How can sensitivity analysis help the insurance industry make more robust decisions based on pricing models?

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[KE Fellowship: NE/R003734/1]

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Aim of my KE Fellowship (Nov 2017 – Oct 2020)

Goal

Improving decision-making under uncertainty by **transferring** state-of-the-art **methods** for **Global Sensitivity Analysis (GSA), tools** (**SAFE software package**), **workflows** and **expertise** to the (re)insurance sector and catastrophe community.

Objectives

- Understand major sources of uncertainty in the insurance modelling process
- Demonstrate benefits of using Global Sensitivity Analysis
- Transfer knowledge to wider insurance sector by embedding SAFE in OASIS platform
- Dissemination and engagement of wider sector (e.g. workshops, publications, …)

Partners

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Where I am now

Nov 2017 – to date:

- developed pilot case study at AXA XL
- developed training material (through Rmarkdown workflow for GSA use and interpretation)
- delivered tutorials on GSA/SAFE use for actuaries at AXA XL

Actuarial community

- developed pilot case studies with OASIS and JBA on CAT models
- developed training material (through jupyter notebook)
- inform how to tailor SAFE to embed it into the OASIS platform

Catastrophe community

- Further disseminate the use of GSA in the actuarial practice
- Size interest for GSA/SAFE

Further reach actuarial community

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Outline

- What is Global Sensitivity Analysis (GSA)?
- What can you use GSA for?
- How does GSA work?
- Introduction to pricing model used
- Examples of benefits of using GSA

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INTRODUCTION TO SENSITIVITY ANALYSIS

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What is Sensitivity Analysis? and how does it compare to Uncertainty Analysis?

UA focuses on quantifying the uncertainty in a model output.

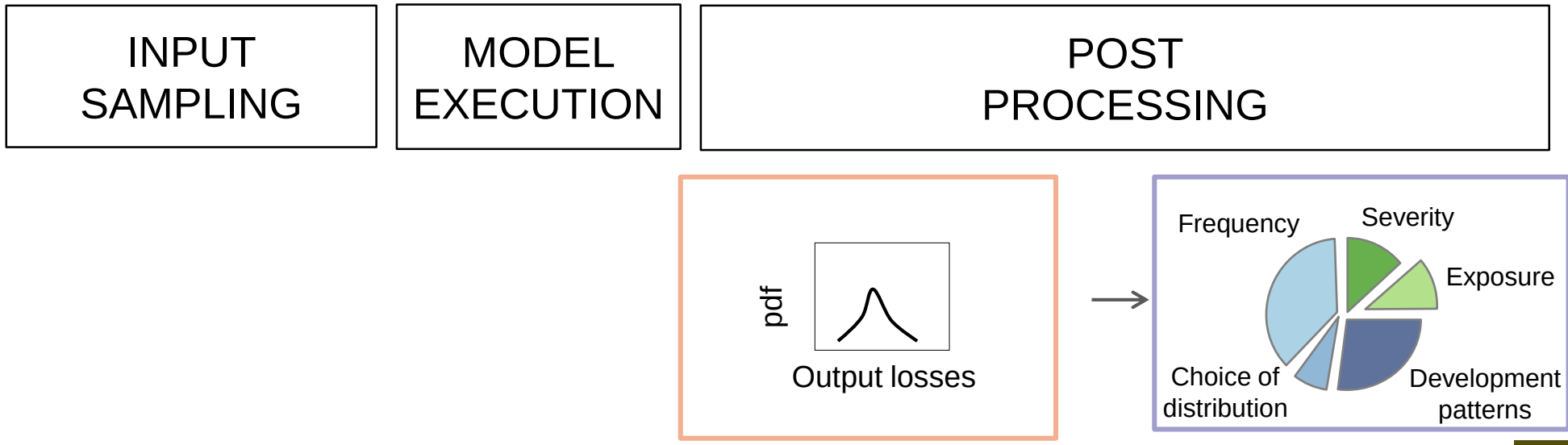
SA focuses on attributing output uncertainty to the different sources of uncertainty.

[1] Characterize uncertainty of input factors

[2] Forward propagation of uncertainty

[3] Uncertainty Analysis

[4] Sensitivity Analysis



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What can you use SA for?

- To increase understanding of the model, beyond default set-up (validation)

  Is the relationship between model inputs and outputs as expected?
  Any odd behaviour?

- To identify priorities for uncertainty reduction (improvement)

  What do I need to make it more robust?

- To support decision-making (use)

  Improve communication between modellers and decision-makers

Pianosi et al 2016, *Environmental Modeling & Software*
Wagener and Pianosi, 2019, *Earth-Science Reviews*

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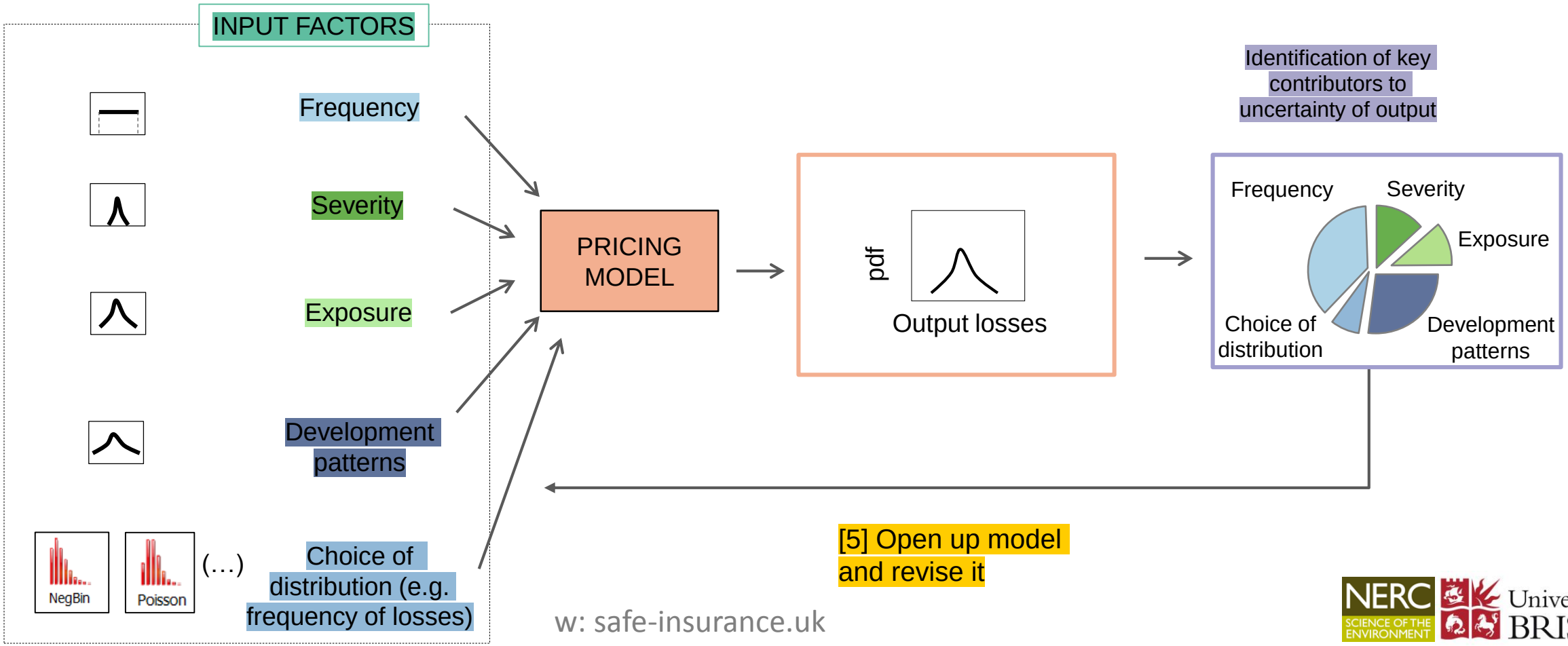
How does SA work?

[1] Characterize uncertainty of input factors

[2] Forward propagation of uncertainty

[3] Uncertainty Analysis

[4] Sensitivity Analysis



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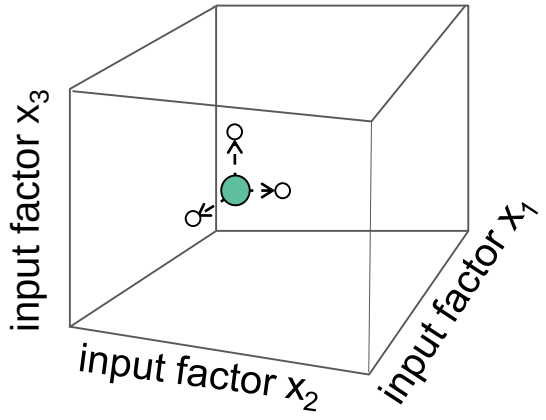
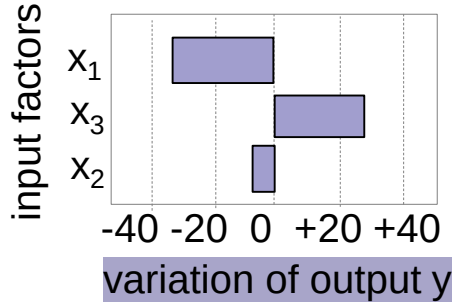
What is the difference between Local and Global SA?

Local SA investigates the effects of variation of uncertain inputs from a baseline point



$y = f(x_1,x_2,x_3)$



Useful when you have a clear baseline point and are only interested in what happens for small deviations from it

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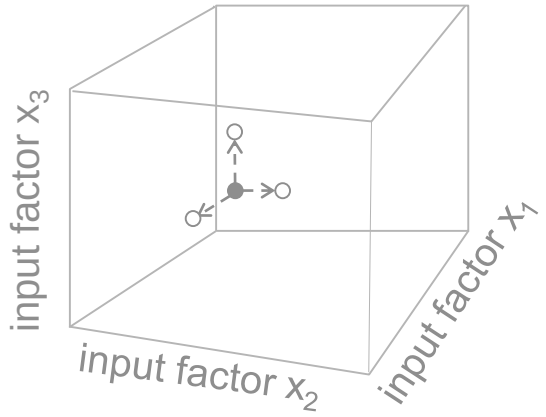
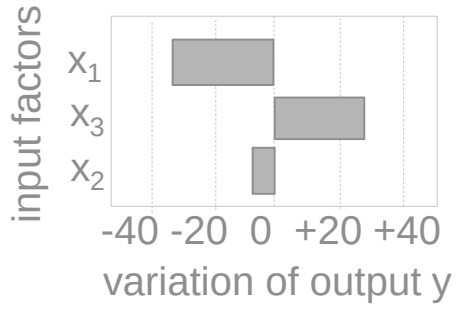
GSA investigates model response independently of baselines

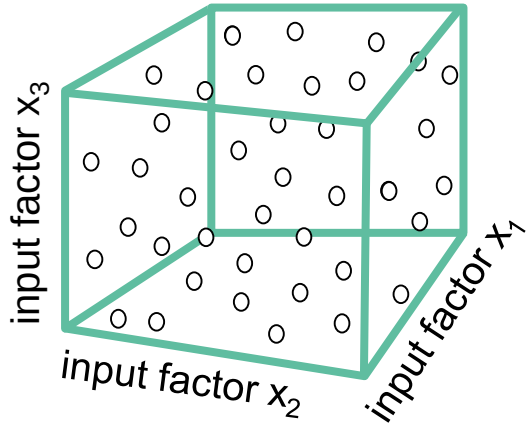
Local SA investigates the effects of variation of uncertain inputs from a baseline point

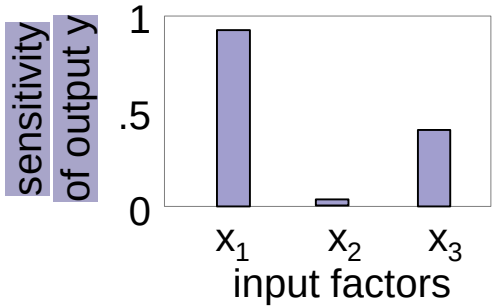


$y = f(x_1,x_2,x_3)$



Global SA investigates the effects of variation of uncertain inputs across their entire variability space





Useful when there is no specific baseline but one is interested in exploring the model response against different combinations of inputs

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INTRODUCTION TO MODEL USED

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Case study model

- Pricing model based on past losses experience
- It produces a price recommendation for the premium to be charged for a new risk to a given company to cover from all classes of business

Objective of case study:

Identify where to focus efforts to reduce uncertainty when reviewing the model.

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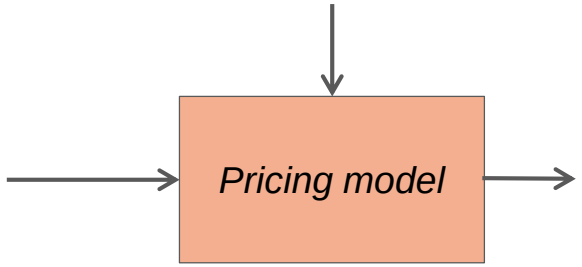
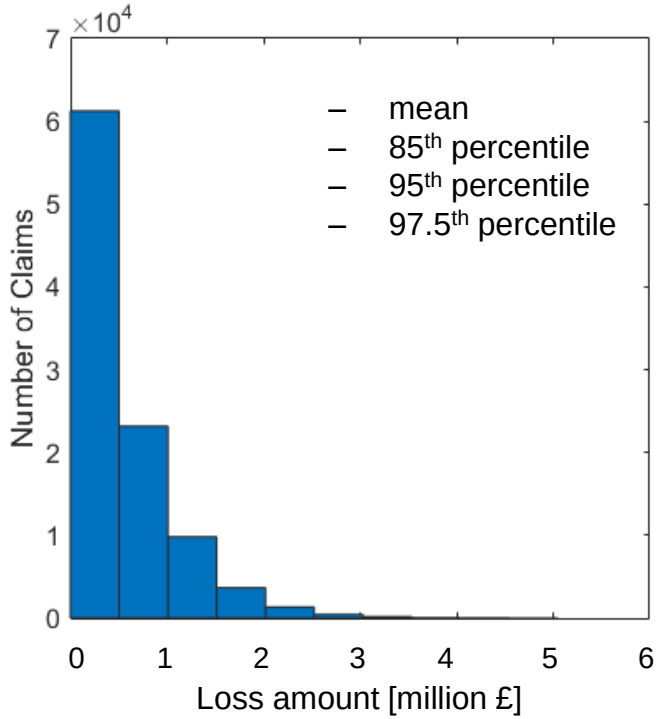
Simplified schematic of pricing model

Fixed Parameters
Development Pattern
Severity Trend
Frequency Trend
Exposure Trend



Output:
Loss amount

Inputs
Claim data
Exposure data
Cover data
Portfolio and market data



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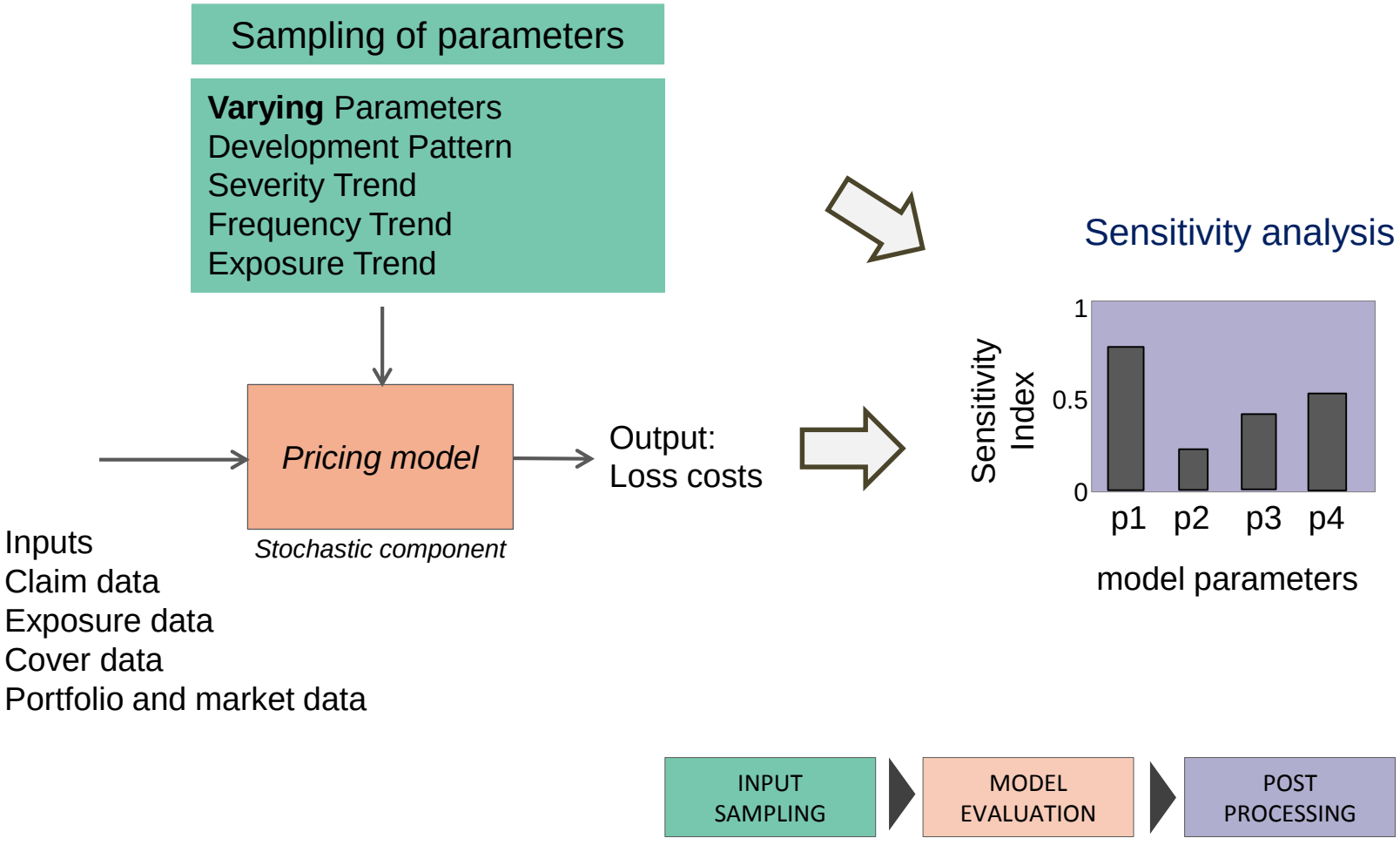
Simplified schematic of pricing model with GSA



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UNDERSTAND MODEL BEHAVIOUR BEYOND SET-UP

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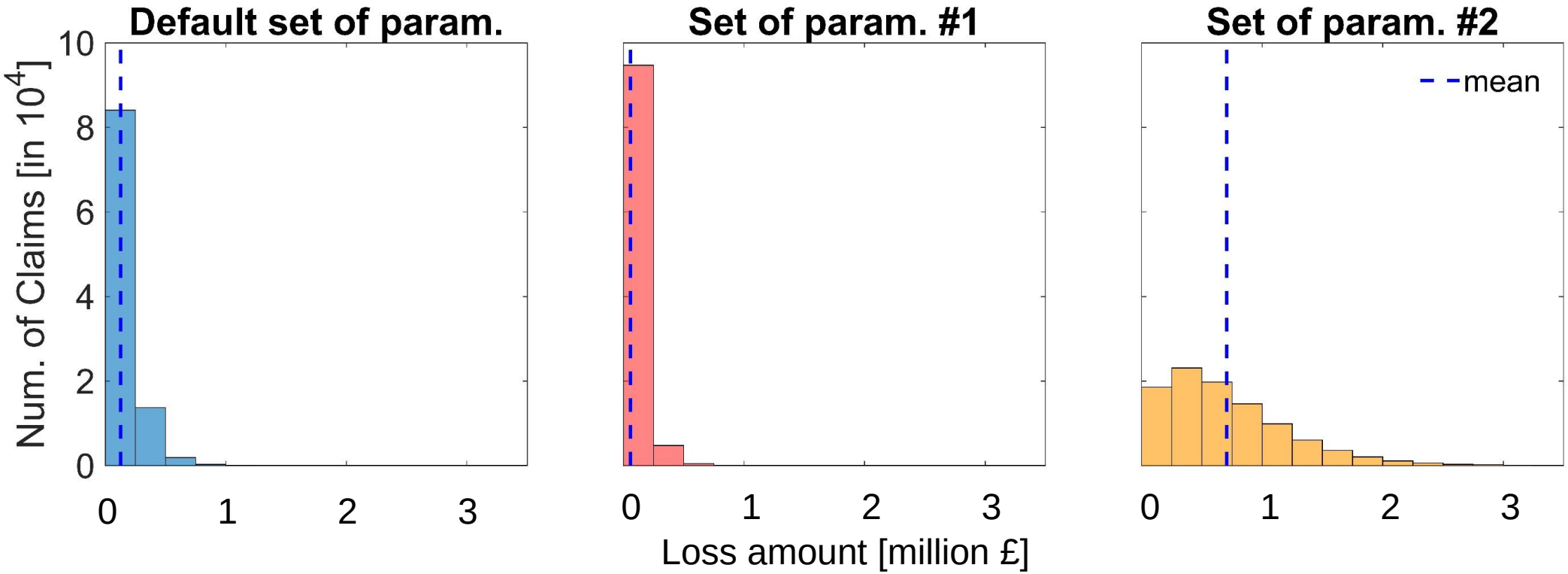
How does the output distribution change by changing the value of parameters?

Qualitative analysis



Implication:

→ Changing the inputs value can skew the distribution to the right, generating very high losses.

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Improving transparency and robustness of decisions

UNDERSTAND MAIN IMPACTS OF UNCERTAINTY ON MODELLING OUTCOME

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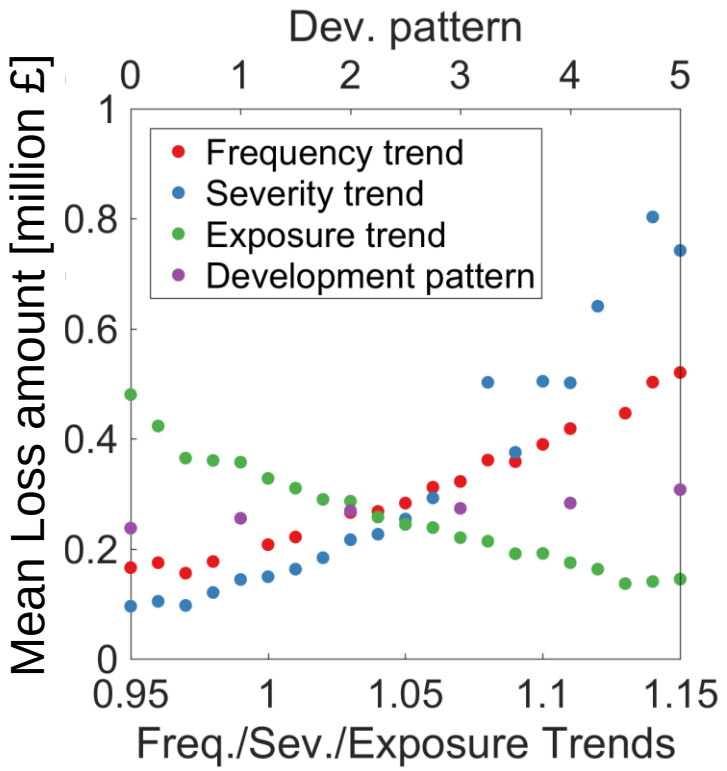
How does the range of variability of the output change when varying the parameters within credible ranges?

One At the Time Sensitivity Analysis



Implication:

→ Changing the inputs range can sensibly increase the output range of variability, this should be taken into account when deciding the premium to suggest to the underwriter.

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Prioritize investments for uncertainty reduction

REDUCING MODEL UNCERTAINTY

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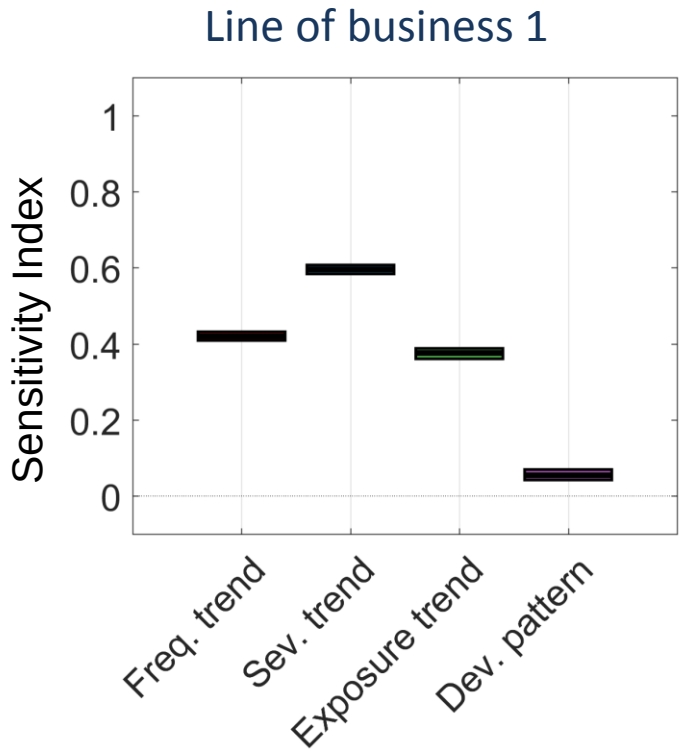
GSA helps to understand where to prioritize investments to reduce uncertainty



Implications:

Given that the Severity Trend is the most influential parameter, more focus could be given to estimate the Severity Trend from portfolio data of businesses of similar nature.

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Does the model meet the expectations?

SANITY CHECKS

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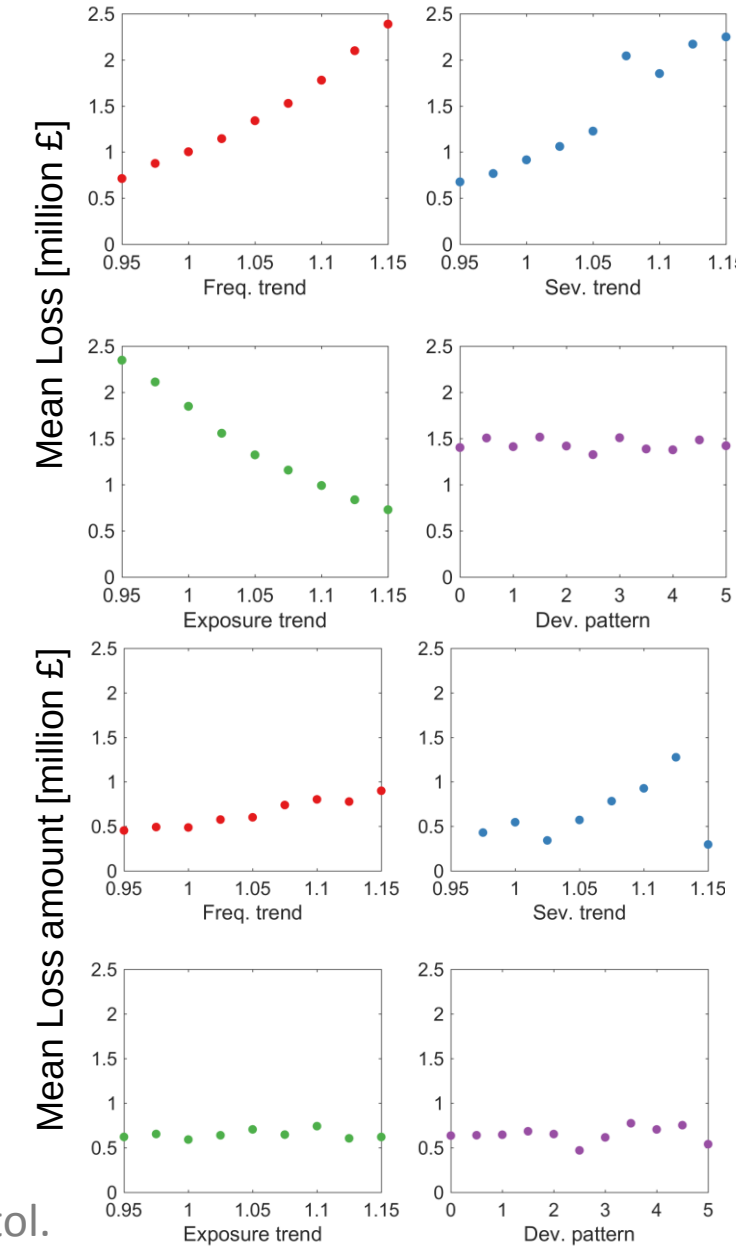
Does the impact of parameters on the output meet expectations?

Line of business 1

Line of business 2



All At the Time (AAT) Sensitivity Analysis

Freq. and Sev. Trends were expected to increase output losses and vice versa for Exposure Trend.

Severity trend has an incoherent behaviour for some values
→ this highlights areas where to focus when reviewing a policy, which could improve the model.

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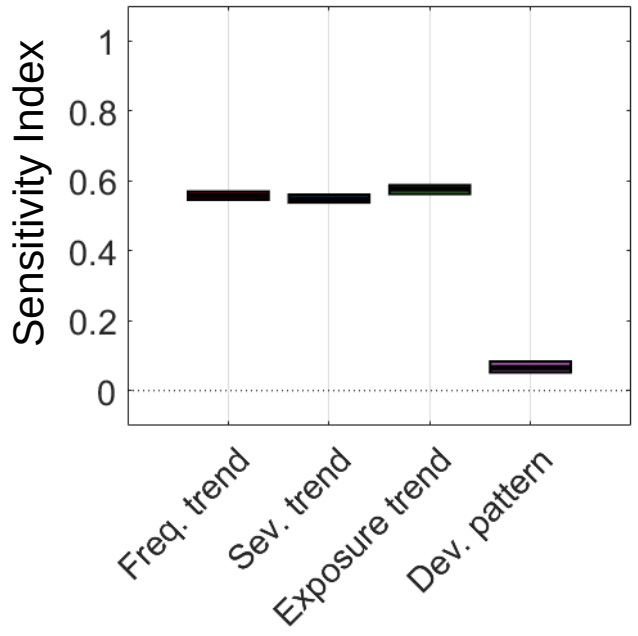
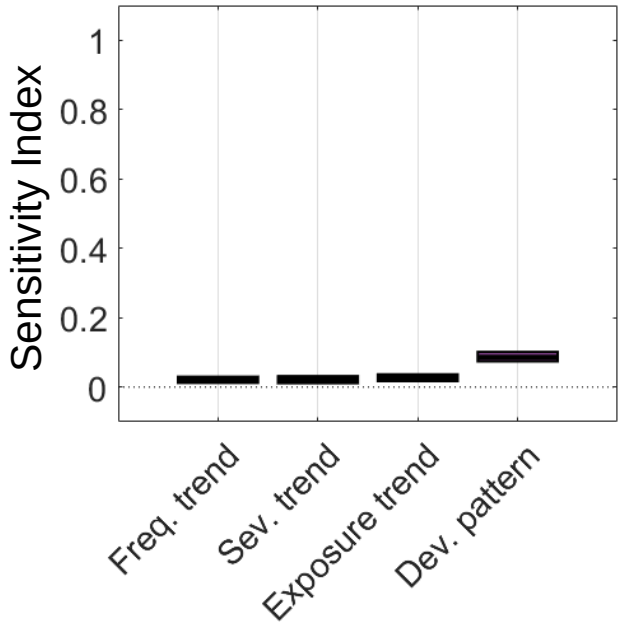
Does the ranking of most influential assumptions meet expectations?

PL line of business 1



Dev. Pattern was expected to be less influential for PL lines of business, where the losses are faster to develop to completion.

PL line of business 2



None of the assumptions is very influential.
→ Need to investigate further what is driving the uncertainty in this line of business.

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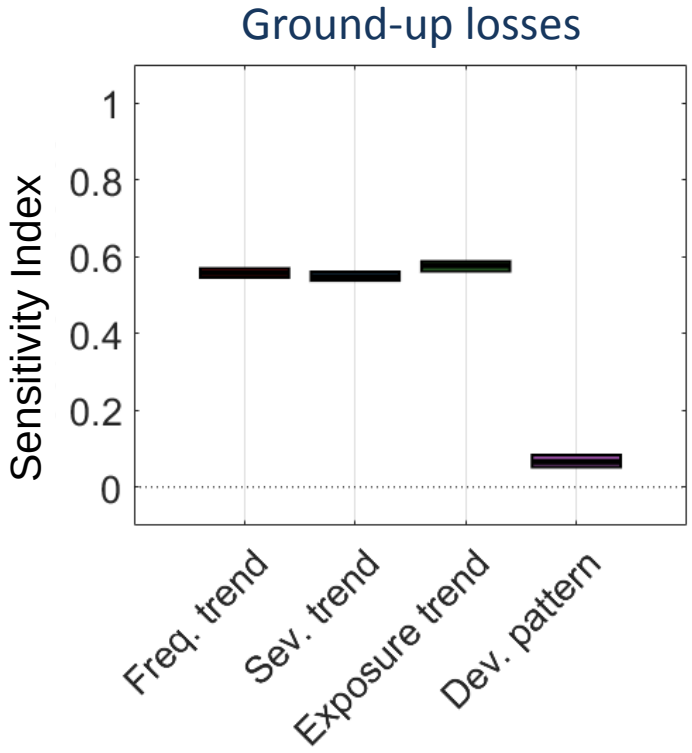
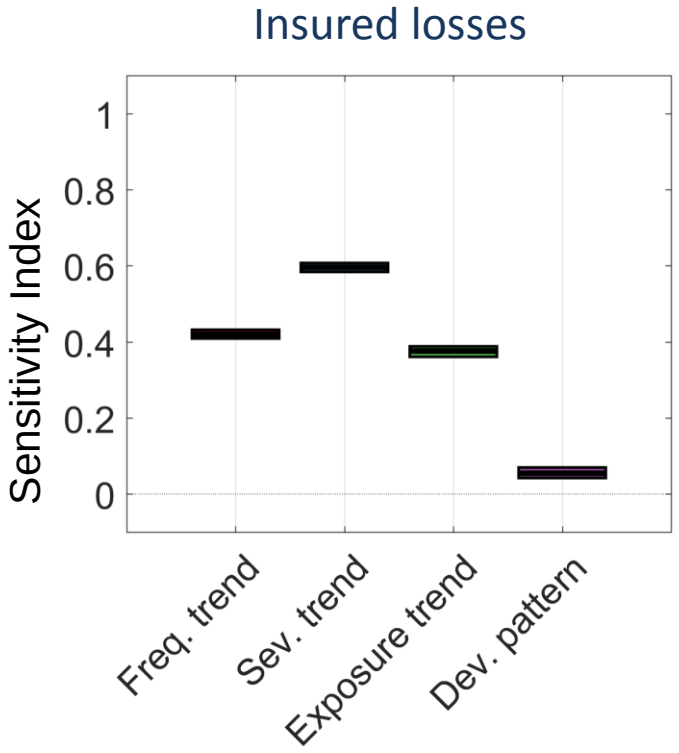
Are different assumptions more influential depending on the output considered?





Different assumptions are expected to be more influential depending on the output considered

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Summary of main results

- GSA shows model behaviour beyond default.
- The analysis helps to focus efforts to reduce uncertainty and enables to better communicate uncertainty to underwriter.
- Varying the inputs within their credible range sensibly increases the variability of the model output, this should be taken into account when decisions are made.
- There are some unexpected behaviours, this highlights areas where to focus when reviewing a policy, addressing these issues could improve the model.

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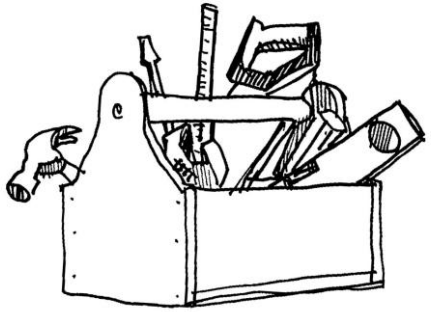
SAFE Toolbox for Sensitivity Analysis

- Developed in 2014 by Pianosi *et al.*
- Over 1800 users in academia in 50+ countries
- R, Python and Matlab versions available
- Easy to use, flexible, modular structure, easy to integrate with models running outside R, Pyhton or Matlab
- **Model agnostic**
- Open source, open access
- Variety of case studies available
- Many **visualisation** functions
- Lots of commented code and **workflows**



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CONCLUSIONS

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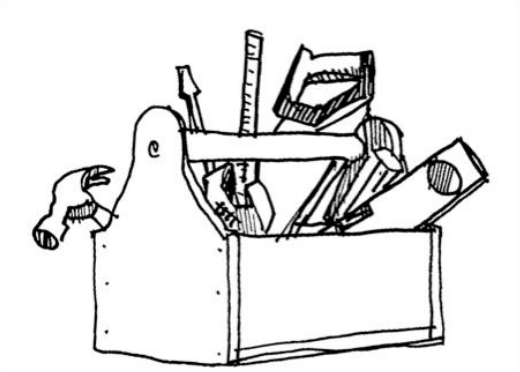
Conclusions

Uncertainty and Sensitivity Analysis are very useful to investigate the propagation of uncertainty through a model and hence support their improvement, validation and use for inference or decision-making



www.safetoolbox.info
(R, Python, Matlab)

The key to a successful application often lies in
making 'good' set-up choices
(definition of input variability space, choice of outputs, etc)

Some guidance in:

Noacco et al. (in press). Matlab/R workflows to assess critical choices in Global Sensitivity Analysis using the SAFE toolbox. *MethodsX*
(currently accessible at: https://eartharxiv.org/pu83z/)

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References

Review papers to get started:

- Pianosi et al. 2016 Sensitivity analysis of environmental models: A systematic review with practical workflow. *Environmental Modelling and Software*, 79.
- Wagener and Pianosi 2019 What has Global Sensitivity Analysis every done for us? … *Earth-Science Reviews*, 194.

Technical guidelines:

- Noacco et al. in press Matlab/R workflows to assess critical choices in Global Sensitivity Analysis using the SAFE toolbox. *MethodsX* (currently accessible at: https://eartharxiv.org/pu83z/)

Introduction to SAFE toolbox:

- Pianosi et al. 2015 A Matlab toolbox for Global Sensitivity Analysis. *Environmental Modelling and Software*. 70.

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