Ph.D. Program in Transportation Systems

Transport Demand Modeling

Filipe Moura

Session 1

Presentation, Objectives and evaluation methods
What is a model? Application limits and interpretation

Objectives

- Be capable of understanding and applying the quantitative transport modeling techniques
- Know how and when to apply the different modeling techniques
- Being able to analyze and communicate the results obtained by each modeling technique
- Being able to apply the results obtained in the elaboration and design of transport public policies and corresponding evaluation

Learning Materials

- The learning materials are available in the course webpage:

  https://fenix.tecnico.ulisboa.pt/disciplinas/MPTra/2020-2021/1-semestre

  And here: https://github.com/U-Shift/Transport-Demand-Modelling

The following elements will be available

- Lecture slides
- Recommended Readings
- Examples and Problems Databases
- R Codes
- Evaluation rules

Evaluation process

- **Continuous evaluation (60%):**
  - Resolution of 4 exercises (one for each topic) in groups of two students;
    - Exercise 1 – Linear Regression;
    - Exercise 2 – Generalized Linear Models;
    - Exercise 3 – Panel Models;
    - Exercise 4 – Discrete Choice Models.

- **Final exam (40%):**
  - Covering all the subjects. Focus on theoretical, methodological and conceptual aspects and in interpretation and communication of results obtained using modeling techniques. Minimum grade in the exam is 8.0/20.0.

Lectures: Detailed Program

Day	Hours	Subjects	Faculty
06-Oct	9h-11h	Presentation, Objectives and evaluation methods. What is a model? Application Limits and interpretation	FM/ GV (IST)
06-Oct	11h-13h	Sampling, statistical tests, Introduction to R	FM/ GV (IST)
13-Oct	9h-13h	Multiple Linear Regression	FM/ GV (IST)
20-Oct	9h-12h	Factor Analysis	FM/ GV (IST)
27-Oct	9h-12h	Cluster Analysis	FM/ GV (IST)
03-Nov	9h-12h	Generalized Linear Models	FM/ GV (IST)
10-Nov	9h-12h	Generalized Linear Models	FM/ GV (IST)
17-Nov	9h-13h	Panel Models	AR (FCTUC)
17-Nov	14h-16h	Panel Models	AR (FCTUC)
24-Nov	9h-13h	Discrete Choice Models	MG (IST)
24-Nov	14h-16h	Discrete Choice Models	MG (IST)
15-Dec	9h-13h	Ordered Choice Models	FM/ GV (IST)
22-Dec	9h-13h	Hazard-Based Duration Models	CR(LNEC)

Notes: FM – Filipe Moura; GV – Gabriel Valença (PhD Student); AR – Anabela Ribeiro; CR - Carlos Roque

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Lecturers

- **Faculties**
  - **Filipe Moura (coordinator)** (Associate Professor of ISTUL)
    - fmoura@tecnico.ulisboa.pt
    - https://ushift.tecnico.ulisboa.pt/team-filipe-moura/
    - https://fenix.tecnico.ulisboa.pt/homepage/ist14188
  - Anabela Ribeiro (Assistant Professor of FCTUC)
    - anabela@dec.uc.pt
    - https://apps.uc.pt/mypage/faculty/dec_anabela
  - Carlos Roque (Assistant researcher at LNEC)
    - croque@lnec.pt
    - http://www.lnec.pt/transportes/pt/equipa/carlos-almeida-roque/
- **Teaching assistants (PhD student at ISTUL)**
  - Miguel Costa
    - mncosta@isr.tecnico.ulisboa.pt; https://ushift.tecnico.ulisboa.pt/team-miguel-costa/
  - Gabriel Valença
    - gabrielvalenca@tecnico.ulisboa.pt; https://ushift.tecnico.ulisboa.pt/team-gabriel-valenca/

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Software needed

- Microsoft Office
- R Studio (*https://rstudio.com/*)
- Pandas Biogeme (*http://biogeme.epfl.ch/install.html*)
- Other Softwares:
  - SPSS: https://delta.ist.utl.pt/software/spss.php (*campus license*)
  - NLOGIT/Limdep: cd rom available on request to Prof. Anabela Ribeiro

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Final Notes

- Classes include a pratical component where faculties will present softwares and case studies for the home assignment exercises.
- Therefore, students should:
  - Bring their laptops
  - Install the softwares before lectures and verify that they are operating properly
  - Donwload the databases required for the exercises before classes.

What is a model? Application limits and interpretation

What is a model? Definition

- A model could be defined as a simplified representation of the real world.
  - It concentrates several elements considered relevant for its analysis according to a specific point of view.

- Another definition
  - Formal expression of one theory, of a causal or associative relationship between variables which is assumed by the analyst as being generated by the observed data.

Essencial properties

- **Mapping** – A model is based in one original reality.
  - In mathematics, it is an operation that associates each element of a given set with one or more elements of a second set.

- **Reduction** – The model reflects only a selection (expectably relevant) of the original properties.

- **Pragmatism** – A model must be useful for a specific purpose.

Models and theory (I)

- Modeling is an important **part of decision processes**
- Intuitively we all have **mental models** on how the world works based on which we make our decisions
- We **simplify the reality** and make it more abstract and simpler so we can make our decisions
- A model could be descriptive but is commonly used to search relationships between **causes and effects**

Models and theory (II)

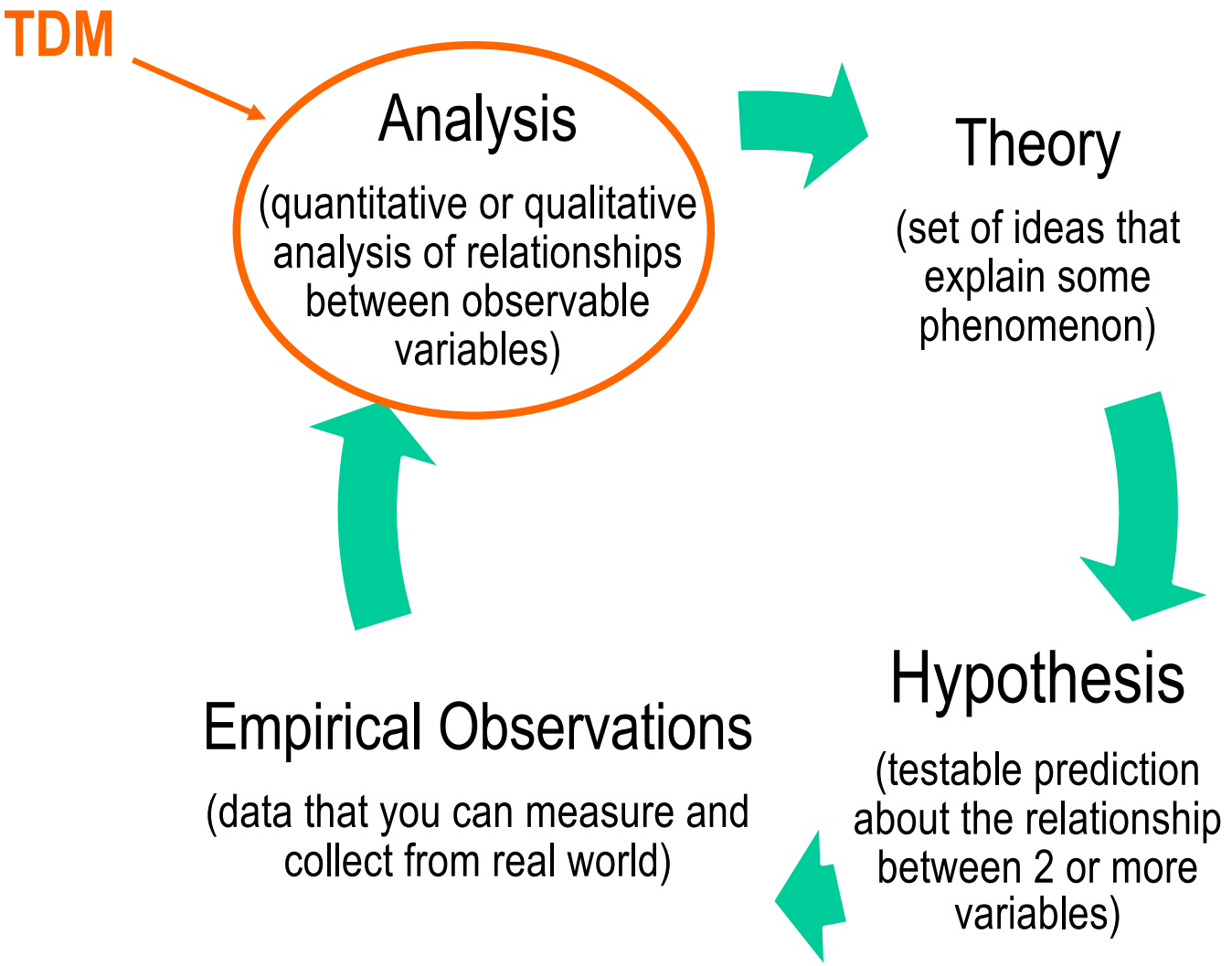
- Most models are based on the premises that by observing individuals and systems **behavior** – **past and present** – we can **infer the rules** that determine that behavior.

- These rules could then be used to **predict behavior in similar situations** (either in the future or in different places)

Models and theory (III)

- The validity of a model depends on the context for which it was conceived.
- A theory could be built using two different approaches:
  - **Inductive** – you begin with a research question and the collection of empirical data, which are used to generate a hypothesis and theory.
    - More common in social sciences
  - **Deductive** – you begin with a theory-driven hypothesis, which guide data collection and analysis.
    - Natural sciences
- Data is central
  - Data availability (quantity and quality) restricts the type of modeling approaches.
  - Avoid "***Garbage in, Garbage out***", by performing data analysis before starting modeling

Research Circle



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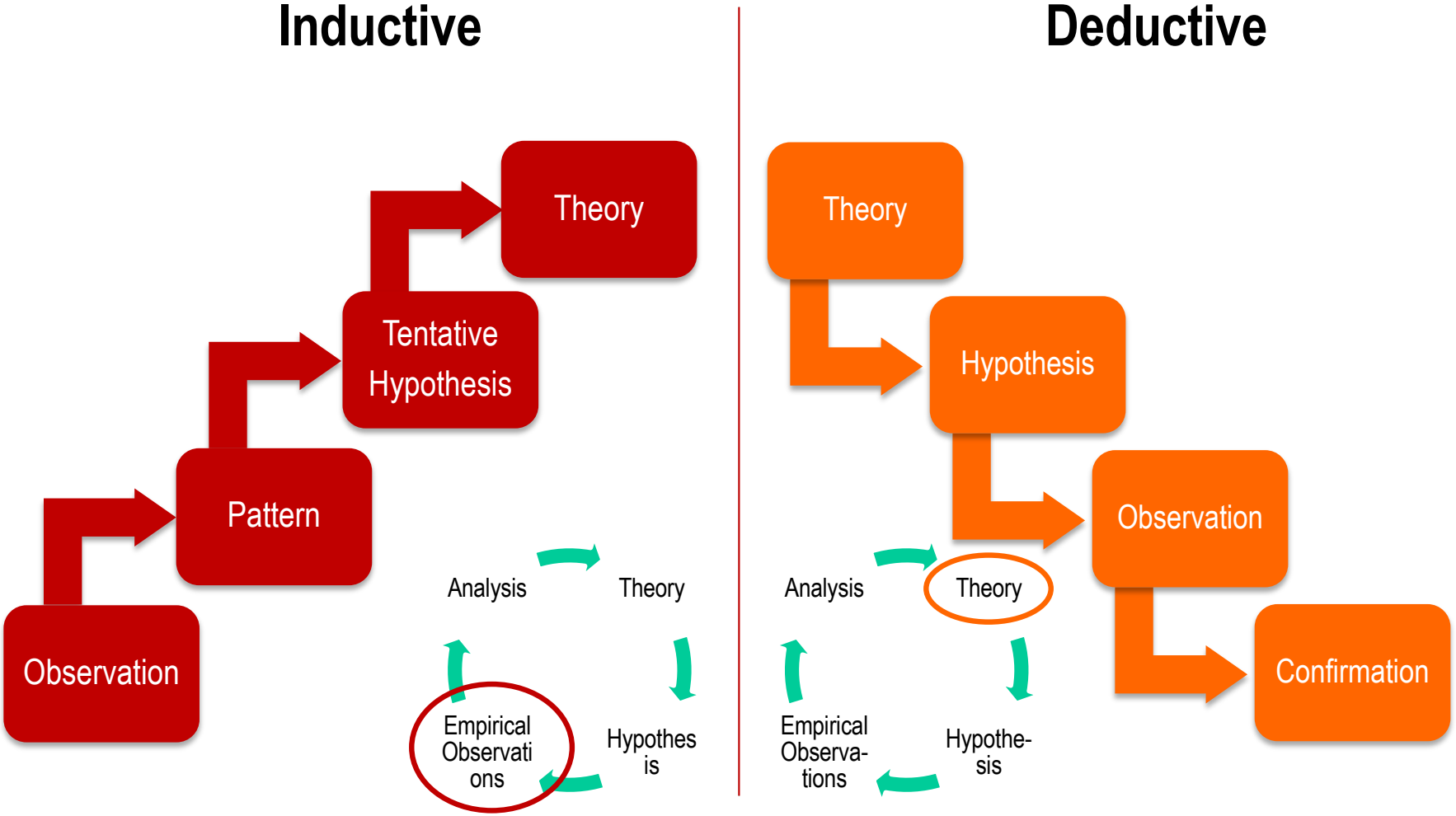
Inductive versus deductive research (I)

- Depends mostly where you start in the research circle



Inductive versus deductive research (II)

EXAMPLES

Inductive research

- **How will students adopt the universities' bike-sharing system? What do they perceive as their main barriers to adoption?**
- You begin with a **survey**, **analyze** data and identify patterns, build a tentative **hypothesis** (review it, possibly), and formulate a **theory**

Deductive research

- **Does 'Mobility-as-a-service' (MaaS) induce modal shift away from private car use in urban areas, towards a more sustainable urban mobility system?**
- You begin with a **theory** of urban mobility, whereby MaaS is seen as the next disruptive concept in urban mobility management, formulate a **hypothesis**, collect **data**, and **confirm** your hypothesis.

Models and Variables

- A model is constituted by exogenous (**independent**) and endogenous (**dependent**) variables.

$$y = f(x_1, x_2, x_3, \ldots, x_n)$$

- **Policy variables must be the ones that could be controlled by the decision maker**, if your model aims to support decision-making
  - In transportation systems, it is often the case.

Data aggregation

- How many **different population segments** do we need to have a good representation of reality and understand it?
- What is the **level of detail** for measuring a specific variable? (for it to replicate adequately a specific phenomena)
- Space – spatial aggregation – **level of detail** - disaggregation?

Parsimony

- Philosophical principle used in scientific research and mathematic modeling.

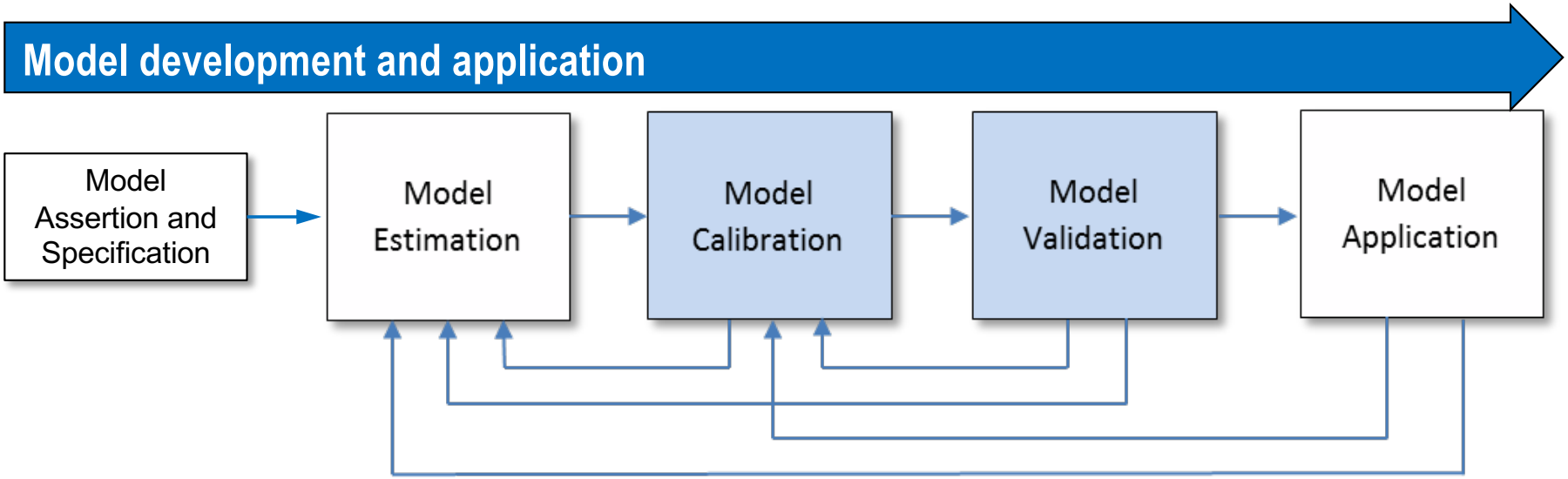
- Proposed by William Occam in the XVII century (Occam´s Razor).

Entities are not to be multiplied without necessity

Pluralities ought not be posited (assumed) without necessity

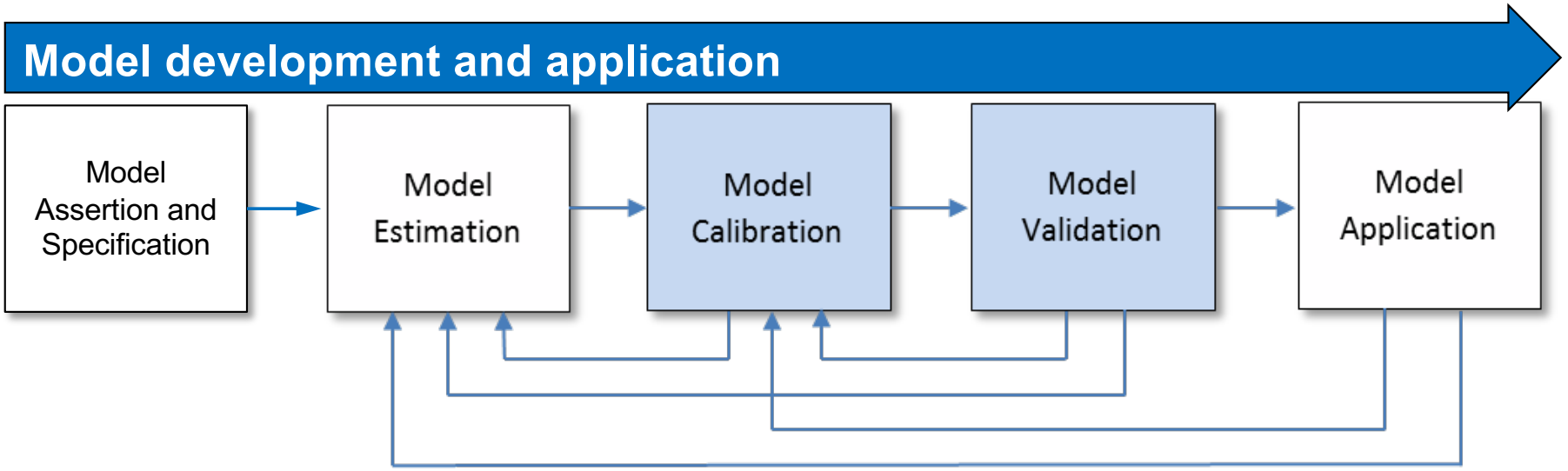
- **A model able to explain more variation with a simpler form is the preferred one** – Parsimony principle.

Model estimation and application process (I)



- **Model assertion** is the declaration of model forms or parameters without the use of statistical analysis of observed data. Based on this assertion, the model is then specified.
- **Model estimation** is the use of statistical analysis techniques and observed data to develop model parameters or coefficients (estimation may include calibration)
- **Model calibration** is the adjustment of constants and other model parameters *("coefficient tweaking")* in estimated or asserted models in an effort to make the models replicate observed data for a base year or otherwise produce more reasonable results

Model development and application process (II)



- **Model validation** is the application of the calibrated models and comparison of the results against observed data
  - ✓ Ideally, the observed data are not the same data used for model estimation or calibration (**reserve 20% of the sample data for validation!**)
- **Model sensitivity testing** is the application of the models and the model set using alternative input data or assumptions to determine if the model results are plausible and reasonable

Model specification

- **Model specification** – which rules should be included in the model:
  - **Model structure** – Simple versus complex structure;
  - **Functional form** - Linear? Non-linear?
    - Trade-off between realism/precision and ability to calibrate the algebraic relation between the dependent and independent variables;
  - **Variables' specification** – How are variables are entered in the model?
    - Should these be transformed?

Model estimation

❒ Model estimation

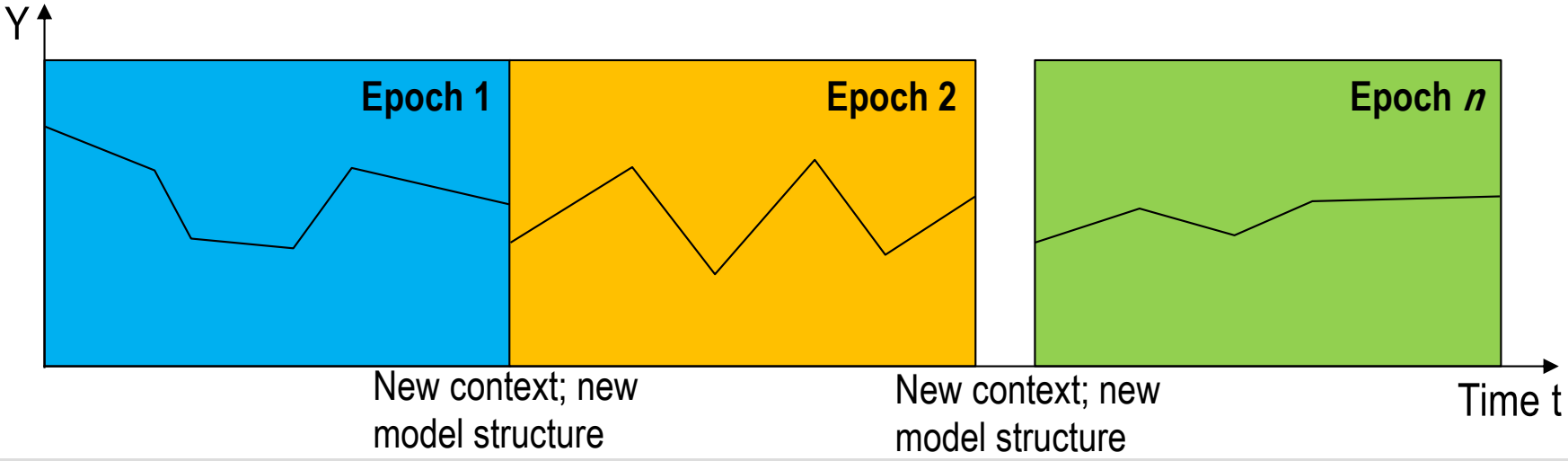
- Estimating parameter values that increase the model's probability of reproducing the observed data, that is to minimize/maximize a function of the prediction errors of the model compared to some pre-specified targets (observed values).
- When the model is acceptable (statistically speaking), the parameters should be considered as statistically significant.
- One parameter not statistically significant has a strong probability of being equal to zero.

Model validation

- Validation means achieving a good estimation or calibration and compare the model results against data not used in these processes.
  - For example, saving 20% of data sample for validation
- Validation also implies that the parameters are in accordance with theory (or mental model):
  - Magnitude (comparing with similar models);
  - Effects direction (algebraic sign).

Forecasts

- Forecasting is to predict or estimate (a future event or trend).
- Models forecasts are conditional, since it produces estimates based on a group of forecasted independent variables:
  - Relative to the values of the policy variables;
  - Relative to the values assumed for the other independent variables.
- In general, forecasts are “epoch” specific, i.e. no radical changes/ breakthroughs are expected to occur within the forecasting horizon, compared with the period of observed data.



What is a good model (I)?

- **Precise** – higher levels of precision imply more costs.
  - Caution against apparent higher precision which is generally spurious – **overfitting**
  - When overfitting, a statistical model describes random error or noise instead of the underlying relationship.
  - It occurs when a model is excessively complex, such as having too many parameters relative to the number of observations.
  - A model that has been overfit has poor predictive performance, as it overreacts to minor fluctuations in the training data.
- **Economic** in the use of resources (data and computation capacity)

What is a good model (II)?

- Capacity to produce **relevant indicators** with an adequate disaggregation level
- Capacity to reproduce the **relevant interaction processes**
- **Adequate** in terms of geographical and temporal scopes
- **Transparent** and **friendly**
  - Allowing a more precise evaluation about its results plausibility.

Model evaluation (I)

- How to evaluate a model?
  - By its capacity to increase our **understanding** and help explaining behavior?
  - By its capacity to generate **good forecasts**?

- Good predictions could be the result of chance.
  - **Be critical** on the underlying phenomenon you are modelling by analyzing the validated variables and parameters

- There is always a pressure to have good calibration results (sometimes overfitting) and only **afterwards** rationalize (understand) the relations present in the model

Model evaluation (II)

- There are very few *ex-post* analyses about model's predictions
  - The ones that exist tend not to show good results…
  - This doesn´t happen only in the public sector.

- Why?
  - Incorrect estimations for future values of independent variables
    - Out of epoch of observed data
  - Prediction capacity is sometimes viewed as more relevant than causality
  - Incomplete information of future context variables (e.g., new road construction)

Recommended readings

- Juan de Dios Ortúzar, Luis G. Willumsen (2001) “Modeling Transport (3rd edition)”, Wiley and Sons - Chapter 1
- Kenneth Button, David Hensher (2000) “Handbook of Transport Modelling”, Pergamon Press – Chapter 1
- Kuhne, Thomas, (2005), What is a model?, Dagstuhl Seminar Proceedings 04101.

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