



EUROPEAN CENTRAL BANK

EUROSYSTEM

Sensitivity analysis in T2-simulator

—

Methods and Framework

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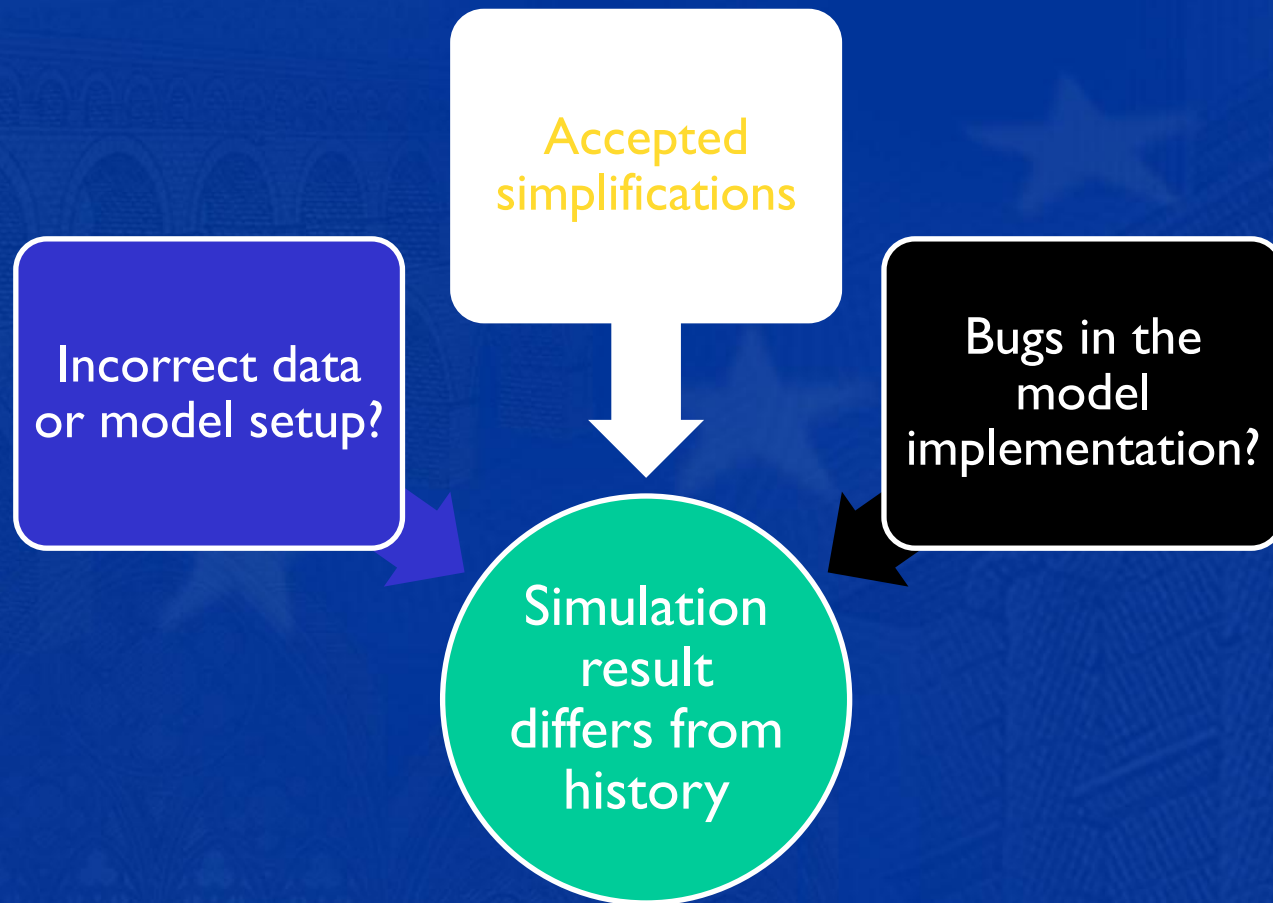
How to avoid
the risk of
GIGO – models?

Validate and know the model you use!

Case of T2-simulator

- **A large and important payment system**
 - **Big volumes and values**
 - **Technically advanced LVPS**
 - **Multiple interfaces**
 - **Different ways to use the system**
- ⇒ **Some simplifications are known and accepted to remain in the T2-simulator model of actual TARGET2**

The first challenge in model validation

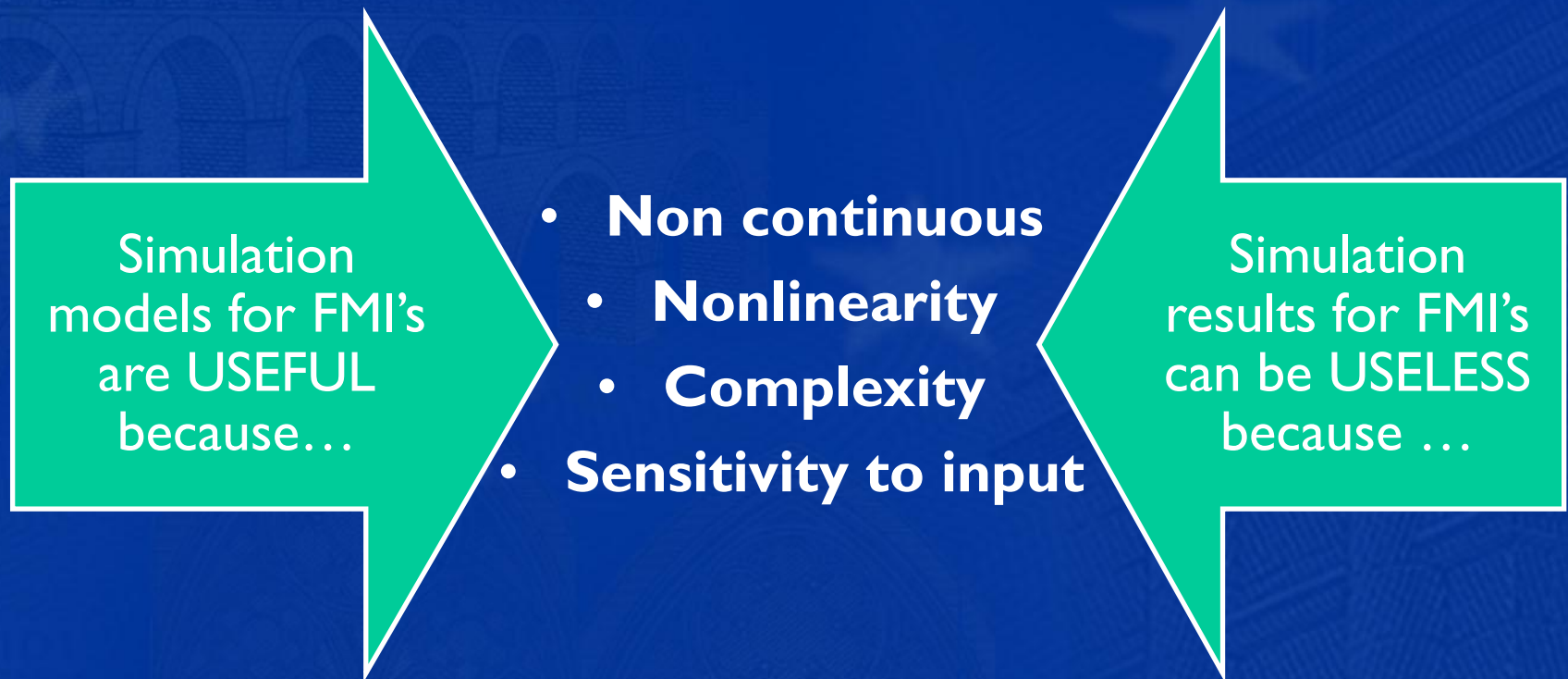


How to identify the real cause of the observed model bias?

Some features of settlement processes and simulations

- **Large number of entities (accounts) or events (transactions) in a accurately defined state**
- **Strict yes/no decisions and logical rules**
- **Non continuous output**
- **Initial state values matter**
- **Strong feedbacks**
- **Path dependency**
- **Outcome of settlement process is NOT linear or continuous function from the input**

The second challenge in model validation



What is the Signal to Noise ratio of your model?

Solution implemented in T2-simulator

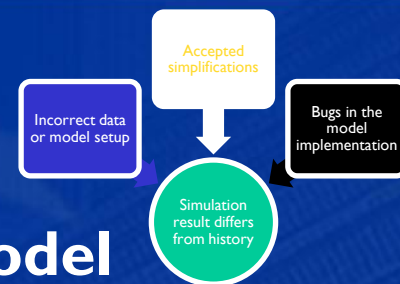
- **Sensitivity analysis tool and work plan**
 - **Monte Carlo simulations of feasible features**
 - **One off “on/off” tests for features not suited for Monte Carlo approach**

This is used to answer

- 1. What are the likely causes for deviations or most significant simplifications**
- 2. What is the overall sensitivity of the model for plausible minor changes in the input data**

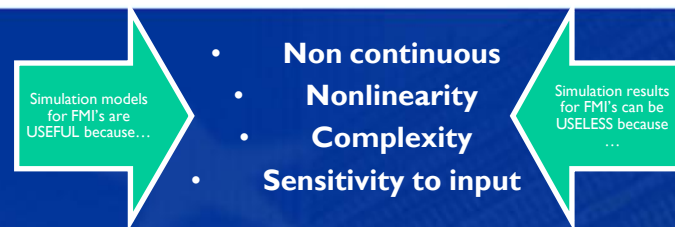
Example for Challenge I

- **Induce random variations in variables related to known simplifications of the model**
 - One by one analysis of the known possible cases
 - Measurement for their average impact in output, kind of "Lagrange multipliers"
 - Identification of the "active constraints"
- ⇒ **Decision support for improvements of the model**



Example for Challenge 2

- Find which variables could be exogenous or random in your model setup
 - Timing or individual arrival order of transactions in small scale...
 - Transaction values, initial liquidity levels...
- Monte Carlo sample all of them:
 1. Around your benchmark simulation (n times)
 2. Around data where some scenario is implied (*m)
- Measure the noise as variations *within* the samples, and signal as variation *between* samples



Practical approach – how to do this

Matlab script for sensitivity analysis.
Define all setup parameters in one place:
Used data variation module, nr of runs, parameters, ...

Data variation modules

Result extract modules

Auto-
mated
run of n
sims

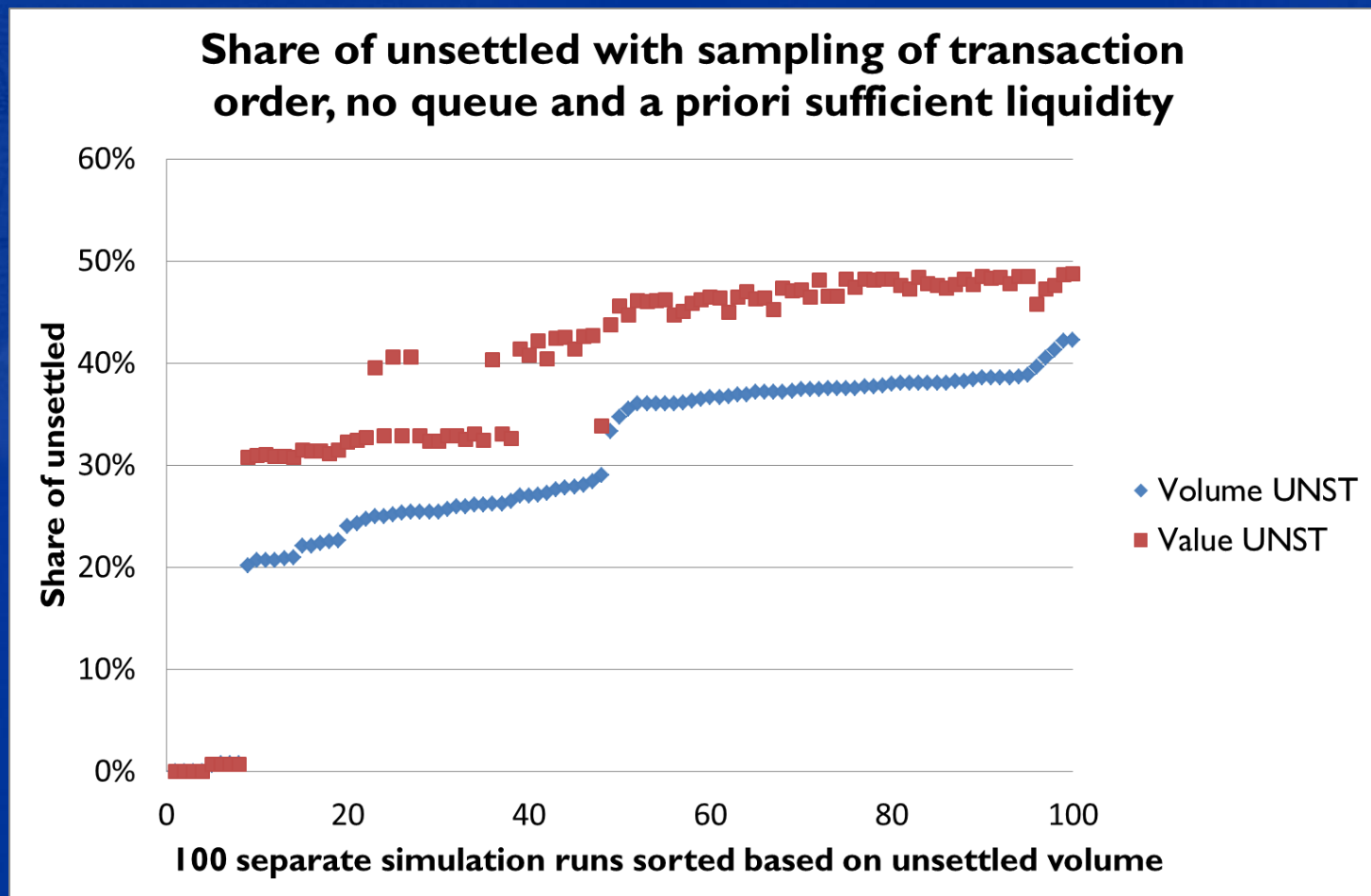
BoF-PSS2 used over Command Line Interface

MySQL database:
Data variations either
1. directly as queries
2. By importing the data first into Matlab

Current status

- **In use in T2-simulator**
 - **Possibility for broader availability will be checked**
- **Modules implemented already e.g. for**
 - **Random sampling of transaction time**
 - **Stepwise changes in liquidity levels**
 - **Stepwise changes in limit values**
- **List can be extended...**
 - **...easily if you can express the data variation with SQL**
 - **...with more flexibility if you import the data into Matlab**

Example results with artificial data



Data: BoF-PSS2 example I material

Possible usages

- **Study the Challenges 1 & 2 in T2-simulator**
 - **Implement a tool, which can be used easily to run sensitivity analysis or benchmark tests on *any* simulation**
- **Other uses?**
 - **Recurring calculation of indicators or scenarios**

Disadvantages or drawbacks

Structural issues

- **All simplifications of models can not be tested**
 - **E.g. Change in settlement algorithm logic which is not related to any specific data or input item**

Temporary inconveniences

- **“User interface” of the tool is a Matlab script**
- **Easy way to combine several data variations is missing**
- **Modules for report generation are missing**
- **Setup does not support parallel computing**

Summary

- **Remember to validate your simulation models!**
 - Measure the significance of your simplifications
 - Measure the sensitivities and signal to noise ratio
- **Possibilities for automated simulations exist with BoF-PSS2**
 - Command line interface
 - Queries to database
 - A generic benchmark tool now implemented in T2-simulator