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# The universe of uncertainty that didn't hide

Andrea Saltelli

SAMO 2025, April 22–25, Grenoble

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 Environmental Modelling & Software  
Volume 188, April 2025, 106430

**Models and the common good** ☆

Andrea Saltelli

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**Ranking the rankers. An analysis of science-wide author databases of standardised citation indicators**

Published: 18 February 2025  
(2025) 130(1):article

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Marta Kuc-Czarniecka & Andrea Saltelli

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### Models and the common good

A short analysis of norms and counter-norms in modelling, discussing how models may misuse their epistemic authority for reasons of occasion, opportunity and interest.

Outline:

Narratives and counter-narratives,  
State of exception,  
Seeking Cinderella,  
Reformation

### Ranking the Rankers

Ranking the Rankers? We investigate using global sensitivity analysis the properties of the science-wide author databases' standardised citation indicators produced since 2015 by a team of researchers led by John P. A. Ioannidis.

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This week happy to be in Grenoble at the 11th sensitivity analysis of model output (SAMO) conference.

April 23–25 2025 Grenoble

11th INTERNATIONAL CONFERENCE ON  
**SAMO**  
SENSITIVITY ANALYSIS OF MODEL OUTPUT

**Invited speakers**  
Tim Bedford (University of Strathclyde, Glasgow)  
Sergei Kucherenko (Imperial College London)  
Frances Kuo (University of New South Wales, Sydney)  
Francesca Pianosi (University of Bristol)  
Arnold Puy (University of Birmingham)

**Chair** Clémentine Prieur — **Co-chairs** Bertrand Iooss & Grégoire Otkrit

Campus de Saint-Martin-d'Hères, France

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From last SAMO



## What can sensitivity analysis contribute to a sociology of quantification?

Monica Di Fiore<sup>(1)</sup>, Arnald Puy<sup>(2,3)</sup>, Andrea Saltelli<sup>(1,3,4)</sup>

SAMO Conference  
Sensitivity Analysis of Model Output Conference  
March 14-16, 2022, Florida State University  
Tallahassee, Florida 32306-1640

- (1) Institute for Cognitive Sciences and Technologies, Consiglio Nazionale delle Ricerche, Roma, (IT)
- (2) Department of Ecology and Evolutionary Biology, University, New Jersey, (US)
- (3) Centre for the Study of the Sciences and the Humanities (CVT), University of Bergen, (NO)
- (4) UTP Barcelona School of Management, Barcelona, (ES)

SAMO 2022

2023



# Sociology of models

2025



## Environmental Modelling & Software

Volume 188, April 2025, 106430



EnviroFutures Invited Opinion

## Models and the common good ☆

Andrea Saltelli ✉

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Research Article

## Mathematical models: a state of exception

Andrea Saltelli ✉, Arnald Puy & Monica Di Fiore

Received 09 Jan 2024, Accepted 07 May 2024, Published online 11 Jun 2024

Cite this article

<https://doi.org/10.1080/02652171.2024.2365727>

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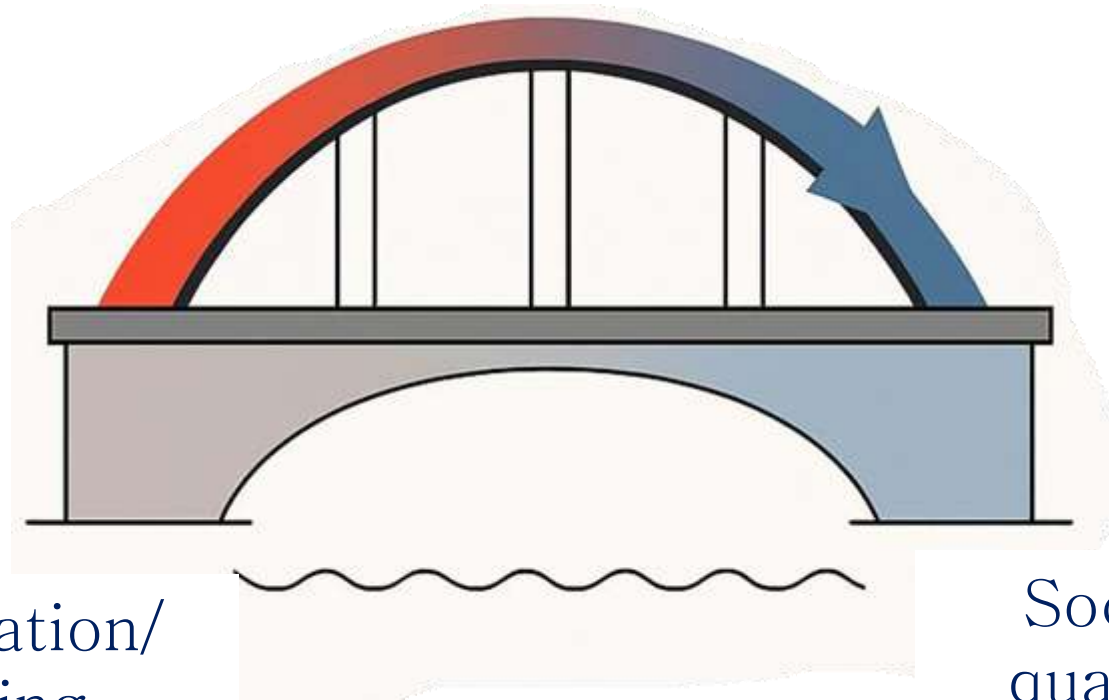
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Quantification/  
modelling

Sociology of  
quantification



Article | [Open Access](#) | Published: 06 May 2023

## What can mathematical modelling contribute to a sociology of quantification?

[Andrea Saltelli](#) & [Arnald Puy](#)

*Humanities and Social Sciences Communications* **10**, Article number: 213 (2023) | [Cite this article](#)

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Volume 81, pages 53–70, (2023) | [Cite this article](#)



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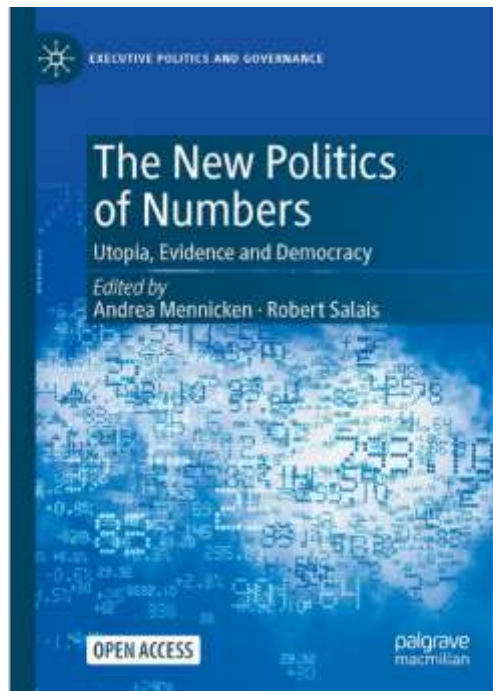
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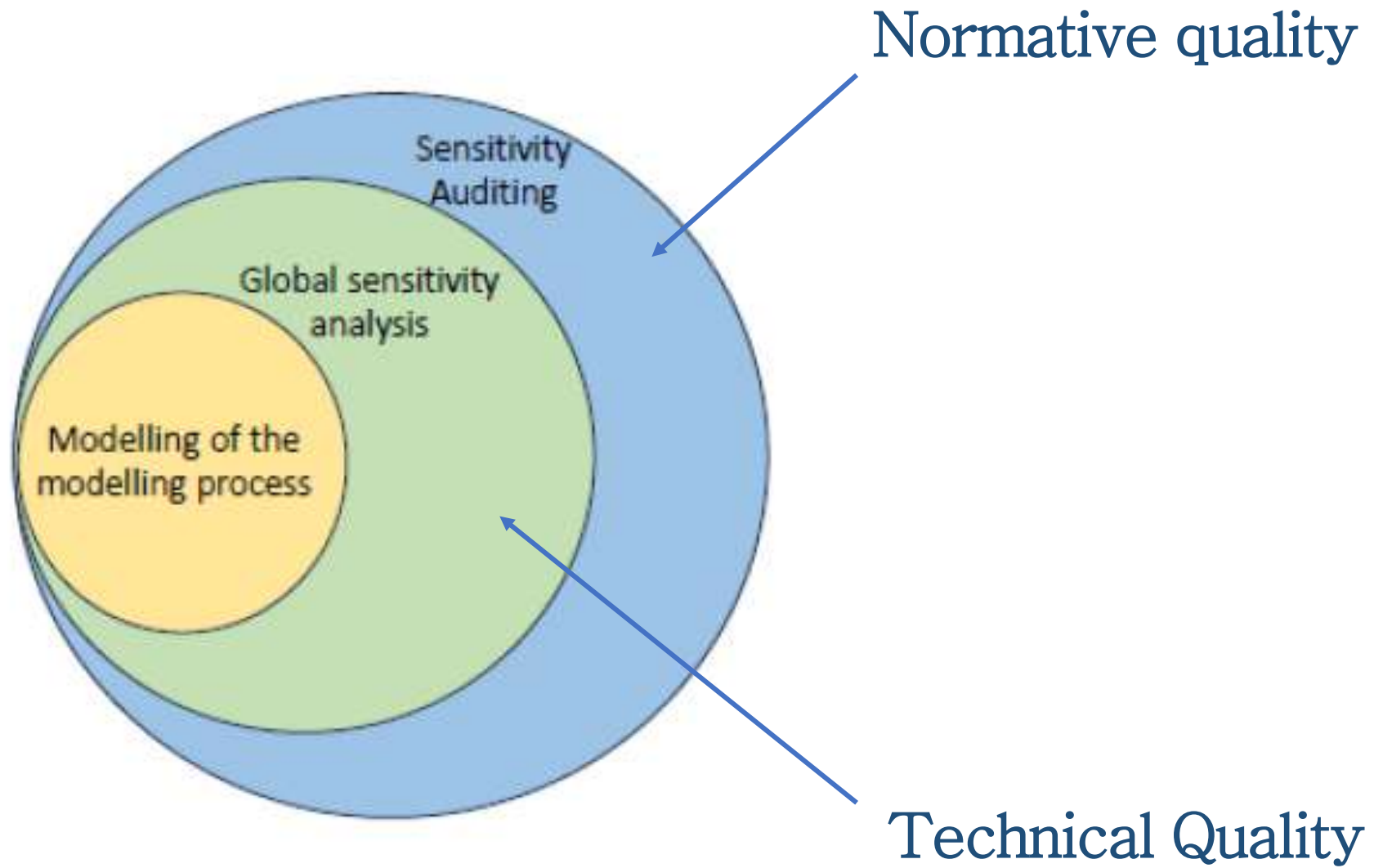
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Sensitivity auditing







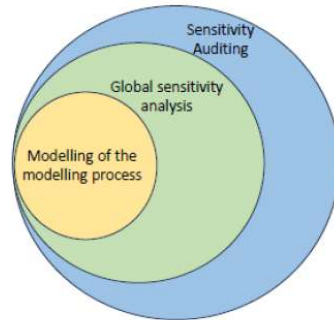
# Unpacking the modelling process via sensitivity auditing

Samuele Lo Piano <sup>a</sup>  , Razi Sheikholeslami <sup>b</sup>, Arnald Puy <sup>c d e</sup>, Andrea Saltelli <sup>f</sup>











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# Impact assessment culture in the European Union. Time for something new?

Andrea Saltelli <sup>a b</sup>  , Marta Kuc-Czarnecka <sup>c</sup> , Samuele Lo Piano <sup>d</sup> ,  
Máté János Lőrincz <sup>d</sup> , Magdalena Olczyk <sup>c</sup> , Arnald Puy <sup>e</sup> , Erik Reinert <sup>f g</sup> ,  
Stefán Thor Smith <sup>d</sup> , Jeroen P. van der Sluijs <sup>b h</sup> 

2023

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## Robustification of structural equation modelling via global sensitivity analysis

Original Paper | Published: 11 March 2025

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Alessio Lachi , Josep Llach, Jordi Perramon, Michela Baccini & Andrea Saltelli

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## Unpacking the modeling process for energy policy making

Samuele Lo Piano , Máté János Lőrincz, Arnald Puy, Steve Pye, Andrea Saltelli, Stefán Thor Smith, Jeroen van der Sluijs

First published: 14 November 2023 | <https://doi.org/10.1111/risa.14248>



Figures



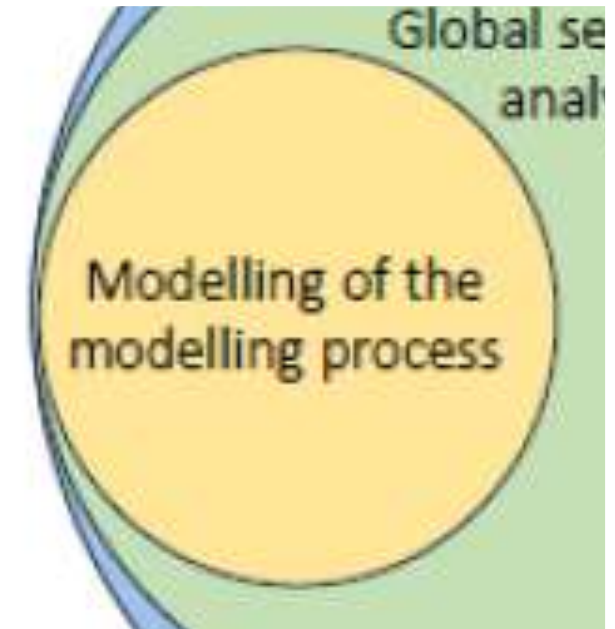
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2023



The multiverse

The universe of  
uncertainty that didn't  
hide: reaching out to  
multiverse analysis



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# Leamer reloaded: a long-neglected suggestion is rediscovered to apply global sensitivity analysis to a quantification before publishing it

**AUTHORS**  
Andrea Saltelli, Alessio Lachi, Arnald Puy, and Nate Breznau

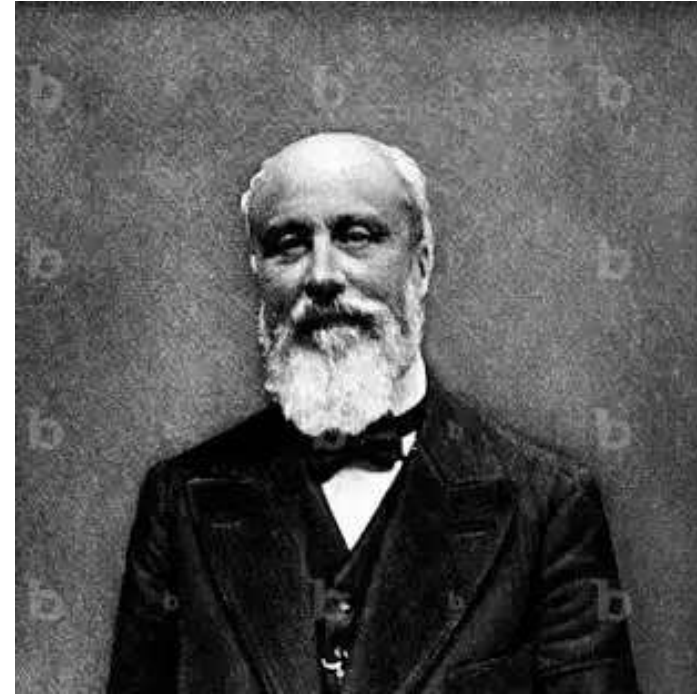
**AUTHOR ASSERTIONS**

CONFLICT OF INTEREST	No ▼	PUBLIC DATA	No ▼	PREREGISTRATION	Not applicable ▼
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# Models are fragile

“... inferences from mathematical models of phenomena to real physical applications must also be demonstrated to be approximately correct when the assumptions of the model are only approximately true” [1]

Pierre Duhem (1861–1916)  
and his ‘Principle of  
stability’



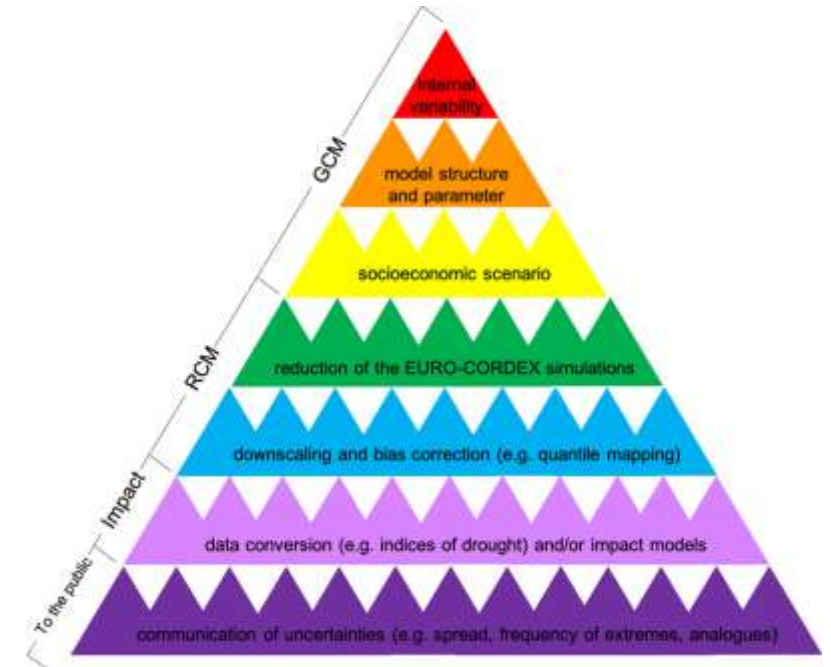
[1] S. C. Fletcher, ‘The Principle of Stability’, *Philosopher’s Imprint*, vol. 20, no. 3, 2020, Accessed: Sep. 08, 2024. [Online].

# Models are fragile

Duhem's principle of stability [1], and the occurrence of either Butterfly [2] or Hawkmoth effects [3].

The accumulation of parametric error in a model, the so-called uncertainty cascade [4], that is the subject of global sensitivity analysis studies.

- [1] S. C. Fletcher, 'The Principle of Stability', *Philosopher's Imprint*, vol. 20, no. 3, 2020, Accessed: Sep. 08, 2024. [Online].
- [2] H. G. Schuster, *Deterministic Chaos: An Introduction*, 2nd Rev edition. Weinheim: Vch Pub, 1998.
- [3] E. Winsberg, 'Appendix: Structural Stability and the "Hawkmoth Effect"', in *Philosophy and Climate Science*, Cambridge: Cambridge University Press, 2018, pp. 232–246. doi: 10.1017/9781108164290.016.
- [4] M. Christie, A. Cliffe, P. Dawid, and S. S. Senn, *Simplicity, Complexity and Modelling*. Wiley, 2011.



“I have proposed a form of **organised sensitivity analysis** that I call **‘global sensitivity analysis’** in which a neighborhood of alternative assumptions is selected and the corresponding interval of inferences is identified.

Conclusions are judged to be sturdy only if the neighborhood of assumptions is wide enough to be credible and the corresponding interval of inferences is narrow enough to be useful.”

Edward E. Leamer, 1990, Let's Take the Con Out of Econometrics, *American Economics Review*, **73** (March 1983), 31-43.



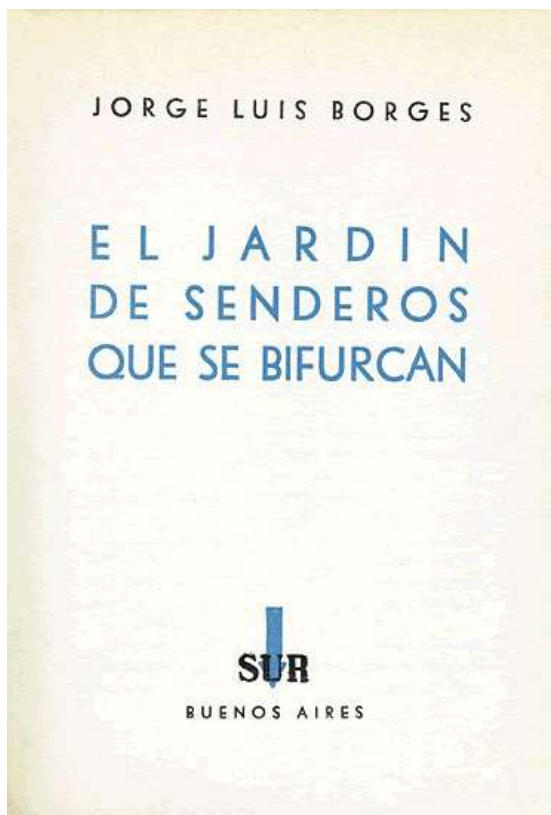


# Fishing expeditions and forking paths ...





Jorge Luis Borges  
(1899–1986)



Taking different  
narratives within the  
same novel like Ts'ui Pên



The garden of forking paths: Why multiple comparisons can be a problem, even when there is no “fishing expedition” or “p-hacking” and the research hypothesis was posited ahead of time\*

Andrew Gelman<sup>†</sup> and Eric Loken<sup>‡</sup>

14 Nov 2013

The garden of forking paths: Why multiple comparisons can be a problem, even when there is no “fishing expedition” or “p-hacking” and the research hypothesis was posited ahead of time\*

Andrew Gelman<sup>†</sup> and Eric Loken<sup>‡</sup>

14 Nov 2013

Can global SA help?



**PNAS**

RESEARCH ARTICLE

SOCIAL SCIENCES

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**Observing many researchers using the same data and hypothesis reveals a hidden universe of uncertainty**



Many multi-analyst studies ongoing, e.g.:

“Are soccer players with dark skin tone more likely to receive red cards from referees?”, Silberzahn et al. 2018

“Is there an impact of compulsory schooling on teenage pregnancy rates?”, Huntington-Klein et al. (2021)



Source: BBC <https://www.bbc.com/sport/football/68435064>

“There are at least twenty multi-analyst experiments brewing”

… some large! 343 authors of Menkveld et al. (2024)”

HUNTINGTON-KLEIN, N., ARENAS, A., BEAM, E., BERTONI, M., BLOEM, J. R., BURLI, P., CHEN, N., GRIECO, P., EKPE, G., PUGATCH, T. et al. (2021). The influence of hidden researcher decisions in applied microeconomics. *Economic Inquiry* 59 944–960.

MENKVELD, A. J., (2024). Nonstandard Errors. *The Journal of Finance* 79 2339–2390. <https://doi.org/10.1111/jofi.13337>.

SILBERZAHN, R., UHLMANN, E. L., MARTIN, D. P., ANSELMINI, P., AUST, F., AWTREY, E., BAHNÍK, Š., BAI, F., BANNARD, C., BONNIER, E. et al. (2018). Many analysts, one data set: Making transparent how variations in analytic choices affect results. *Advances in Methods and Practices in Psychological Science* 1, 337–356.

We take this →

**PNAS**

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**Observing many researchers using the same data and hypothesis reveals a hidden universe of uncertainty**



Source: Britannica <https://www.britannica.com/topic/human-migration>

The question to be answered was the effect of migration on public attitude toward social policies

Literature says: negative correlation but Brady and Finnegan (2014) test 3 hypotheses:

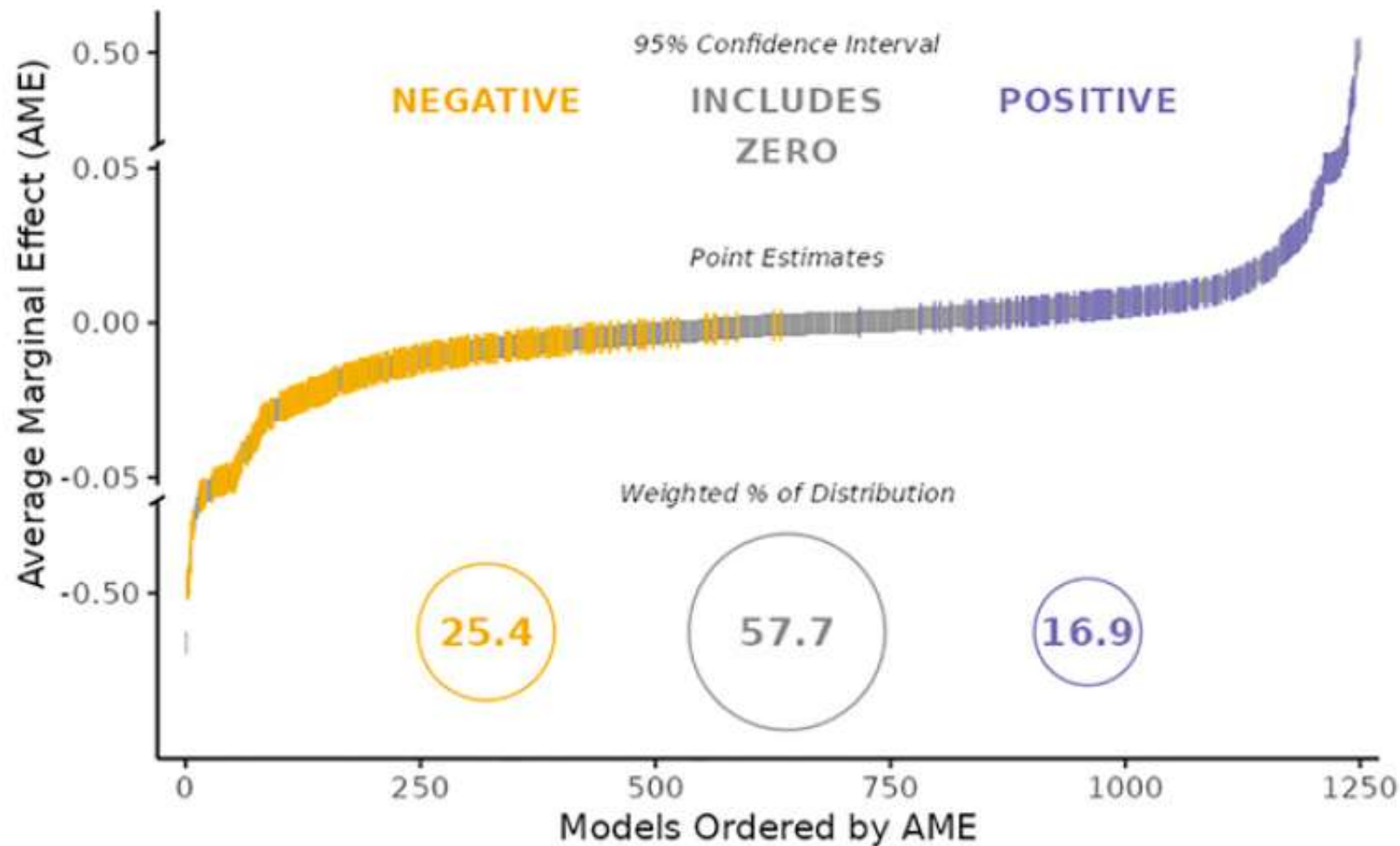
- ethnic and linguistic heterogeneity make class-based solidarity more difficult
- competition for jobs increases support for social policy (compensation hypothesis)
- the chauvinism hypothesis, no to policies that benefit immigrants

BRADY, D. and FINNIGAN, R. (2014). Does immigration undermine public support for social policy? American sociological review 79 17–42.

BREZNAU, N., RINKE, E. M., WUTTKE, et al. (2022). Observing many researchers using the same data and hypothesis reveals a hidden universe of uncertainty. Proceedings of the National Academy of Sciences 119 e2203150119.

ENGZELL, P. (2023). A universe of uncertainty hiding in plain sight. Proceedings of the National Academy of Sciences 120 e2218530120.





“Will different researchers [73 teams] converge on similar findings when analyzing the same data?”

“...teams’ results varied greatly, ranging from large negative to large positive effects”

“A universe of uncertainty hiding in plain sight” (Engzell, 2023)

In the original multi-analyst study the normative (political) orientation of the analysts was found not to explain the variance

The modelling variables were found to explain at most a few percent of the variance of the results ... where does the variance come from?



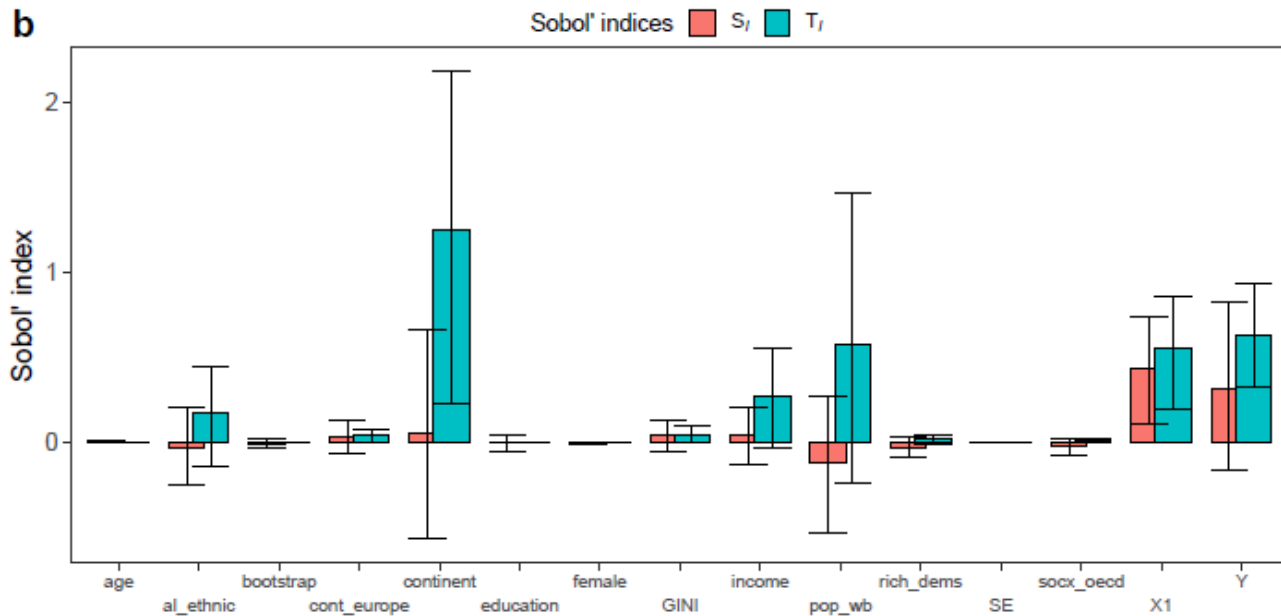
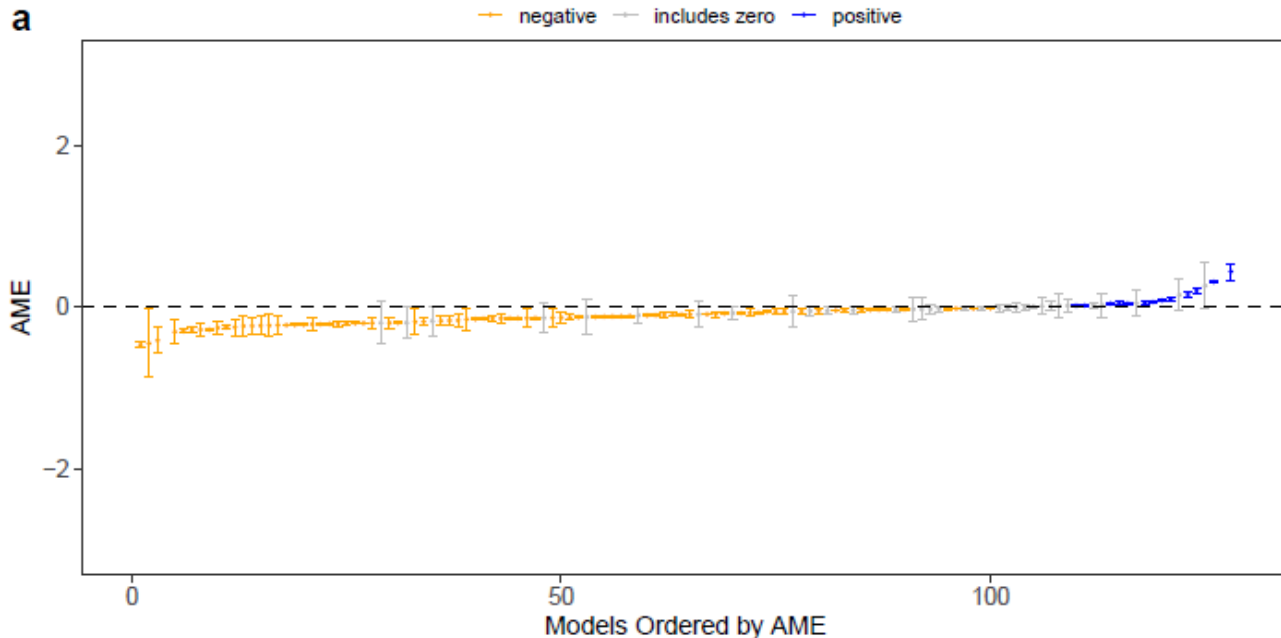
<https://www.istockphoto.com/>

$k_i$	Variable	Description
1	<i>age</i>	Inclusion or non-inclusion of the covariates age and square age of participants
2	<i>all – ethnic</i>	Inclusion or non-inclusion of a covariate that takes into account all ethnic categories
3	<i>bootstrap</i>	Inclusion or non-inclusion of the bootstrap procedure
4	<i>cont – europe</i>	Inclusion or non-inclusion of continental Europe countries in the analysis
5	<i>continent</i>	Inclusion or non-inclusion of different continents in the analysis
6	<i>education</i>	Inclusion or non-inclusion of the covariates level of education
7	<i>female</i>	Inclusion or non-inclusion of the covariates gender as self-reported by respondents in the survey
8	<i>GINI</i>	Inclusion or non-inclusion of the covariates related to the Gini indexes
9	<i>income</i>	Inclusion or non-inclusion of the covariate related to the income
10	<i>pop – wb</i>	Inclusion or non-inclusion of the covariate related to the information about country-specific numerosity of population
11	<i>rich – dems</i>	Inclusion or non-inclusion of rich democracies in the analysis
12	<i>SE</i>	Inclusion or non-inclusion of clustered standard error
13	<i>socx – oecd</i>	Inclusion or non-inclusion of the covariate related to social expenditure
14	<i>X1</i>	Inclusion or non-inclusion of the covariates related to the migration indexes
15	<i>Y</i>	Choice of policy dependent variable

**Table 1.** Descriptions of variables included in the analysis.

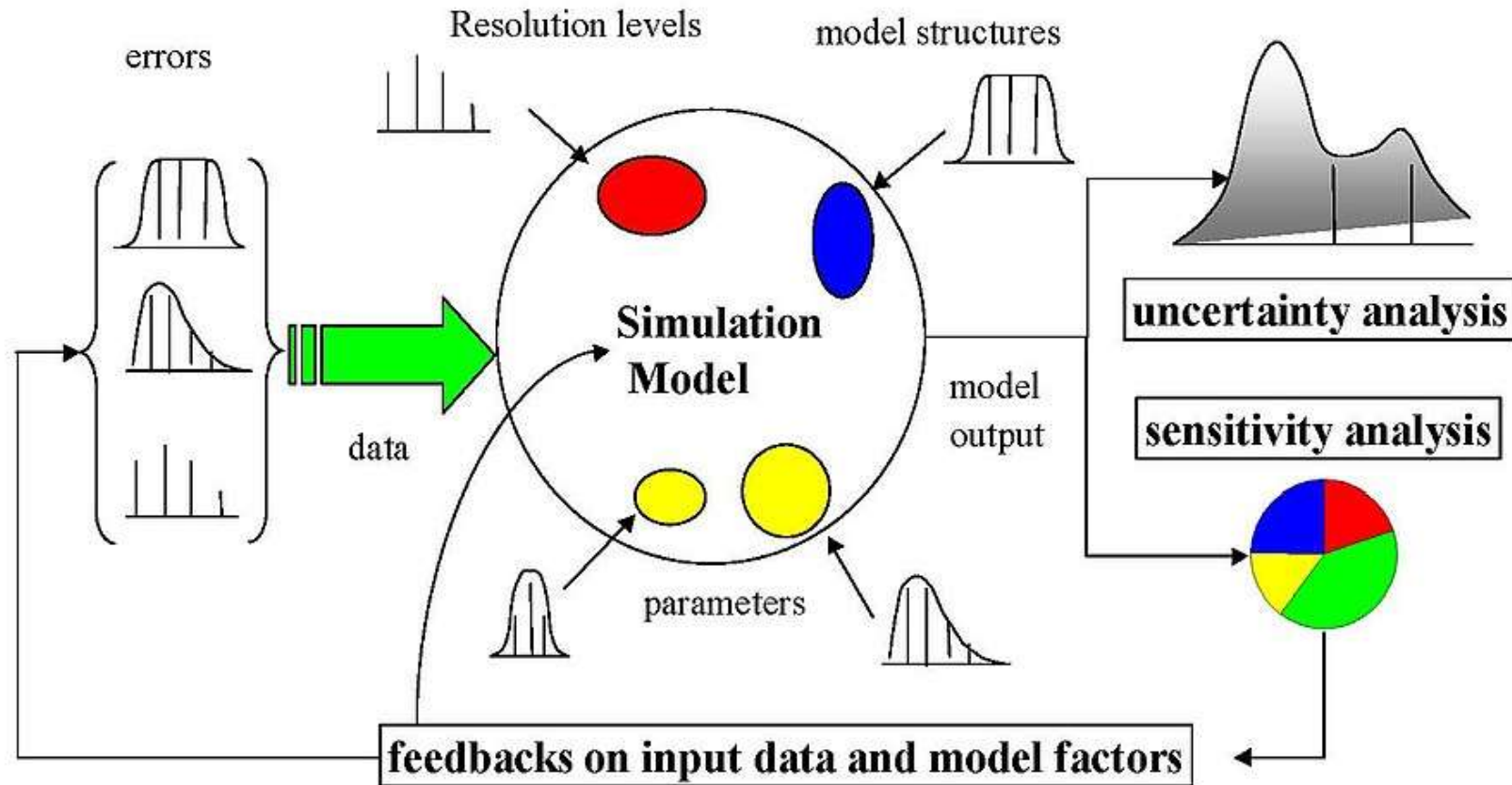
We simulate different paths using triggers  
then we do a global sensitivity analysis





Uncertainty analysis reproduces the results of the multi-analyst experiment

Our sensitivity analysis explains where the missing variance went: **interactions**



Isn't 1999 figure from Stefano already a multiverse analysis?



Other stuff

Scientists have built a 'digital twin' of Earth to predict the future of climate change



Digital twins

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## Digital Twins of the Earth Between Vision and Fiction

[Open access](#) | Published: 09 April 2025

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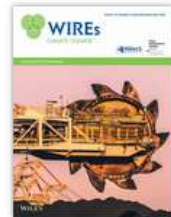
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## Bring digital twins back to Earth

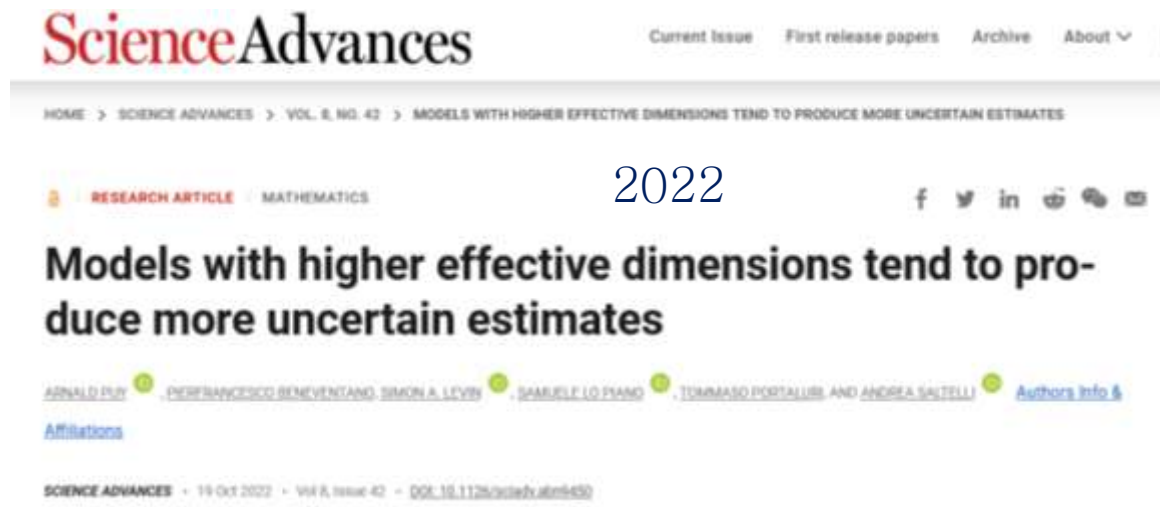
Andrea Saltelli [✉](#), Gerd Gigerenzer, Mike Hulme, Konstantinos V. Katsikopoulos, Lieke A. Melsen, Glen P. Peters, Roger Pielke Jr, Simon Robertson, Andy Stirling, Massimo Tavoni, Arnald Puy

First published: 26 August 2024 | <https://doi.org/10.1002/wcc.915> | Citations: 3



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## Sensitivity analysis

Powering up



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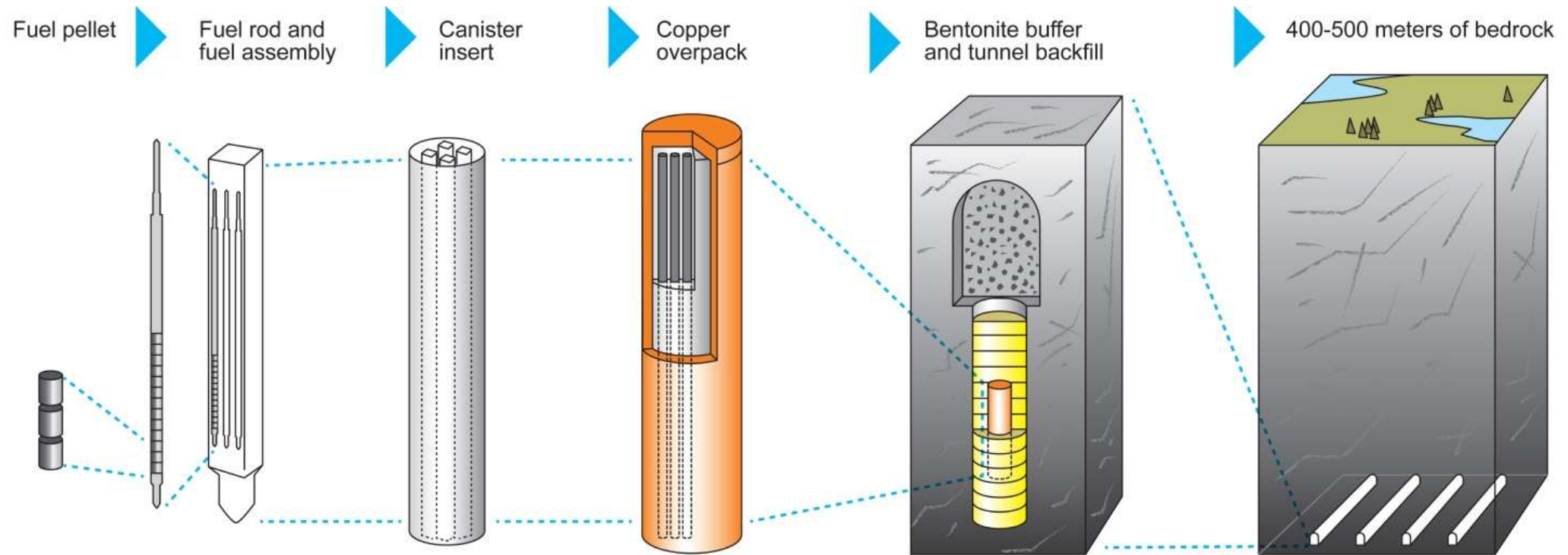
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## Models with higher effective dimensions tend to produce more uncertain estimates

ARNALDO POLI, PERFRANCESCO RENEVENTANO, SIMON A. LEWIS, SAMUELE LO PIANO, TOMMASO PORTALURI, AND ANDREA SALTIELLI

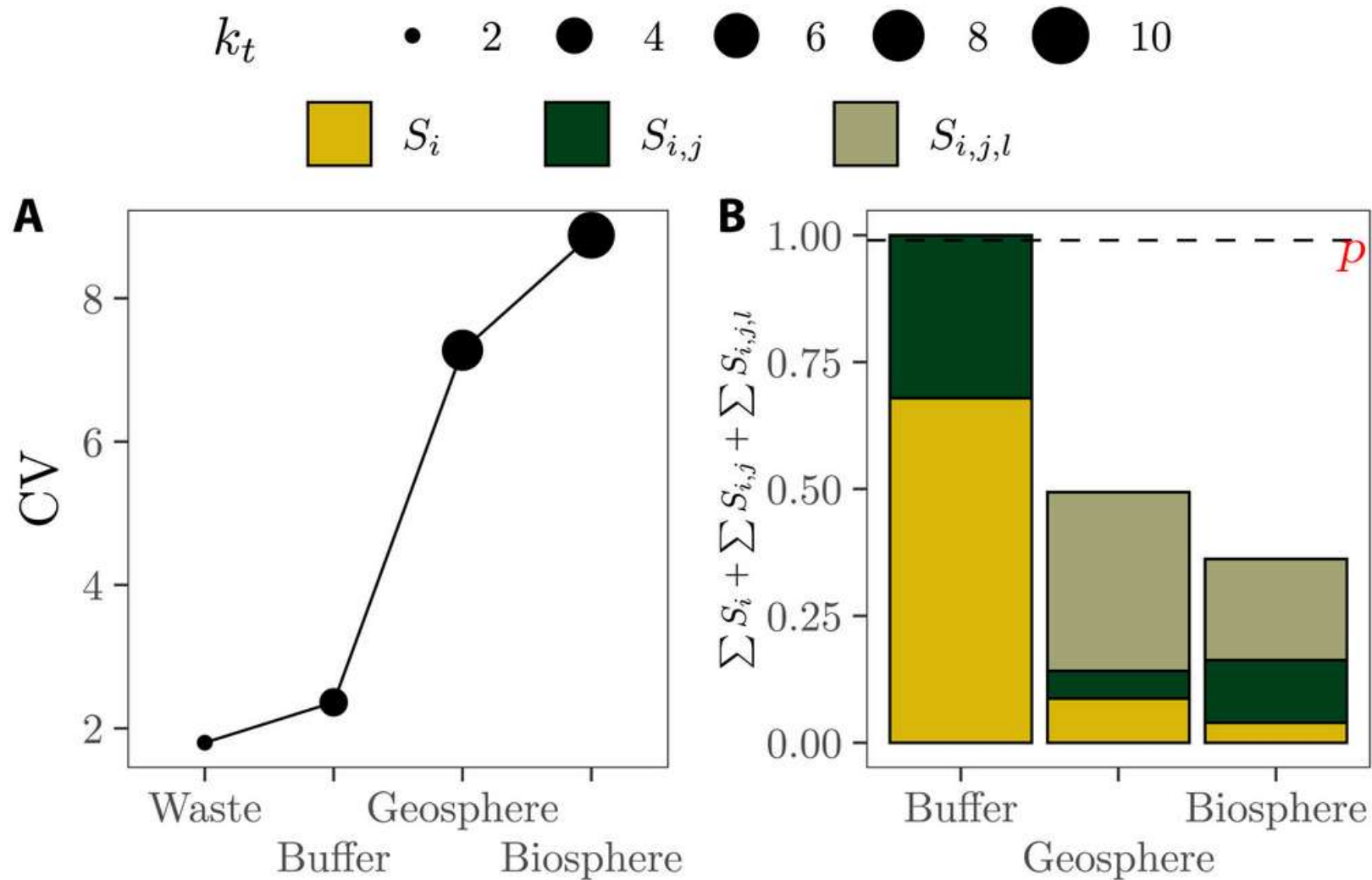
Authors Info &amp;

Affiliations



Source: World Nuclear Organization, <https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx>

A typical nuclear waste disposal concept: the waste is separated from humans by a series of barriers

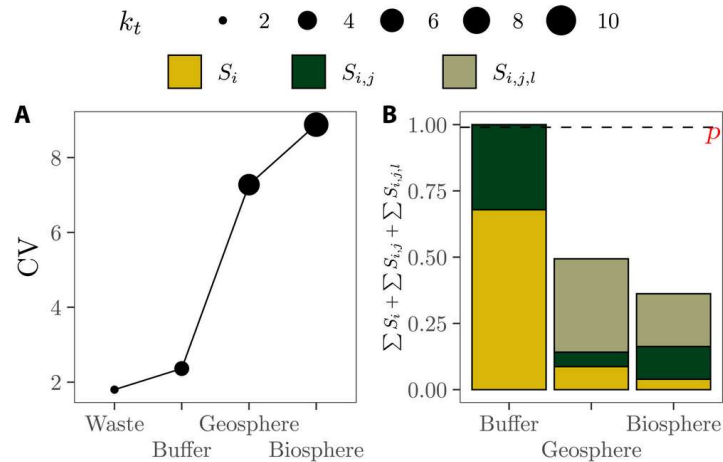


Propagating uncertainty across the barriers increases variability (CV=std/mean), effective dimension ( $k_t$ ) and the importance of interactions ( $S_{ij}$ ,  $S_{ijk}$ )



The regulation should not set limits on doses to humans in the biosphere, as done e.g. in the US, since these are impossible to predict with any certainty

A more realistic and defensible safety standard could be set as a maximum level of radioactivity leaving the buffer



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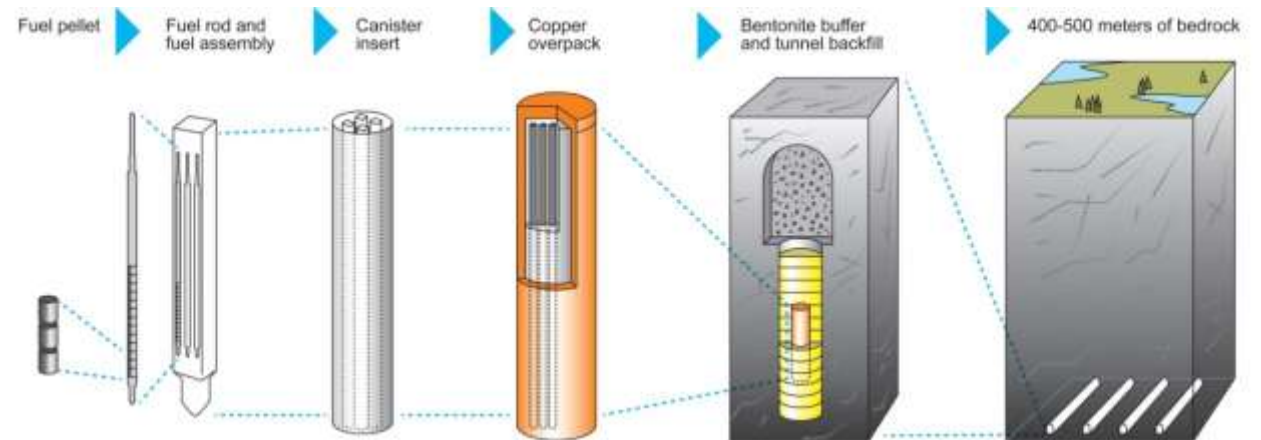
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## Models with higher effective dimensions tend to produce more uncertain estimates

ARNALDO PINI, PERFRANCESCO RENEVENTAND, SIMON A. LEVIN, SAMUELE LO PIANO, TOMMASO PORTALLAS, AND ANDREA SALTIELLI

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