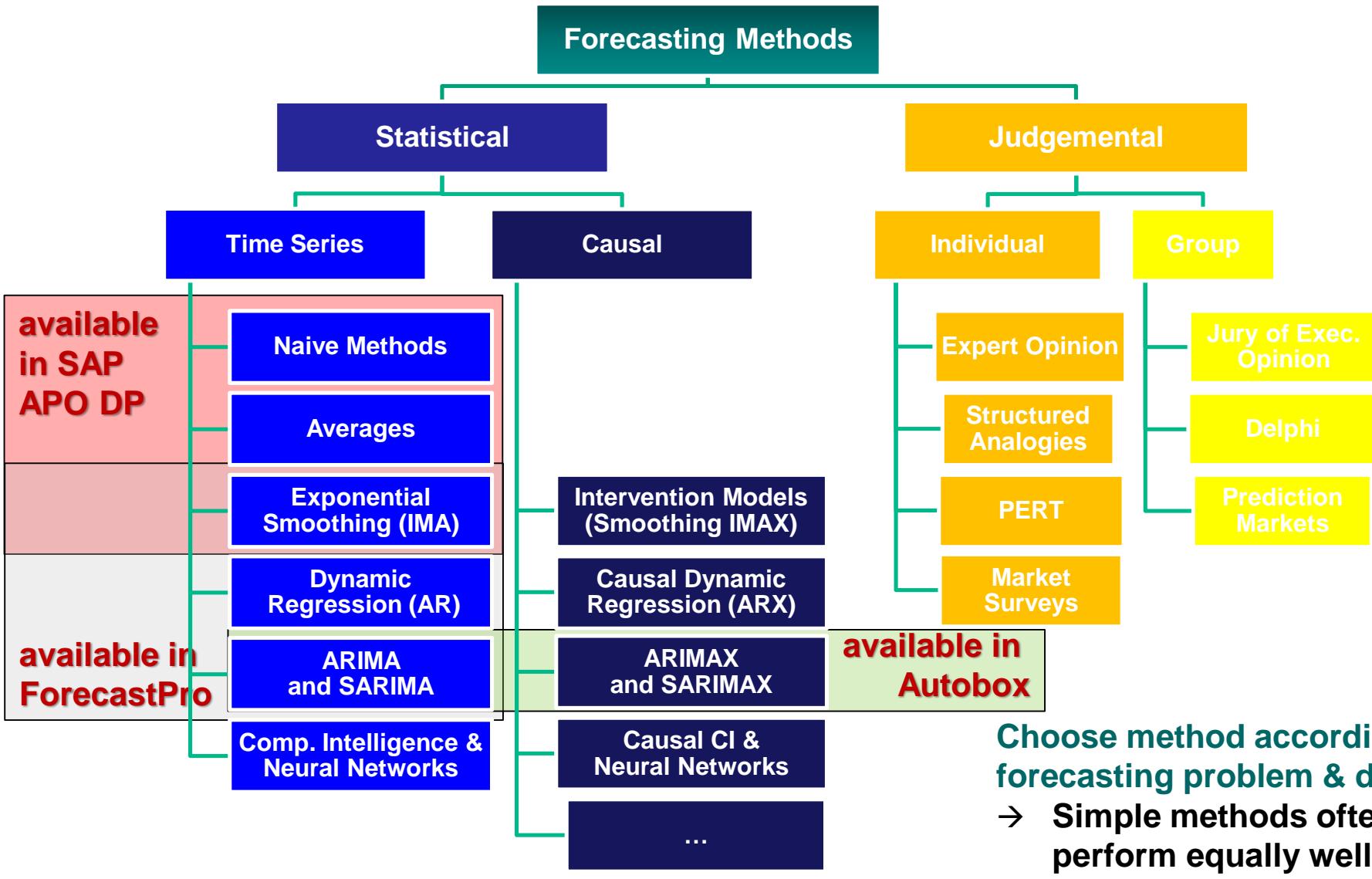


- **Time series prediction (Univariate)**
 - Assumes that data generating process that creates patterns can be explained only from previous observations of dependent variable
- **Causal prediction (Multivariate)**
 - Data generating process can be explained by interaction of causal (cause-and-effect) independent variables

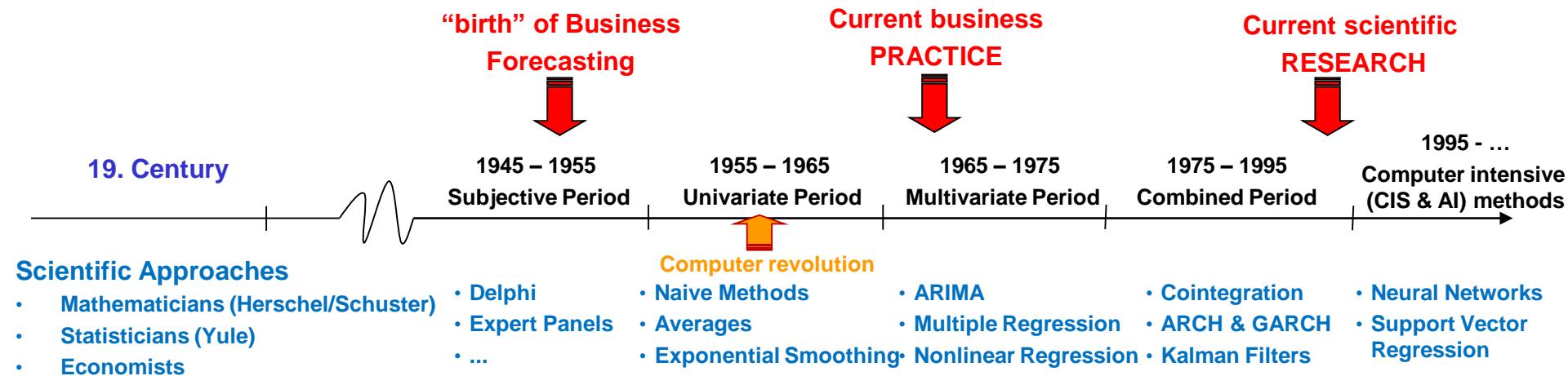




Forecasting Methods



Advances in Forecasting – the History of Forecasting?



- ▶ **Efforts since beginning of mankind in various disciplines**
 - Astronomy (Ptolemeus 100 A.D. → Copernicus → today ?)
 - Movement of objects (Aristoteles → Gallileo → Newton → Einstein → today ?)
 - Fields: sunrise, tides, trajectory of satellites, speed of falling objects, rainy weather ...
- ▶ **Only limited Applications before 1940**
 - no reliable data sources
 - no computing power without computers
- ▶ **1940-1960 first applications of scientific / formal methods in practice**
 - WWII & REVOLUTION commercially usable computers
 - continuous development in data analysis and forecasting
- ▶ **1950s change of market structure → required sales forecasting!**

→ 30 year GAP between development and use of methods
 → “Simple” methods dominate applications and accuracy

Advances in Forecasting – academic survey evidence

► Fildes (1979) → State of the art extrapolative methods

- Additions to Exponential Smoothing [Brown (1956, 1963), Holt (1960)] (= Filtering)
 - ARIMA-Models (Box & Jenkins (1970, 3rd ed. 1994)) (= FIR & IIR-Modelling)
 - State Space Models (Mehra (1979), Harvey (1984))
 - Bayesian multi-state Kalman filtering (Harrison & Stevens (1971))

► Fildes (1985) → State of the art econometric methods

- Emphasis on regression model dynamics
- General-to-specific modelling (GETS) [Hendry (1985) → Gilbert (1986)]

► Fildes, Crone et al. (2008) → method extensions & applications

- **Extensions of extrapolative methods**
 - Damped Trend ES (Gardner & McKenzie, 1985) & State-space formulation of ES
 - Rule-Based Forecasting (Collopy & Armstrong, 1992)
 - Selecting & Combining Methods (Bates & Granger, 1969), Fildes, 1989)
 - Development of computationally intensive methods
- **Extensions of econometric methods: Dynamic & Heteroscedasticity**
 - Cointegration (Engle & Granger, 1987) & Spurious relationships in regression methods
 - Modelling & Forecasting heteroscedastic error variances ((ARCH, GARCH)) (Engle, 1982)
 - Density Forecasts (Tay & Wallis, 2006) & Quantile Regression (Koenker, 2002)
- **Applications in Operations & Marketing**
 - Process of forecasting: combining Statistical forecasts with Expert Judgement
 - Intermittent Demand & Demand uncertainty in Supply Chains (Collaboration & Infosharing)
 - New Product Forecasting (Diffusion & Trend curve models) & Market share models



Advances in Forecasting – the last 25 years



- ▶ **Founding of the International Institute of Forecasters**
→ “unify the field and bridge the gap between theory & practice”
- ▶ **Publication of 2 core interdisciplinary journals**
 - International Journal of Forecasting 1985, Journal of Forecasting 1982
 - Various publications in Operational Research, Management Science, Finance, Econometrics, Economics, Marketing, Retailing etc.
- ▶ **Annual conference**
 - The International Symposium on Forecasting (ISF) by IIF
- ▶ **4 Nobel Prices for research in forecasting & related areas**
 - Clive Granger & Robert Engle
 - Daniel Kahneman
- ▶ **Practitioner oriented activities**
 - Foresight – The Journal of Practical Forecasting
 - Professional conferences (Forecasting Summit, commercial IBF & software company conferences)



→ Forecasting has developed as a discipline of its own
→ State of the art in 25 year issue of the IJF

AI in Forecasting Practice?

Practitioner Survey

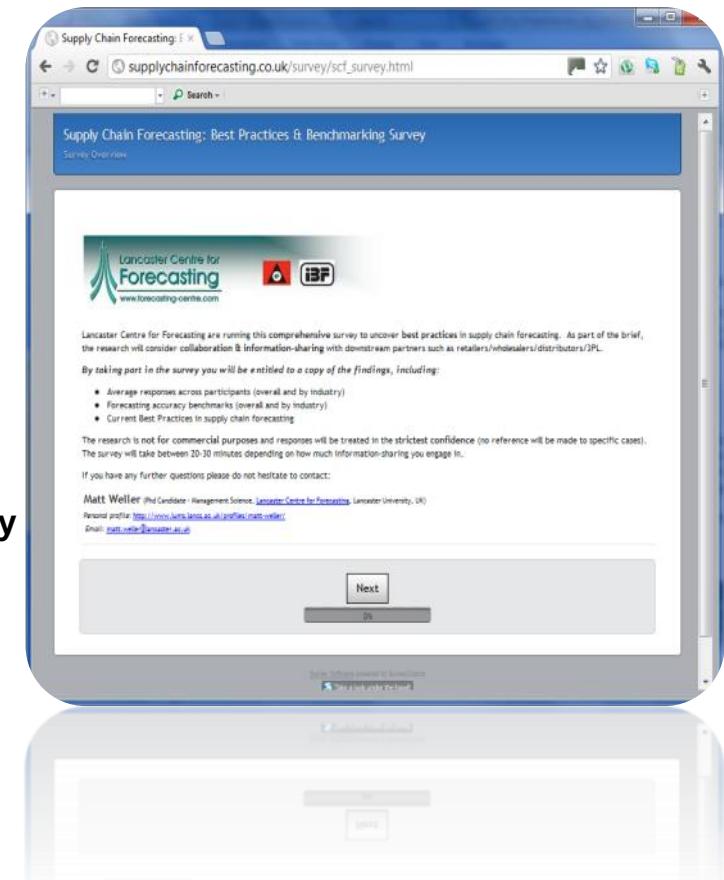
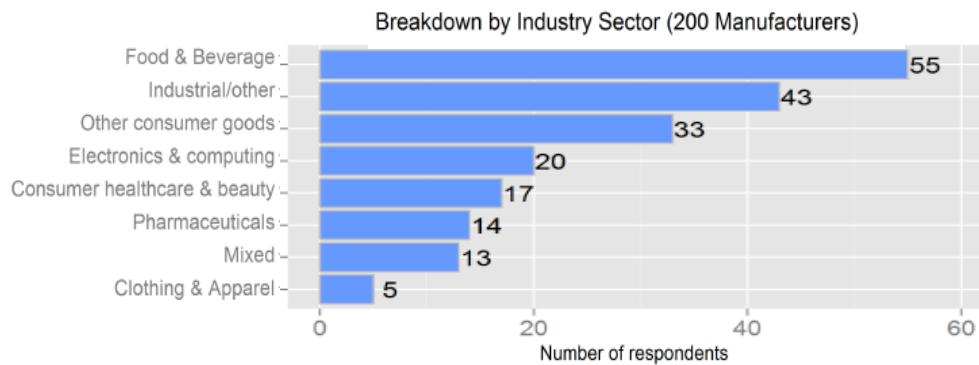
- Target group: demand planning & forecasting professionals (in manufacturing)
- LCF Mailing list, forecasting lists / blogs (ISF, SAS), 100s of LinkedIn Groups, 2000+ personalised LinkedIn invites

→ 540 responses (representative)

→ 200 valid surveys in manufacturing

Robust Questionnaire Design

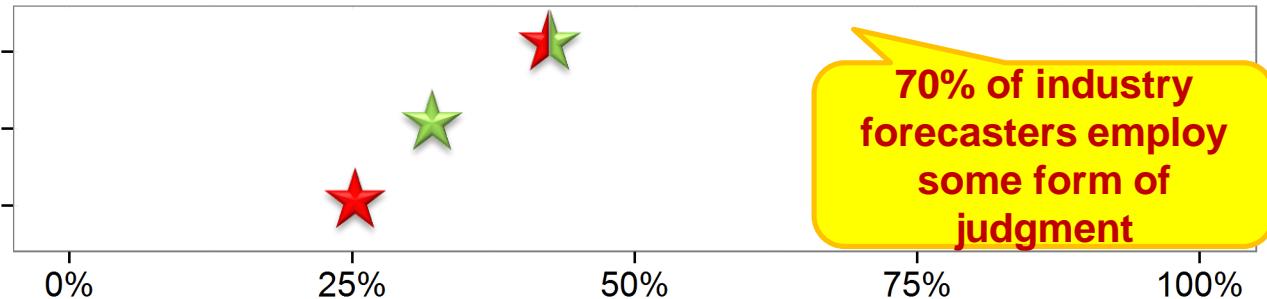
- Pilot study in 2011 (to ensure validity)
- Final pre-version pre-tested with 18 FMCG forecasters
- Conducted January 2012-August 2012
- Validity for large manufacturers active in the FMCG / CPG industry



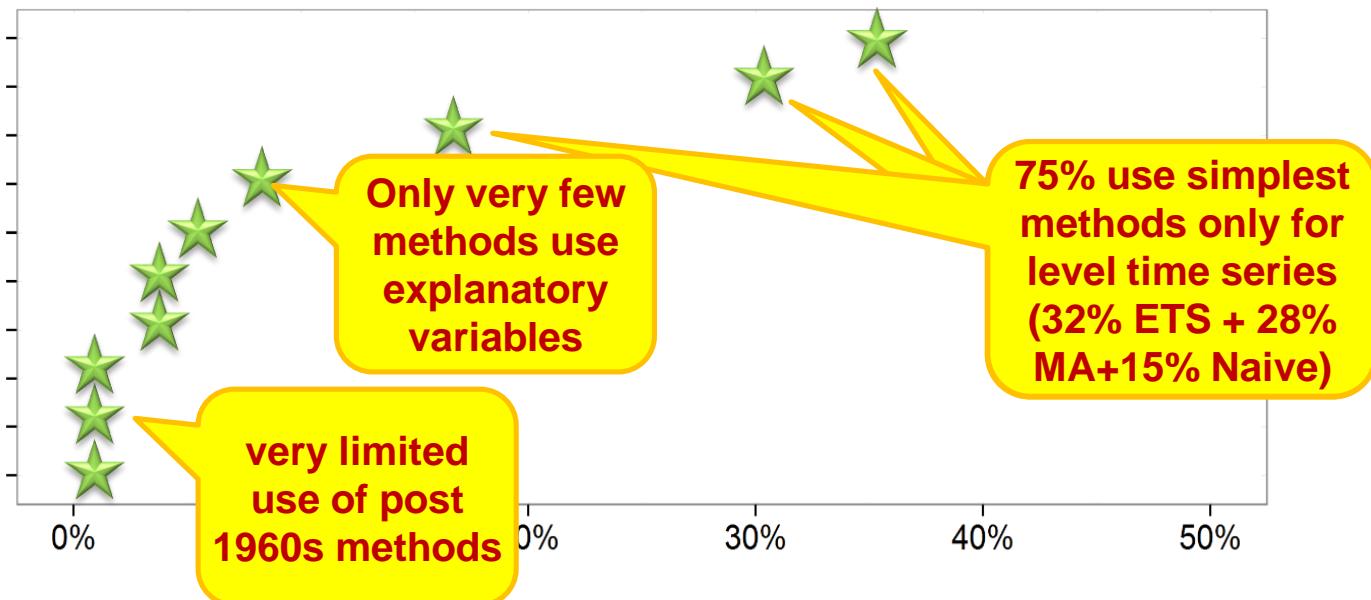
Evidence from Forecasting Practice?

- 1
- 2
- 3

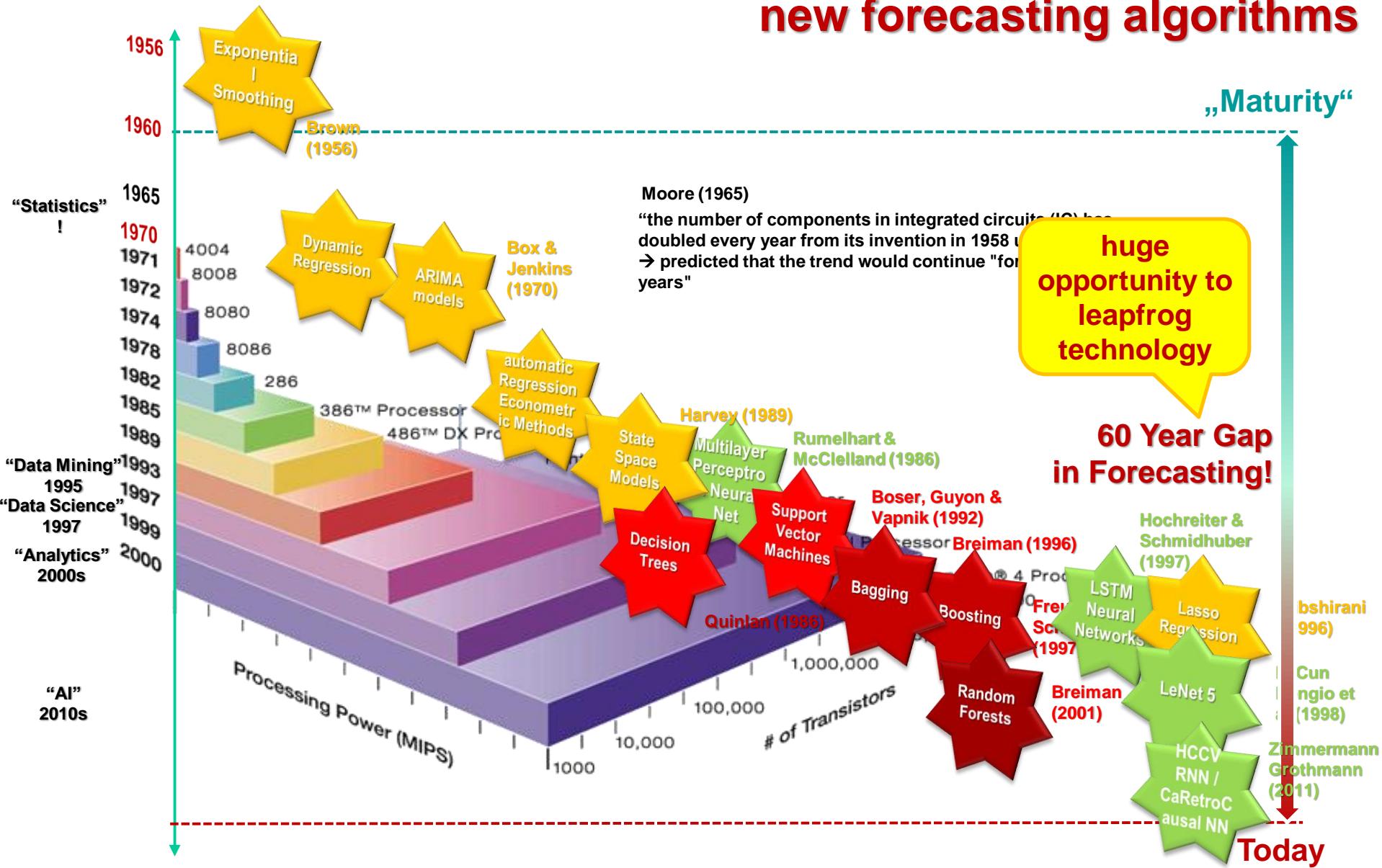
What approach do you use in forecasting?



What statistical forecasting methods do you use?



Compute power & new forecasting algorithms



Improving Forecast Accuracy with the latest in Data Science, Artificial Intelligence & Big Data?

A story of learnings from running many POCs at Janssen



Andrea Franco
Demand Management
Janssen Supply Chain



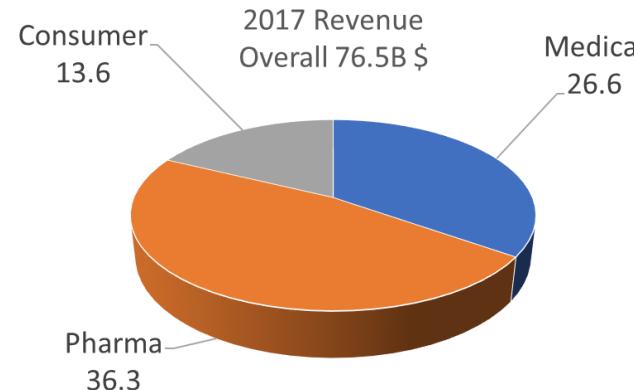
Dr. Sven Crone
Assistant Professor, Lancaster University
Co-director, Lancaster Centre for Forecasting
Founder, iqast



About Johnson & Johnson

Healthcare company founded in **1886** in NJ, USA

250 subsidiary companies in **60** different countries employing almost **130'000** employees

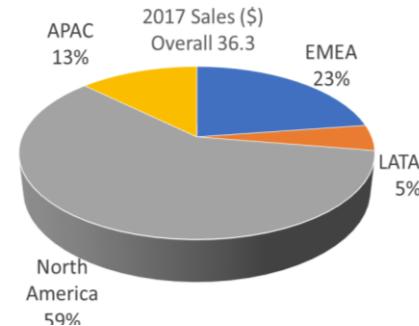
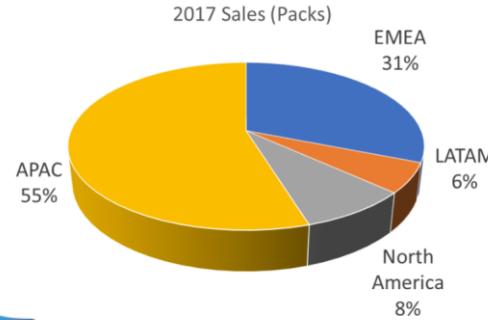


About Janssen

Pharmaceutical company, joined J&J in 1963

Ranked #4 pharma company by revenue in the world

Overall sells **145** brands for a total of **5'500** SKUs covering different therapeutic areas (cardiovascular diseases, immunology, infectious diseases, neuroscience)

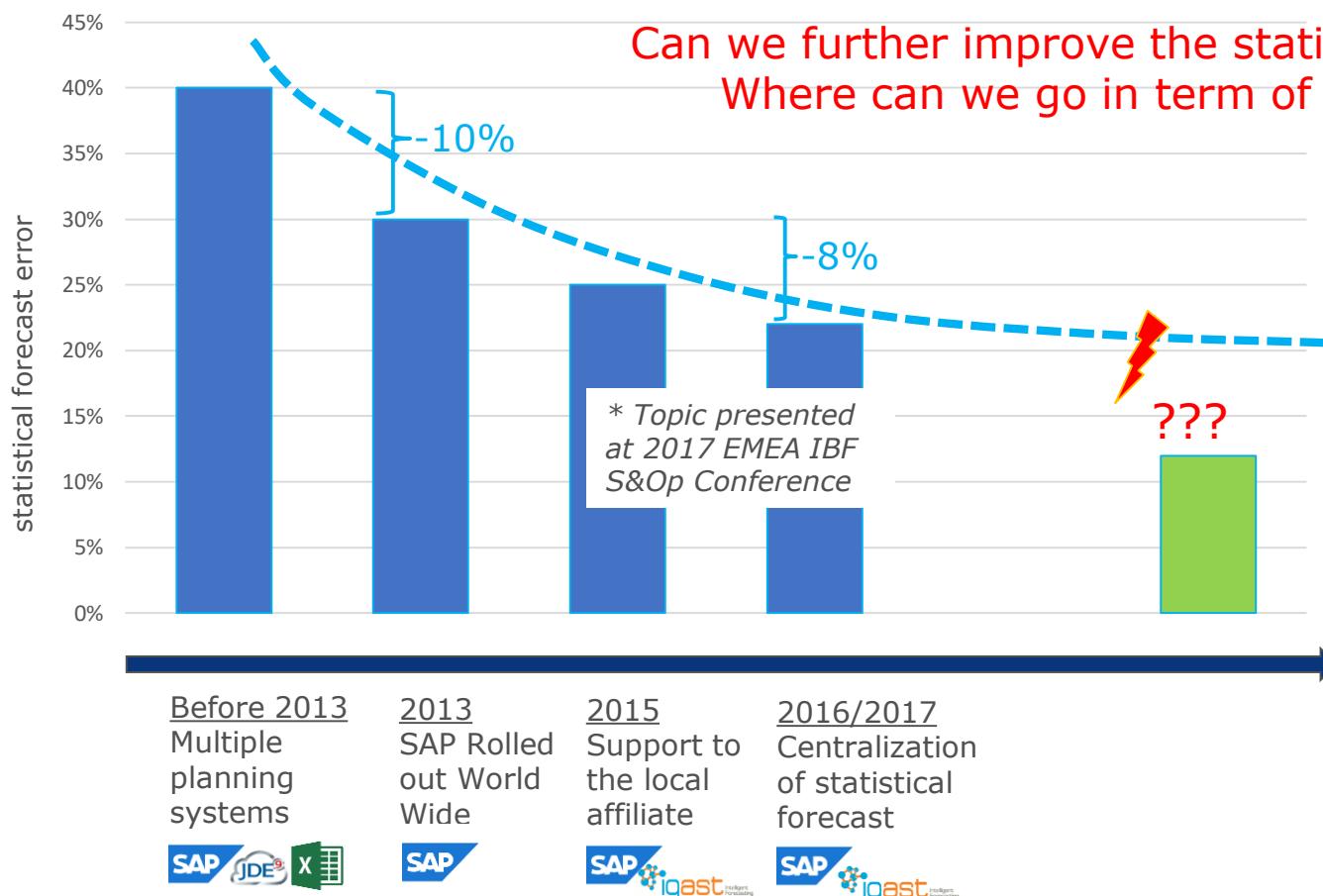


PHARMACEUTICAL COMPANIES
OF Johnson & Johnson

Journey of Statistical Forecast

Have we squeezed the most out of our current system & organization?

Can we further improve the statistical forecast?
Where can we go in term of accuracy?



Rule of thumb

FG: 1% MAPE -3 → 7M \$ Safety Stock Reduction
BULK: 1% BIAS-6 → 4M \$ Safety Stock Reduction
API: 1% BIAS-12 → 5M \$ Safety Stock Reduction

Advance Analytics and Forecasting projects

How can we improve further the statistical forecast?

Let's test new advance technologies that are now available in the market and internally!

Data Scope (3 months to collect the data INTERNALLY)

5 EMEA countries → 500 SKUs

2013	2014	2015	2016	2017 (may)
Monthly Shipments and Orders at affiliate-SKU level		Daily Shipments and Orders at customer-SKU level		

- + Reduced # of SKUs + Granularity + Mature affiliates + Single dataset to compare solutions
- Reduced # of SKUs - Messy Data - No external data

Technology

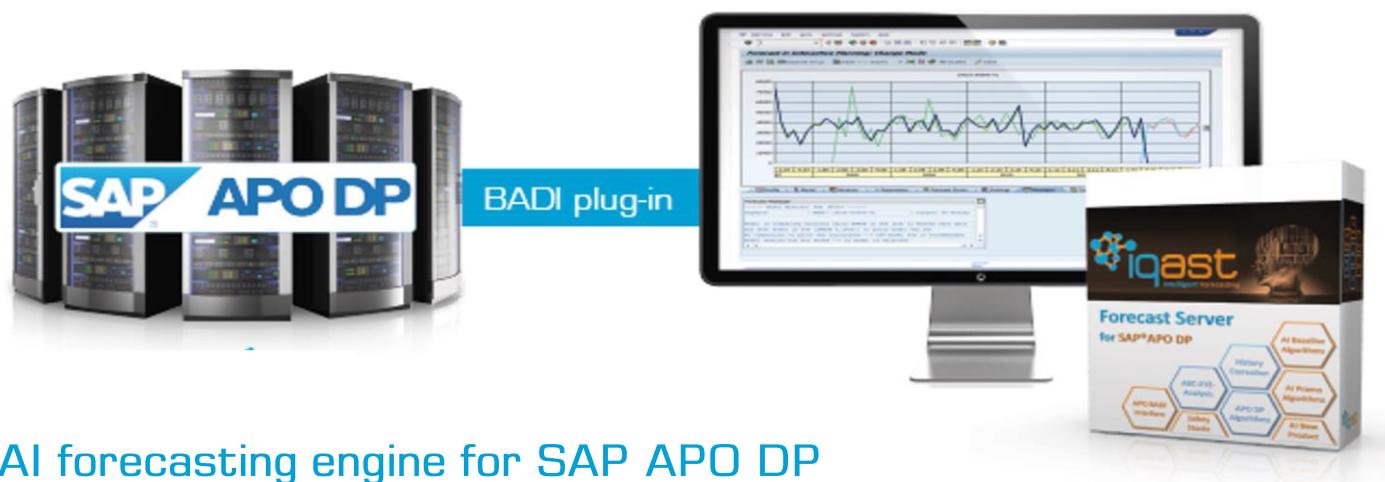
Provider	Technology	Duration [months]	Cost
1	Not Shared	7	Free of charge
2	Regularized ETSx with Regularization and Cross-Validation	6	As a part of a bigger project
Iqast	Artificial Neural Network (ANN)	3	Free of charge
4	Random Forest and Ridge Regression	7	Free of charge



MSc Analytics Master Project
Pharma Forecasting using Artificial Neural Network
@Janssen (a Johnson & Johnson company)



pioneers in forecasting with artificial intelligence



New AI forecasting engine for SAP APO DP

- ❖ intelligent model selection
- ❖ intelligent forecast algorithms
- ❖ intelligent safety stocks
- ❖ intelligent history correction



Bayer Business
Services

Johnson & Johnson Janssen



Masters project (MSc Analytics)

- Master project of 13 weeks with Iqast's expertise and Janssen's support



Objectives

- Investigating Artificial Neural Network (ANN) for forecasting Janssen sales
- Identifying relevant Causal variables
- Exploring different time aggregations (Daily, Weekly, Monthly)

Limited Scope POC

- Top 10 SKUs (by Volume) for two countries: Germany and France



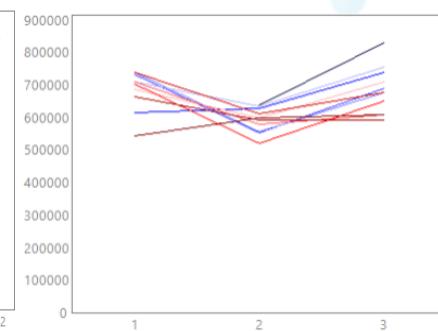
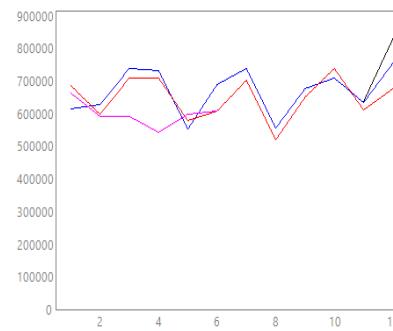
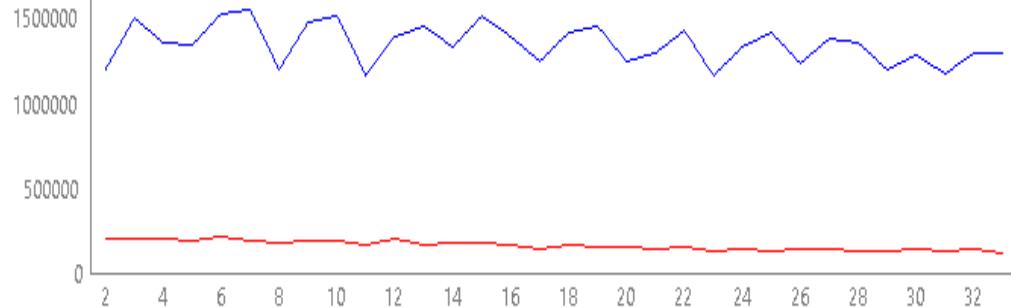
Motivation

- ANN are universal approximators
- ANN are capable of modelling non-linear behaviours
- ANN are flexible and have good generalisation properties

National Aggregation

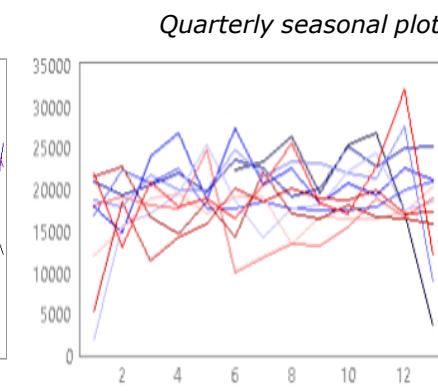
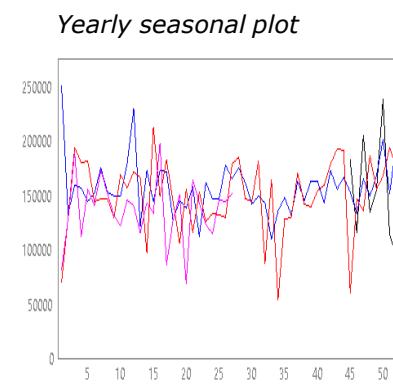
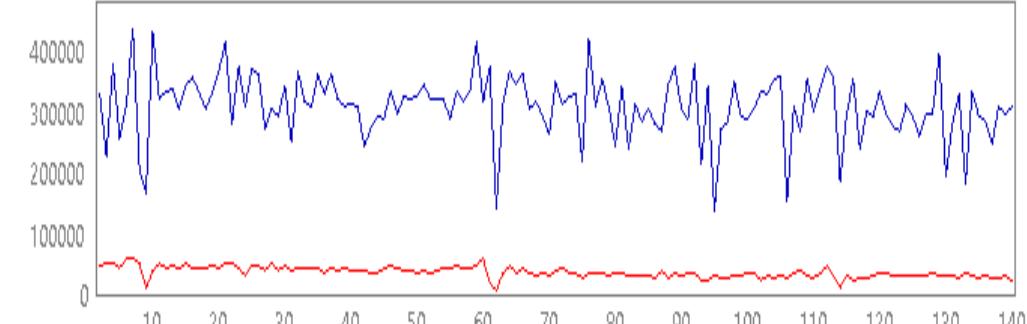
Time Series

Monthly



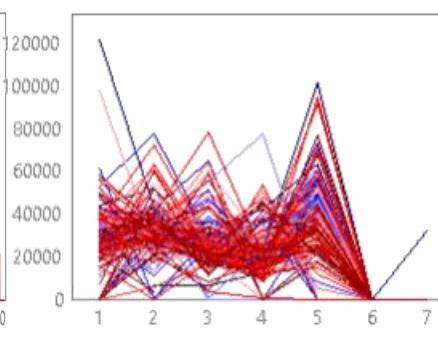
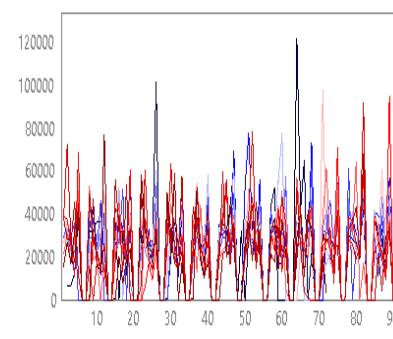
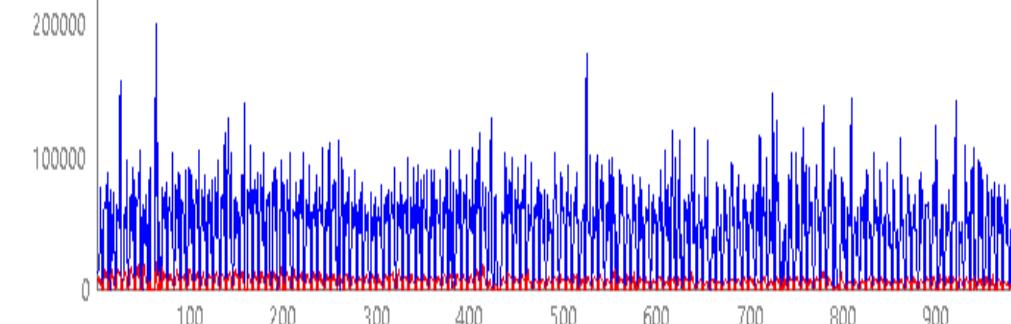
Time Series

Weekly



Time Series

Daily



-- French Total Market (163 SKU)

-- German Total Market (257 SKU)

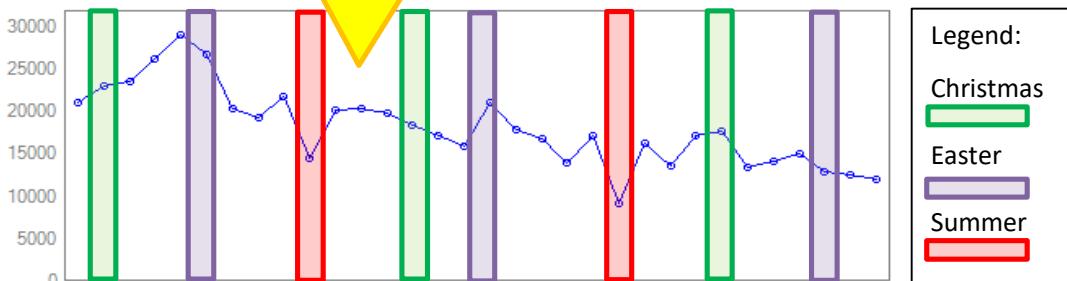
Data Exploration

Bank Holidays

Monthly

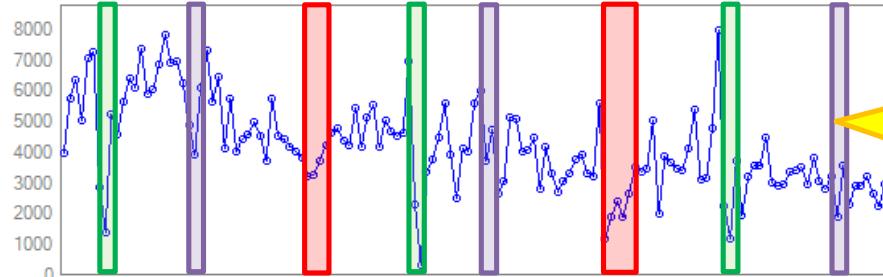
Not affected by bank holidays or working hours

Binary Bank Holidays



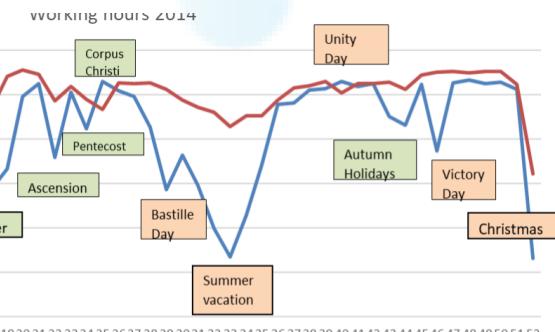
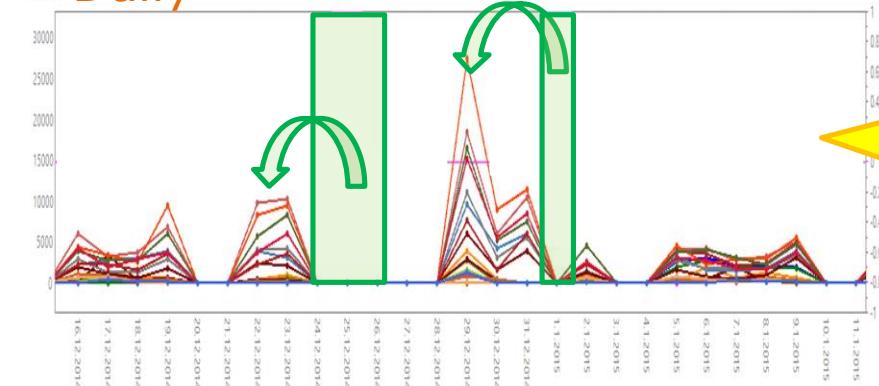
Weekly

Clearly affected by bank holidays or working hours



Daily

VERY clearly affected by lags of bank holidays or working hours



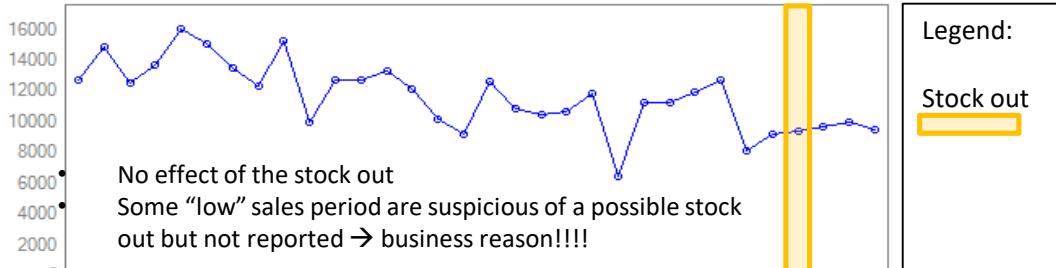
Different facts has been found correlating bank holiday and working hours at different granularity

Data Exploration

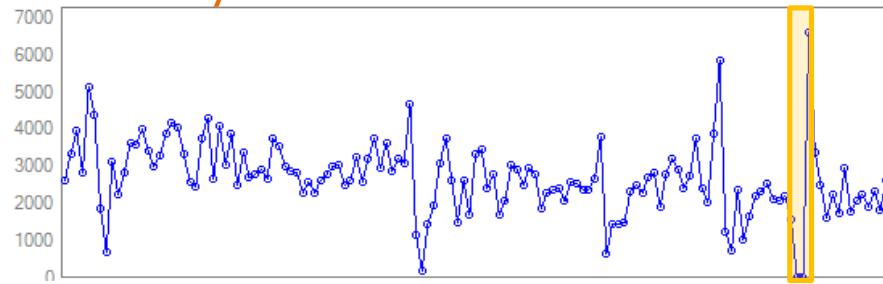
Out of Stocks

Monthly

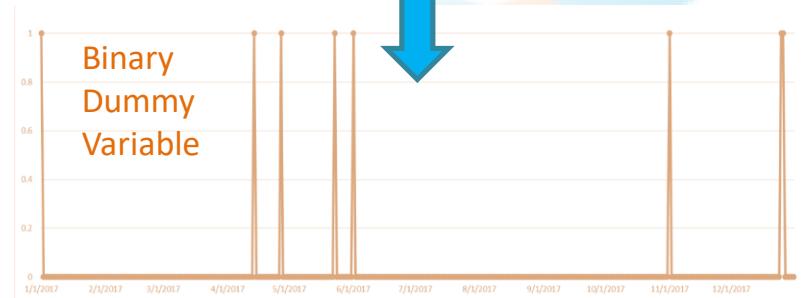
Stock Out (Example SKU 386365):



Weekly

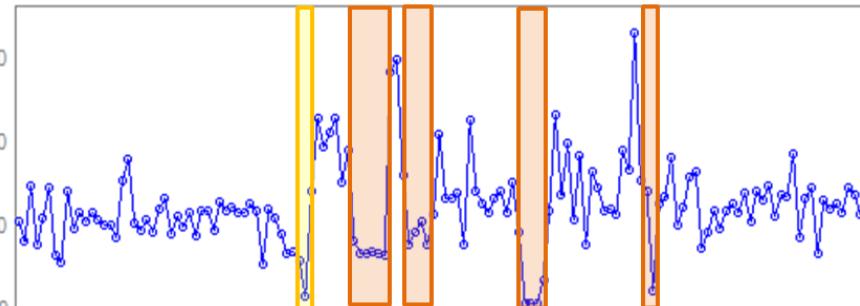


Stock Out (SO) report					
Customer	SKU	SO Begin	SO End	Days	Reason
61928	128482	4/4/2017	4/6/2017	2	Supply
88457	48754	8/1/2017	8/4/2017	3	Demand



Data Quality?

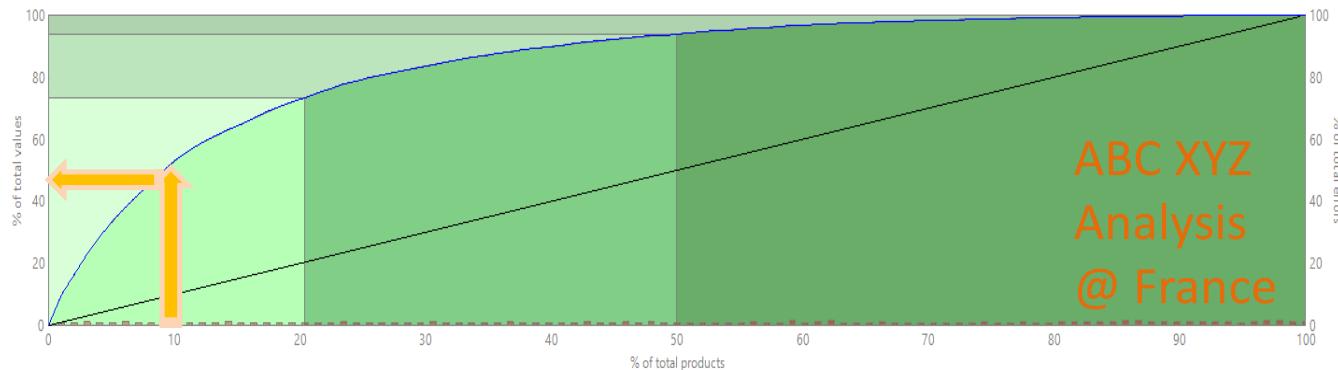
- Clear evidence of a drop when a stock out occurs
- Suspicious "low" sales are possible stock outs, but not reported



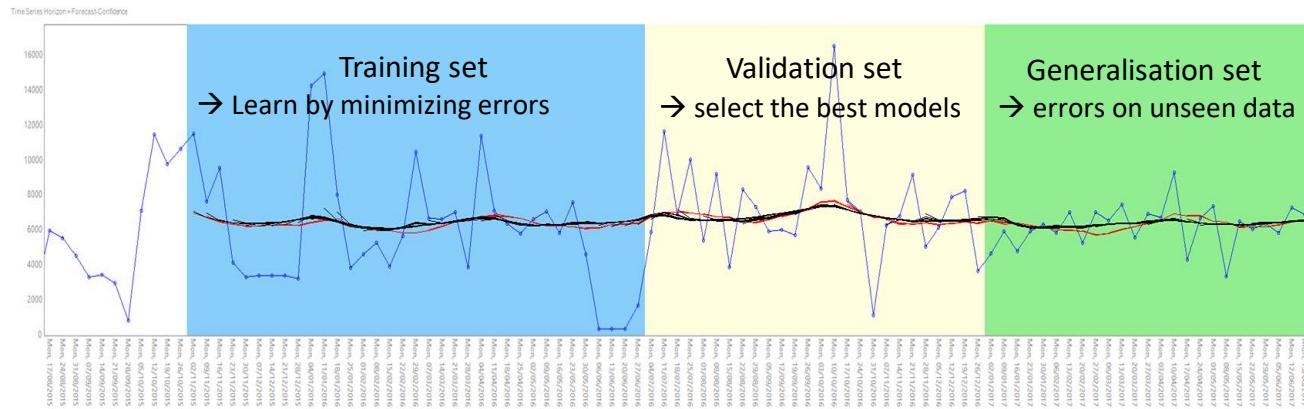
Experiment Design

Neural Networks

ABC Analysis



Data partition



Benchmark - Models

- Näive & Seasonal Naive
- Exponential smoothing
- Janssen SAP/APO forecast
- Janssen consensus forecast

Subsample selected:

- 10 SKUs from France (= 46% of total Volume)
- 10 SKUs from Germany (37% of total Volume)

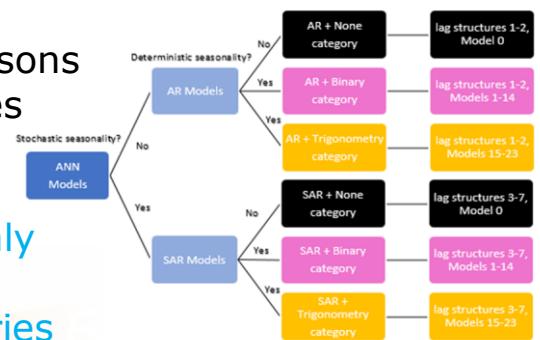
Valid Evaluation

- holdout evaluation
- multiple steps ahead (t+3)
- rolling time origins

Neural Network Models

- Deterministic & stochastic Seasons
- Bank Holidays & Holiday Leaves
- Out of stocks

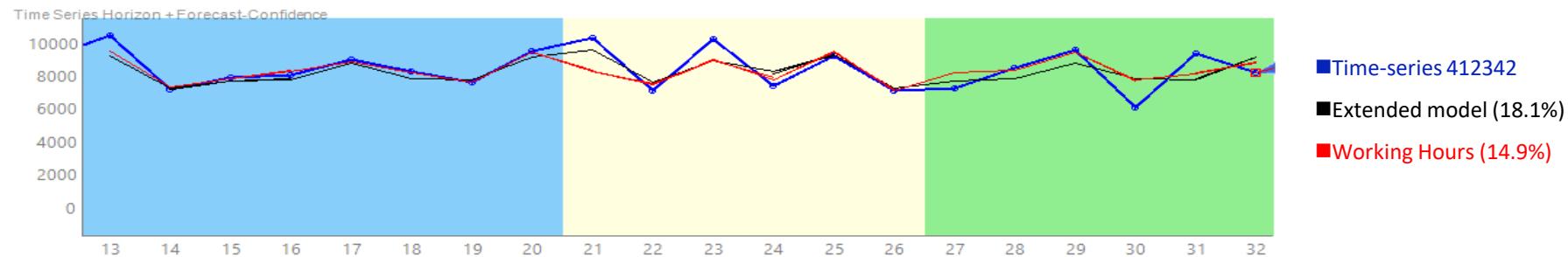
→ 93 networks variants per monthly & weekly & daily frequency
→ 100,000s of Neural Nets per series



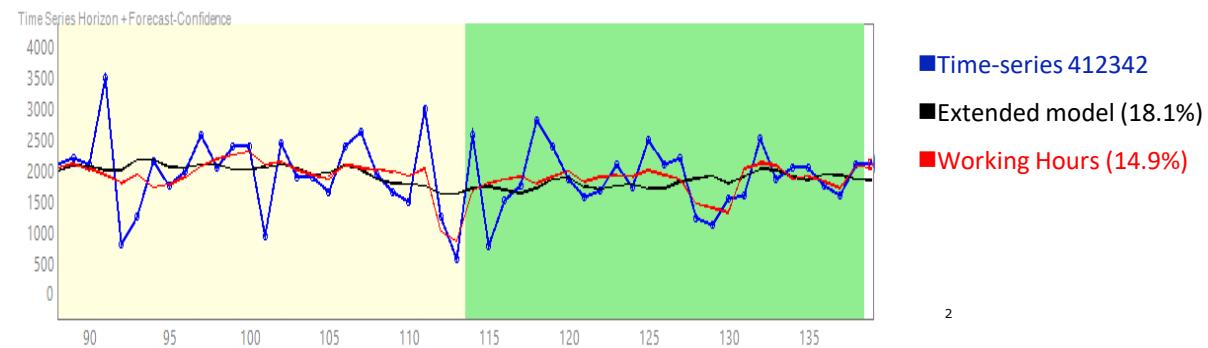
Multivariate ANN – Bank Holidays – Example SKU 412342



Monthly granularity:

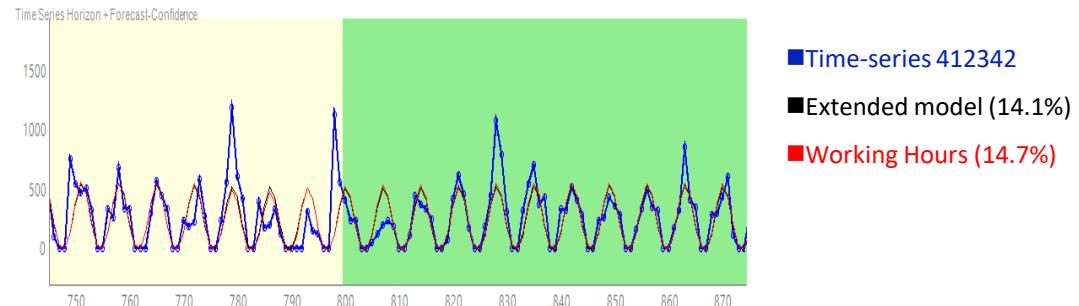


Weekly granularity:



2

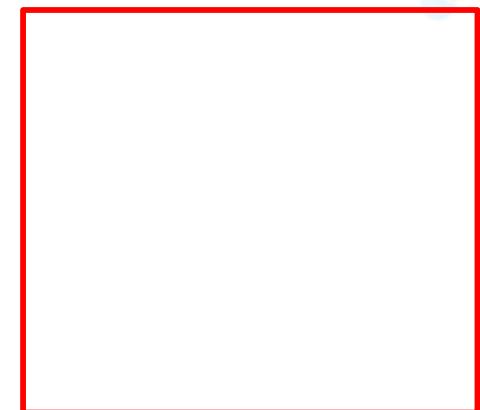
Daily granularity:



Accuracy Results

MAPE improvements

WMAPE h4 (%)	Janssen (Planner)	SAP External methods (reference)	Naïve	Seas. Naïve	ExpSmo iqast	ANN All
Monthly	12.0	14.1	17.6	15.3	14.5	13.1
Weekly						
Daily						



Conclusions

- Neural Networks outperform all other methods against SAP APO models (and Janssen planners!)
- Normally errors increase with time frequency – but not for Neural Networks!
- ANN are capable of good generalization and capture trend and seasonality

Causal Bank Holiday & Stock-out Models

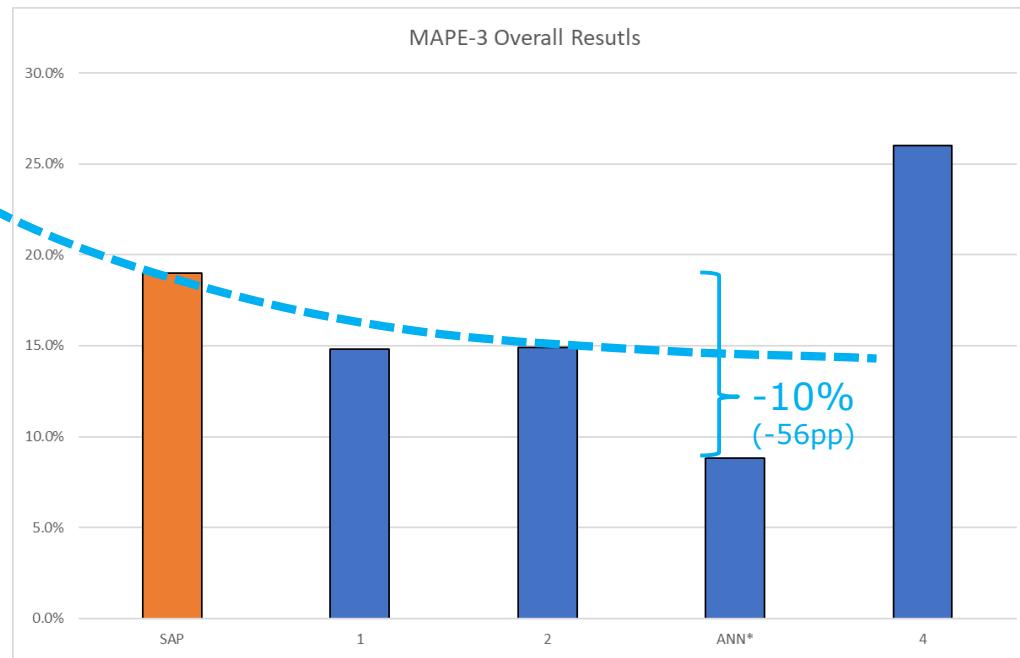
- Bank Holidays improve weekly & monthly accuracies (no leads & lags modelled yet → improve)
- Working Hours seem to worsen accuracy (not used in conjunction with bank holidays yet → imp!)
- Stock out periods display mixed results: weekly & daily improve (only 3 SKUs had stock out!)
- Results vary across individual time series

+ the forecasts are more meaningful & interpretable!

Other Project Results

- All other providers tested on a bigger scope than ANN
- All provide a 12 months rolling forecast to evaluate performance over an year
- All found monthly data to be the best, only ANN prefers weekly

Provider	Technology
1	Not Shared
2	Regularized ETSx
Iqast	Artificial Neural Network (ANN)
4	Random Forest and Ridge Regression



- Provider 1 and 2 have good accuracy improvements at aggregate and single SKU level
- Provider 4 provides poor results

But....we learn a lot from all the PoC, much more the forecast accuracy improvements



Homework!

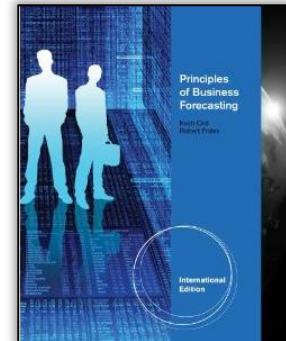
MUST HAVE (!): Principles of Business Forecasting

1. **Recap Lecture 1 (today):**

Read Chapter 1 (complete: pages 2-16)

2. **Prepare Lecture 2 (next session):**

Read Chapter 2 (complete: pages 20-41)
and Chapter 6 (only pages 152-154 on ACF)



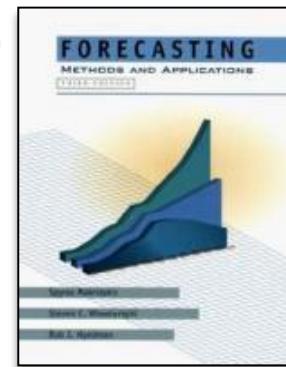
MUST HAVE (!): Forecasting Methods & Applications

1. **Recap Lecture 1 (today):**

Read Chapter 1

2. **Prepare Lecture 2 (next session):**

Read chapter 2 → Skip sections 2/4 - 2/6 (for later)
Read chapter 3 → Skip sections 3/5 – 3/6



NICE TO HAVE

1. Read Fildes, Nikolopoulos, Crone et al. (2008)

2. Read Fildes (1979) State of the art extrapolative methods

3. Read Fildes (1985) → State of the art econometric methods

Questions?



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