Bayesian Data Analysis for Software Engineering

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ICSE 2021 Technical Briefings

Part 1: Why Should I Use Bayesian Data Analysis?

Bayesian Data Analysis for Software Engineering

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Takeaway message

Use Bayesian data analysis as much as possible!

Bayesian data analysis techniques offer many key advantages over the classical/frequentist techniques that are more commonly used in (empirical) software engineering.

When should I not use Bayesian data analysis?

Ten key reasons for using Bayesian data analysis

When Bayesian statistics are at a disadvantage

Performance:
fitting may take a long time

Effort:
more modeling work is needed

Research standards:
your research area may require frequentist statistics

Ten key reasons
for using Bayesian data analysis

#1
Beware of the replication crisis

Ten key reasons for using Bayesian data analysis

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ESSAY

Why Most Published Research Findings Are False

John P. A. Ioannidis

Published: August 30, 2005 • https://doi.org/10.1371/journal.pmed.0020124

nature International weekly journal of science

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NATURE | NEWS FEATURE

1,500 scientists lift the lid on reproducibility

Survey sheds light on the 'crisis' rocking research.

Monya Baker

25 May 2016 | Corrected: 28 July 2016

The Atlantic

SCIENCE

Psychology's Replication Crisis Is Running Out of Excuses

Another big project has found that only half of studies can be repeated. And this time, the usual explanations fall flat.

ED YONG **NOVEMBER 19, 2018**

What factors could boost reproducibility?

- Better understanding of statistics
- More robust design
- Better teaching

#2
More and more disciplines
find practical value
in Bayesian techniques

Ten key reasons for using Bayesian data analysis

What's missing from classical statistics?

Classical [statistical] tools are not diverse enough to handle many common research questions.

Richard McElreath: Statistical Rethinking, 2020, CRC Press

How are Bayesian statistics better?

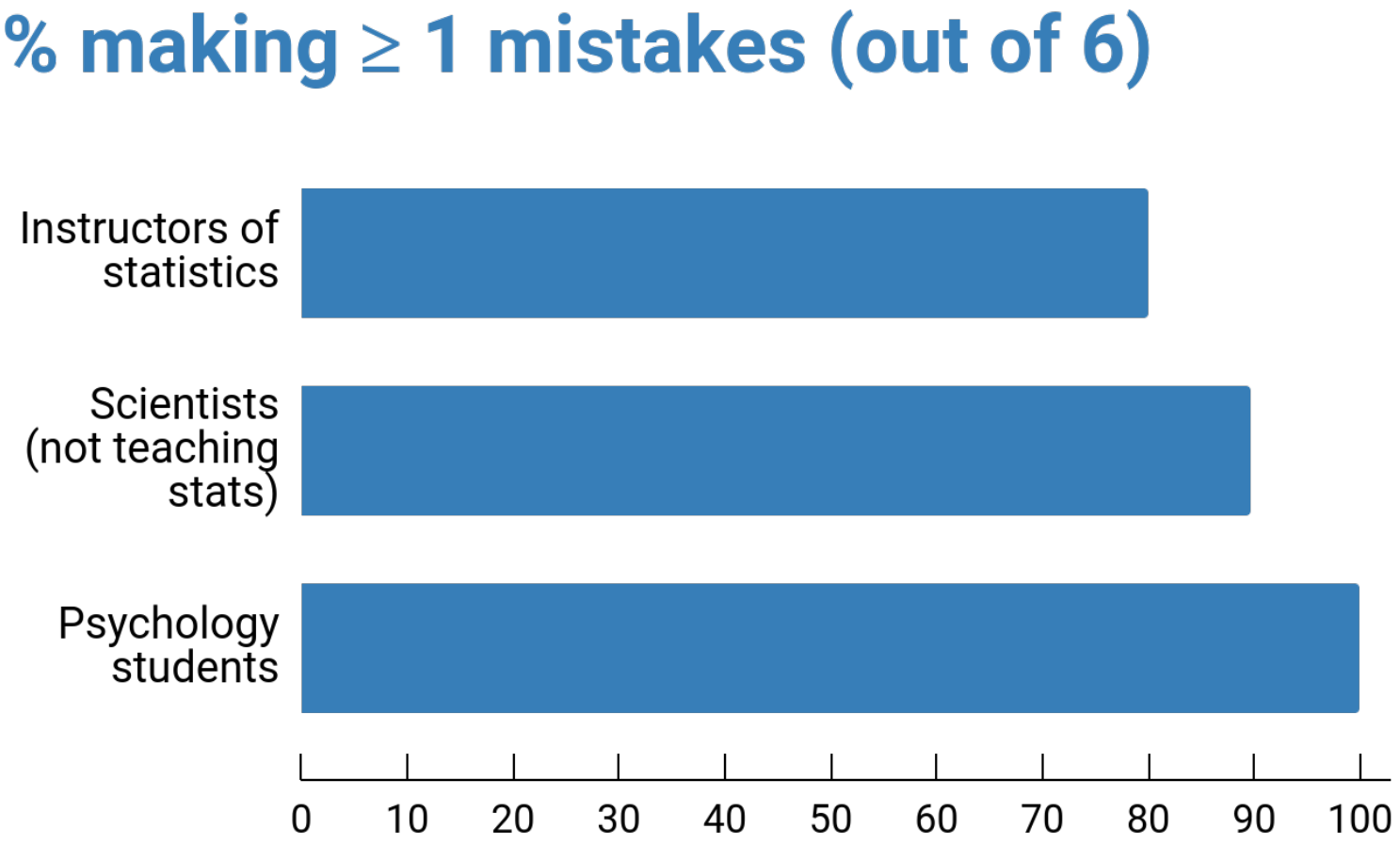
When Bayesian methods work best, it's by providing a clear set of paths connecting data, mathematical/statistical models, and the substantive theory of the variation and comparison of interest.

Andrew Gelman: Bayesian statistics: What's it all about?, 2016

#3
Bayesian models are easier to understand

Ten key reasons for using Bayesian data analysis

Misunderstanding *p*-values



Haller and Krauss: Misinterpretation of significance, 2002

Misunderstanding confidence intervals

Both researchers and students endorsed, on average, more than three [incorrect] statements [out of six], indicating a gross misunderstanding of CIs.

› Psychon Bull Rev. 2014 Oct;21(5):1157-64. doi: 10.3758/s13423-013-0572-3.

Robust misinterpretation of confidence intervals

Rink Hoekstra [1], Richard D Morey, Jeffrey N Rouder, Eric-Jan Wagenmakers

#4
Avoid dichotomous (yes/no) reasoning

Ten key reasons for using Bayesian data analysis

Yes-or-no scientific questions

Scientific conclusions and business or policy decisions should not be based only on whether a p-value passes a specific threshold.

Editorial

The ASA Statement on *p*-Values: Context, Process, and Purpose

Ronald L. Wasserstein & Nicole A. Lazar

Pages 129-133 | Accepted author version posted online: 07 Mar 2016, Published online:09 Jun 2016

We are calling for a stop to the use of P values in the conventional, dichotomous way — to decide whether a result refutes or supports a scientific hypothesis.

nature

COMMENT · 20 MARCH 2019

Scientists rise up against statistical significance

Valentin Amrhein, Sander Greenland, Blake McShane and more than 800 signatories call for an end to hyped claims and the dismissal of possibly crucial effects.

Valentin Amrhein ✉, Sander Greenland & Blake McShane

#5
Safeguard against overfitting

Ten key reasons for using Bayesian data analysis

The risk of overfitting

Techniques against overfitting

Regularizing priors:

Do not learn only from the data

Partial pooling:

Propagate information across data clusters

Out-of-sample predictive effectiveness:

Penalize models that make poor predictions

#6
Quantitative distributional information

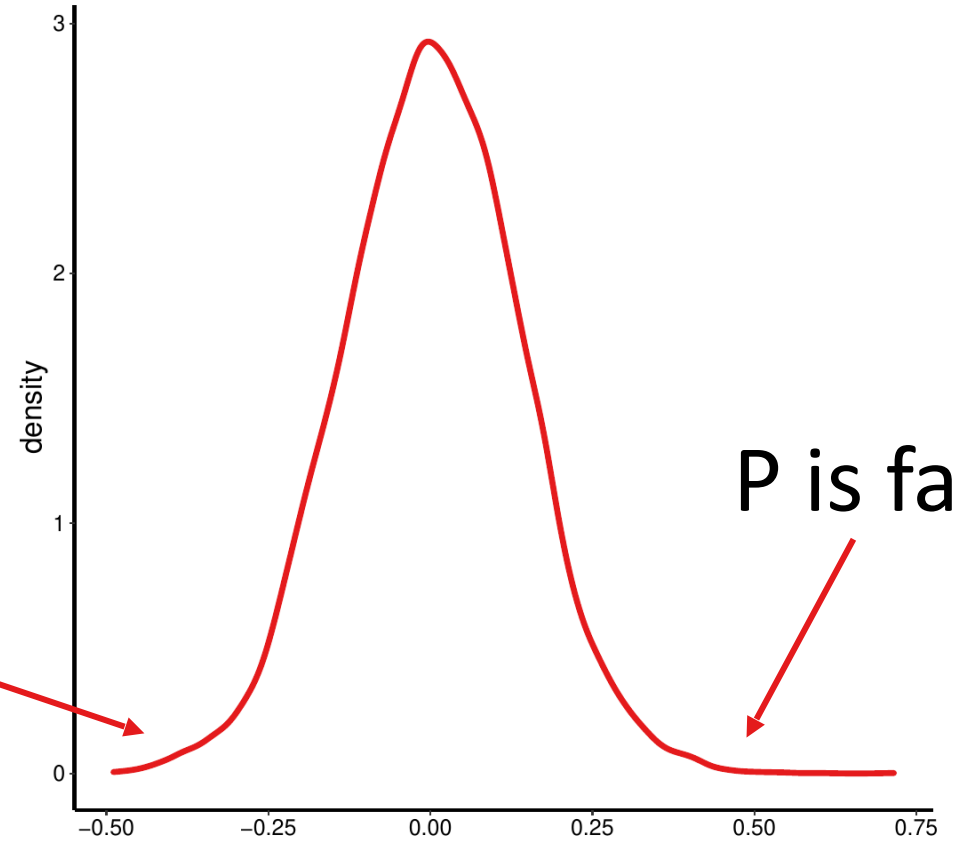
Ten key reasons for using Bayesian data analysis

Outcomes of a statistical analysis

Is language H usually faster than language P?

p-value:
$p = 0.334$

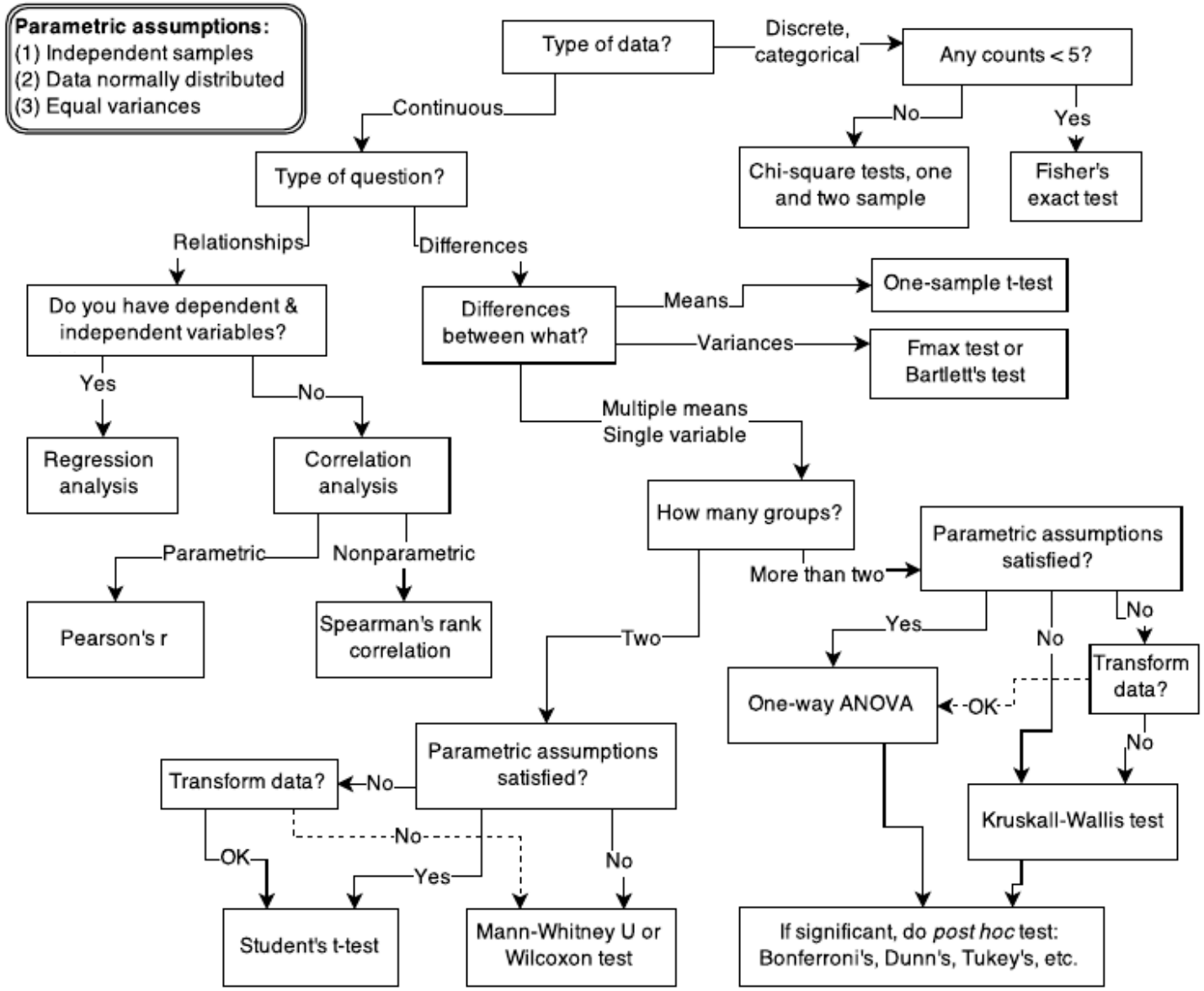
Cliff's delta:
$\delta = 0.048$



#7
Flexibility of modeling

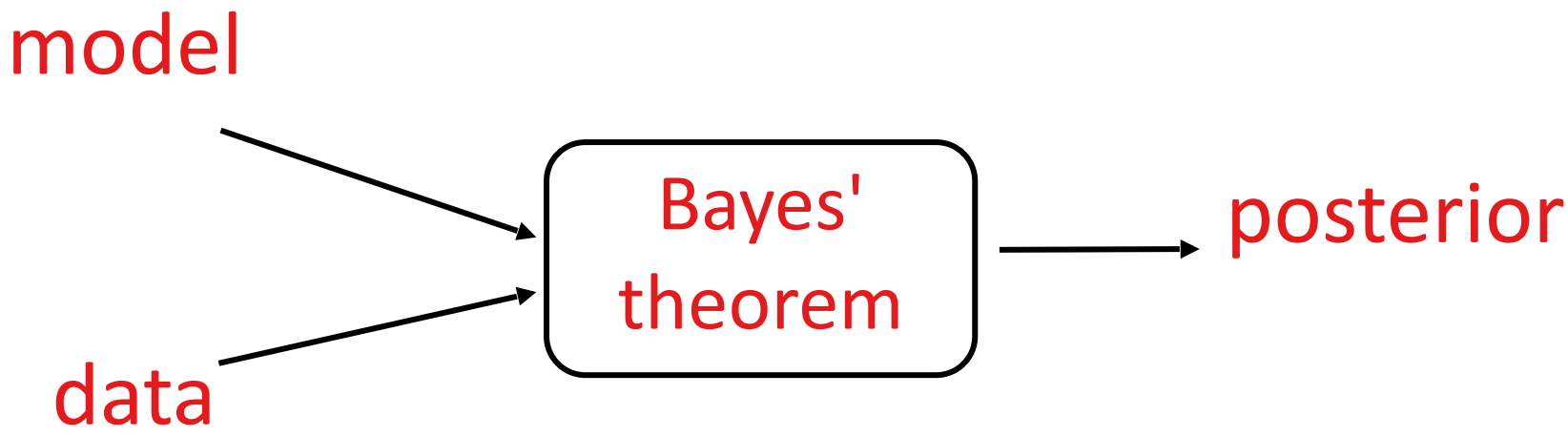
Ten key reasons for using Bayesian data analysis

What statistical model should you use?



Source: R. McElreath, Statistical Rethinking (2nd ed), CRC press, 2020

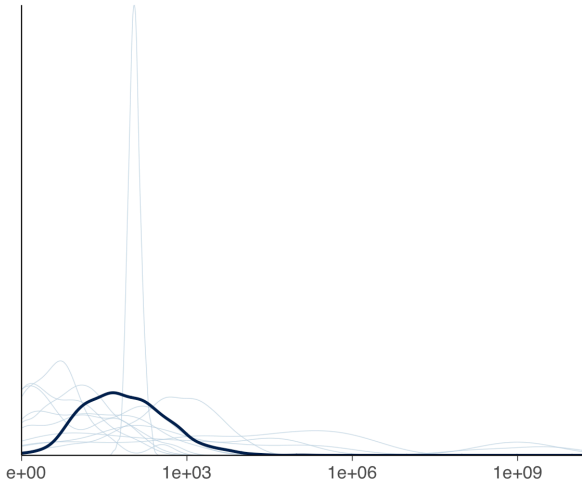
One rule to rule them all

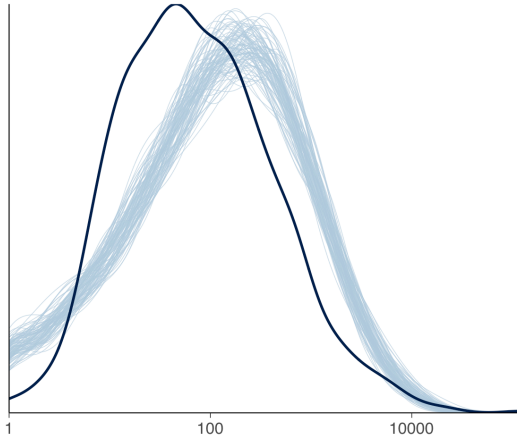


#8
Find fitting problems and test assumptions

Ten key reasons for using Bayesian data analysis

Powerful diagnostics

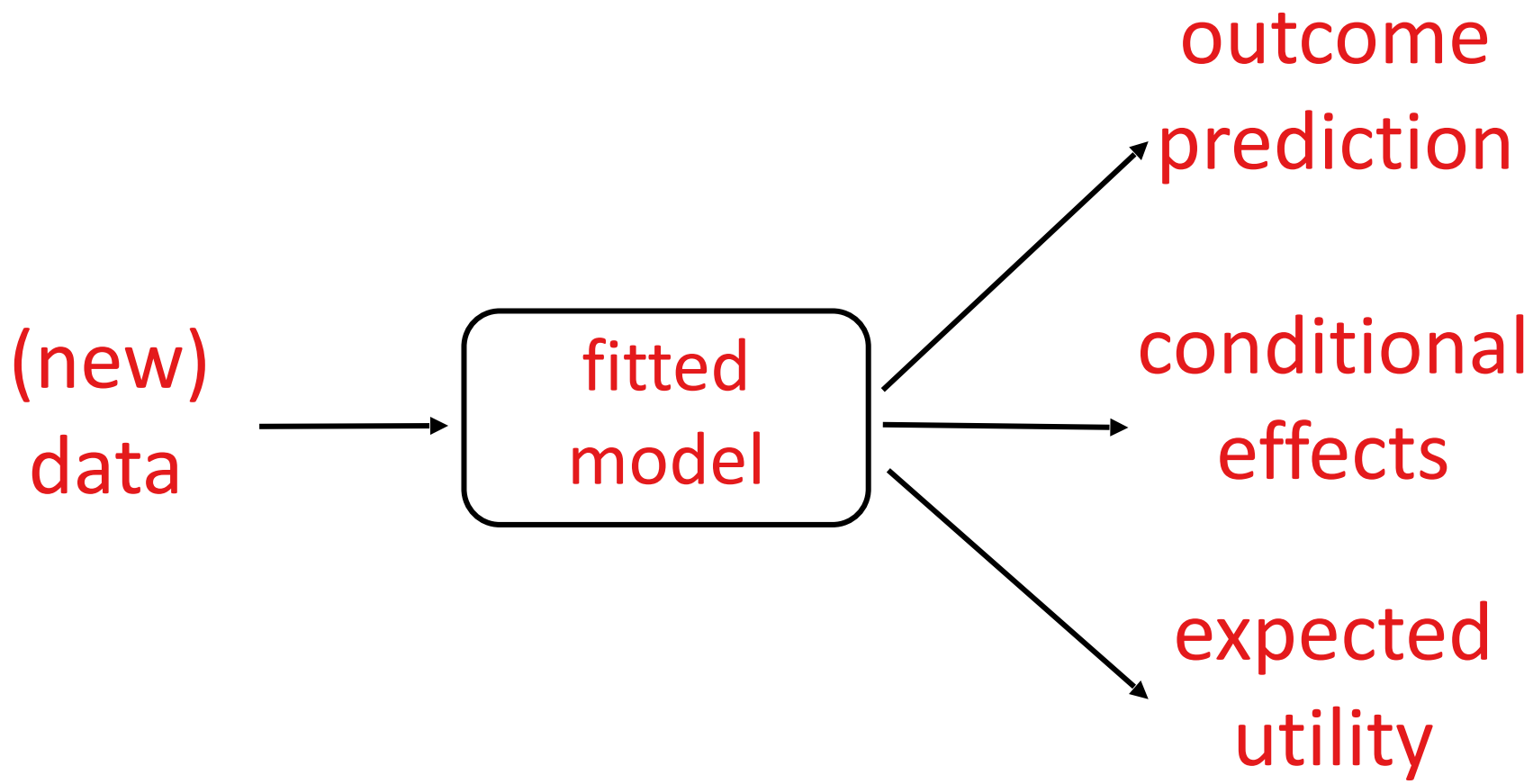




#9
Let's talk practical significance

Ten key reasons for using Bayesian data analysis

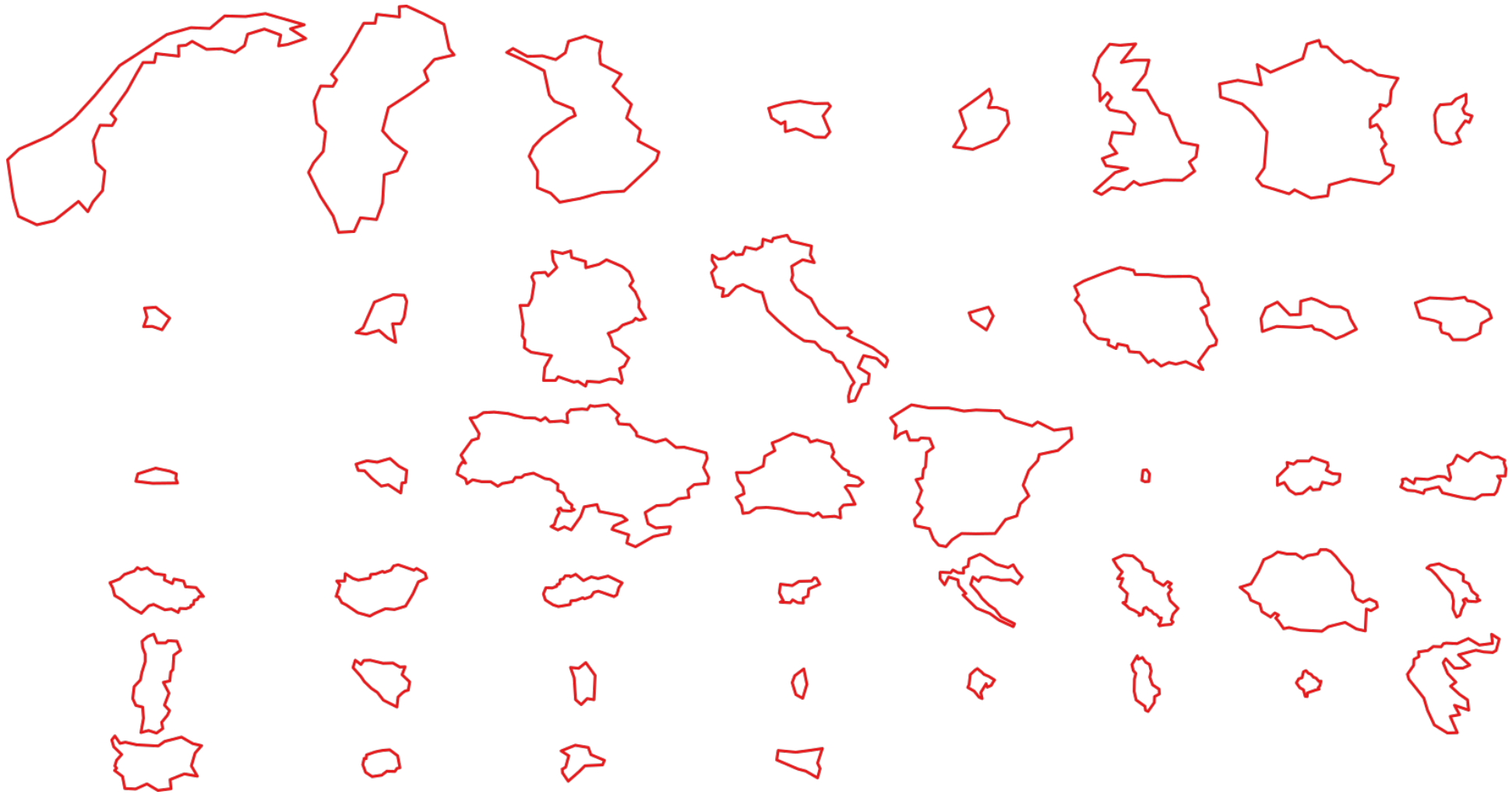
Derived distributions



#10
Plan and connect follow-up studies

Ten key reasons for using Bayesian data analysis

From isolated studies…



To a connected whole

Ten key reasons for using Bayesian data analysis

1. Beware of the replication crisis
2. More and more disciplines find practical value in Bayesian techniques
3. Bayesian models are easier to understand
4. Avoid dichotomous (yes/no) reasoning
5. Safeguard against overfitting
6. Quantitative distributional information
7. Flexibility of modeling
8. Find fitting problems and test assumptions
9. Let's talk practical significance
10. Plan and connect follow-up studies

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