Quantifying Information Leakage of Deterministic Encryption

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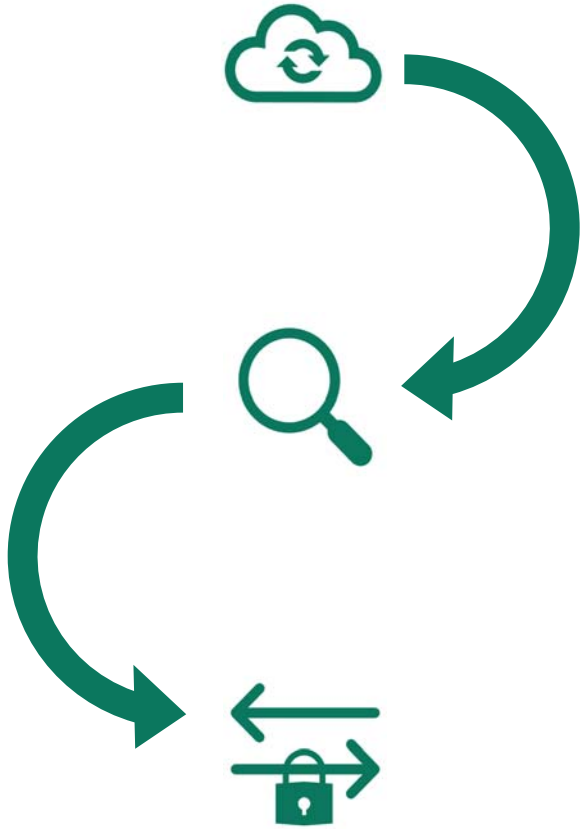
November 11, 2019

CCSW 2019: Cloud Computing Security Workshop

FIU
Engineering & Computing
School of Computing & Information Sciences

Challenge

- We want to store sensitive data remotely
- Encrypted databases aim to balance security and functionality



Question: How do you measure information leakage of deterministic encryption?

Quantitative Information Flow (QIF)

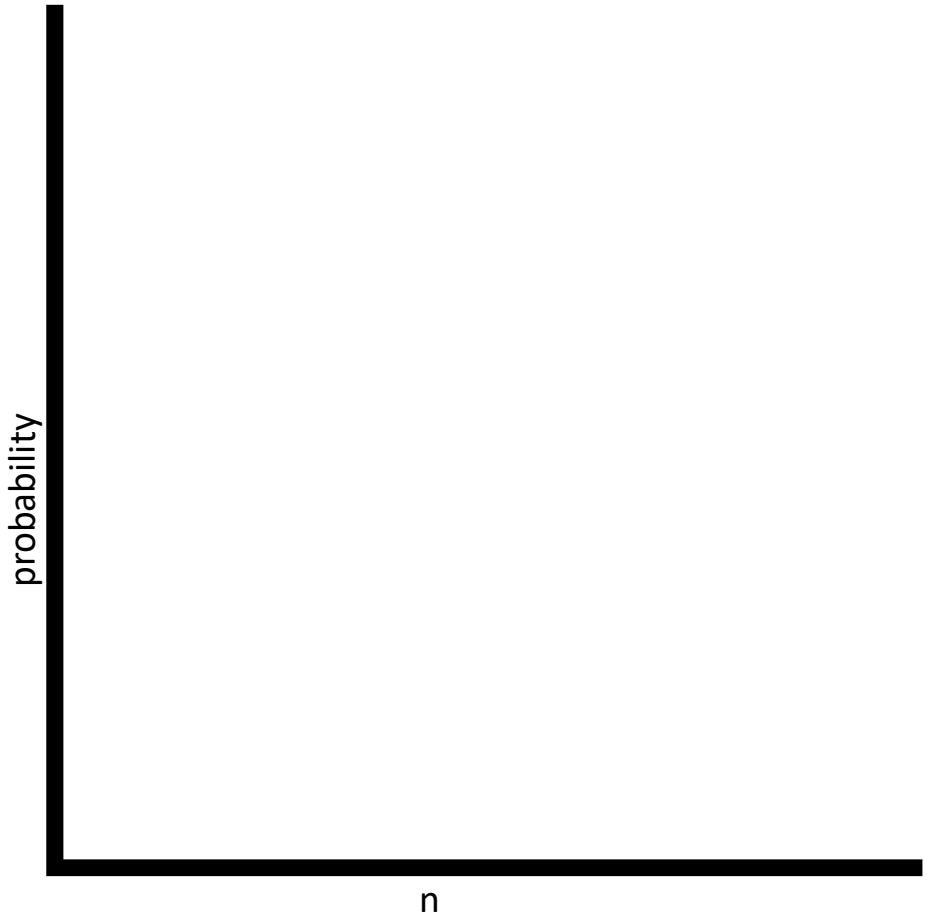
Diabetes
Measles
Measles
Stroke
Diabetes
Measles

Xq2gZZ
pg73Qq
pg73Qq
w5KL2z
Xq2gZZ
pg73Qq

The database column of diseases, drawn independently according to some prior distribution δ on diseases

The deterministic encryption of the column, modeled as a random permutation (the “ideal object”)

Quantitative Information Flow Concepts



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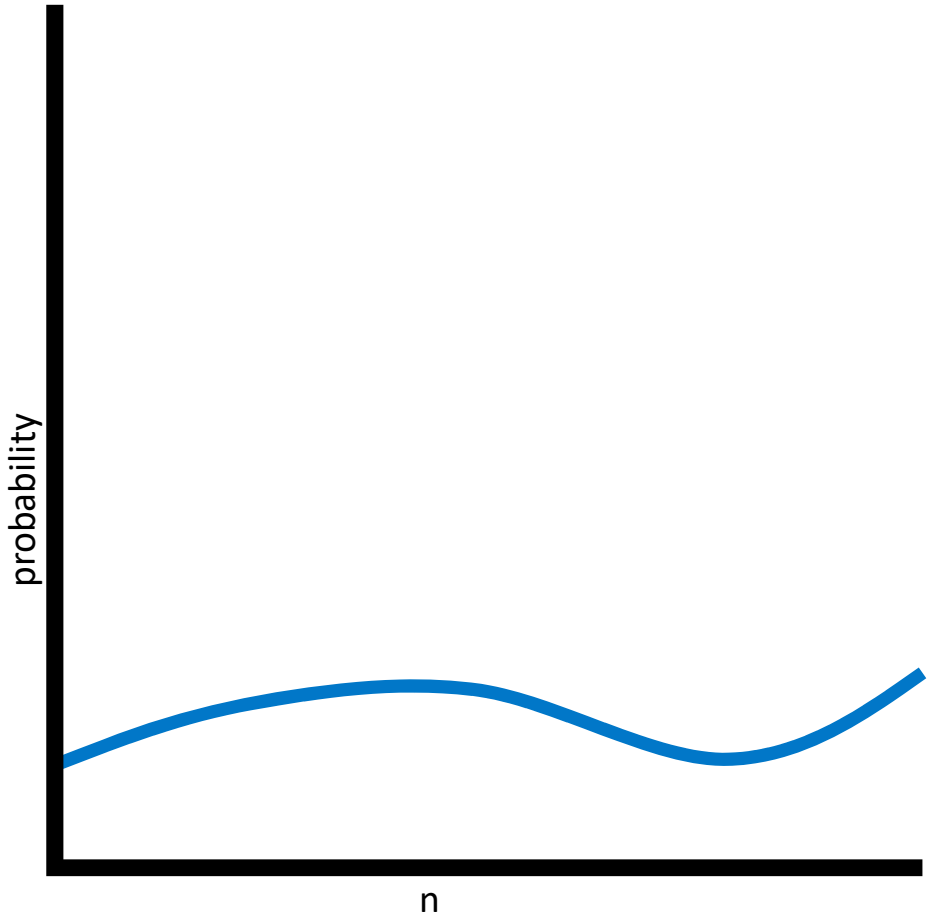

Prior vulnerability:
Adversary's probability of accomplishing goal given only δ

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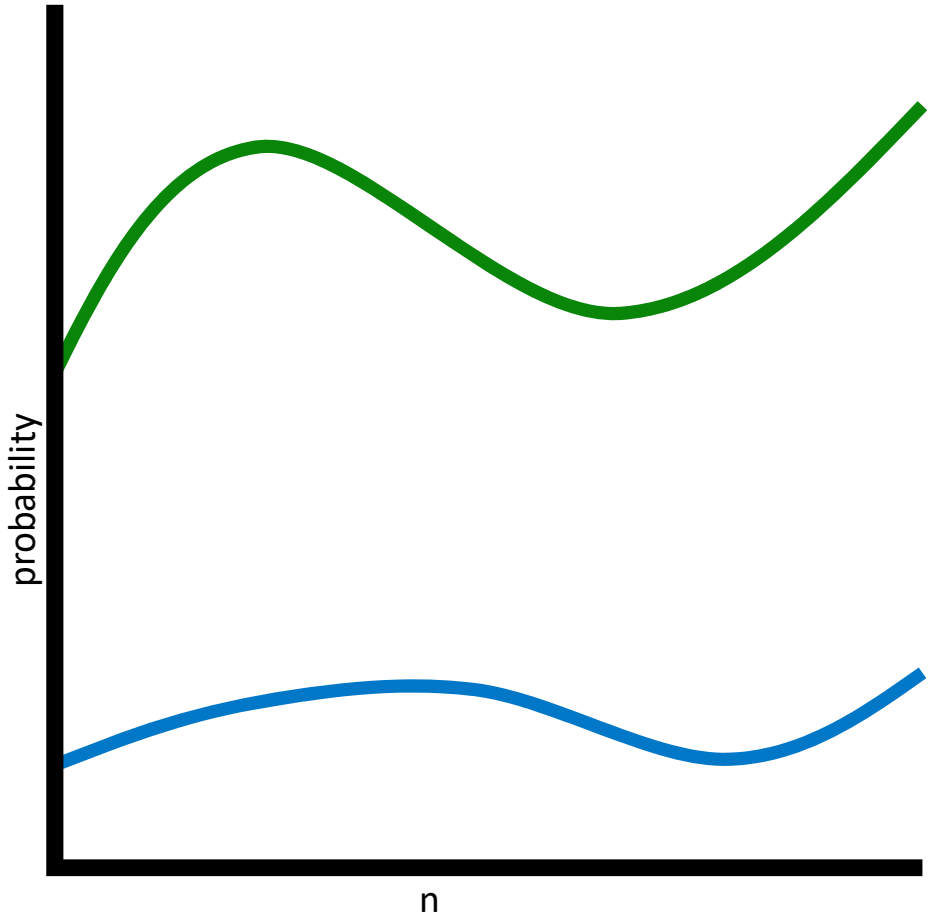

Posterior vulnerability:
Adversary's probability of accomplishing goal given δ **and** output *Y*

Prior vulnerability:
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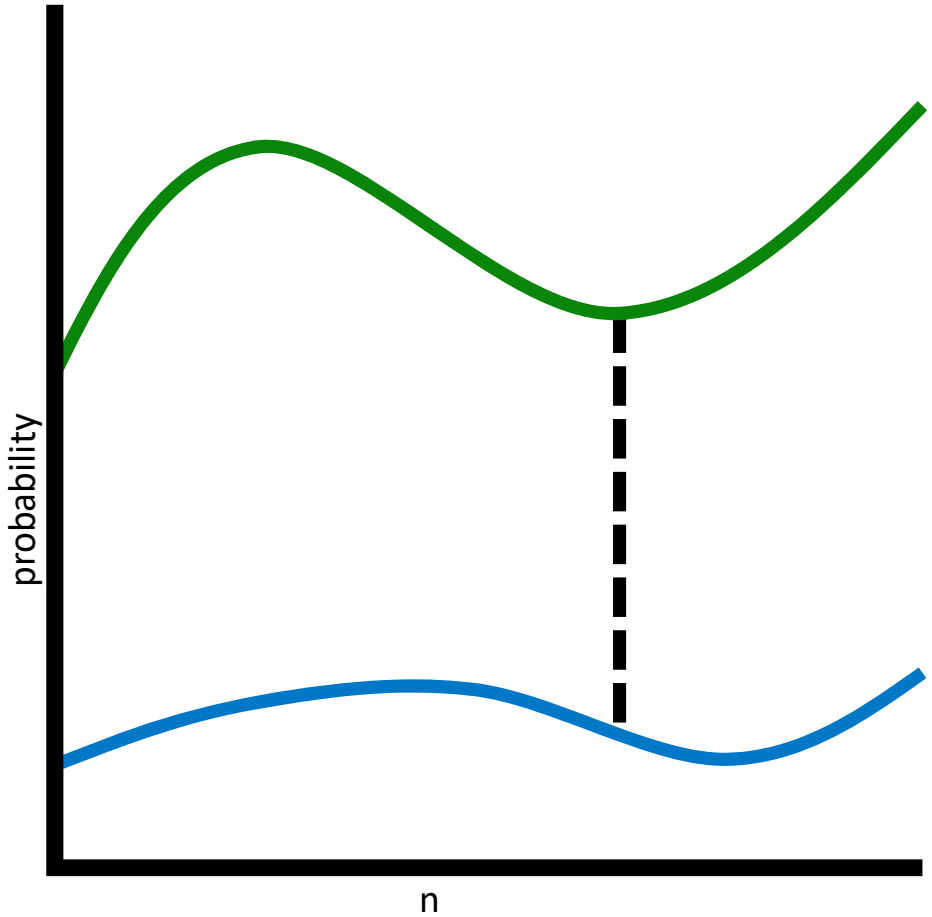

Posterior vulnerability:
Adversary's probability of accomplishing goal given δ **and** output *Y*

Leakage:
The difference between prior and posterior vulnerability

Prior vulnerability:
Adversary's probability of accomplishing goal given only δ

Intuition of Model

Disease	Probability δ
a	$1/2$
b	$1/3$
c	$1/6$

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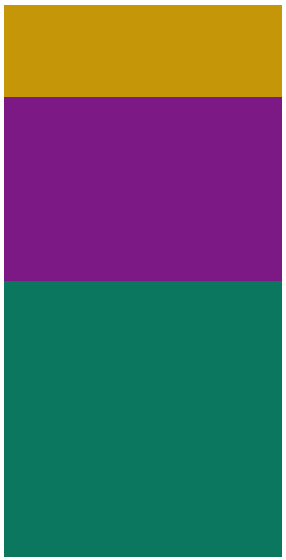

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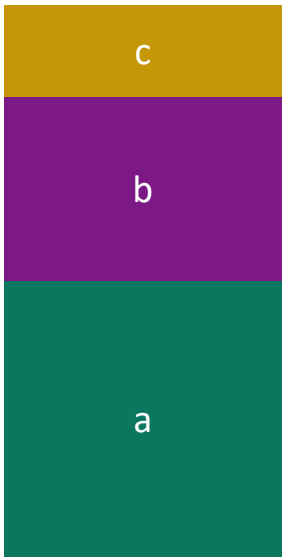

Results: Bayes Scenario

Goal: guess the entire secret in one try

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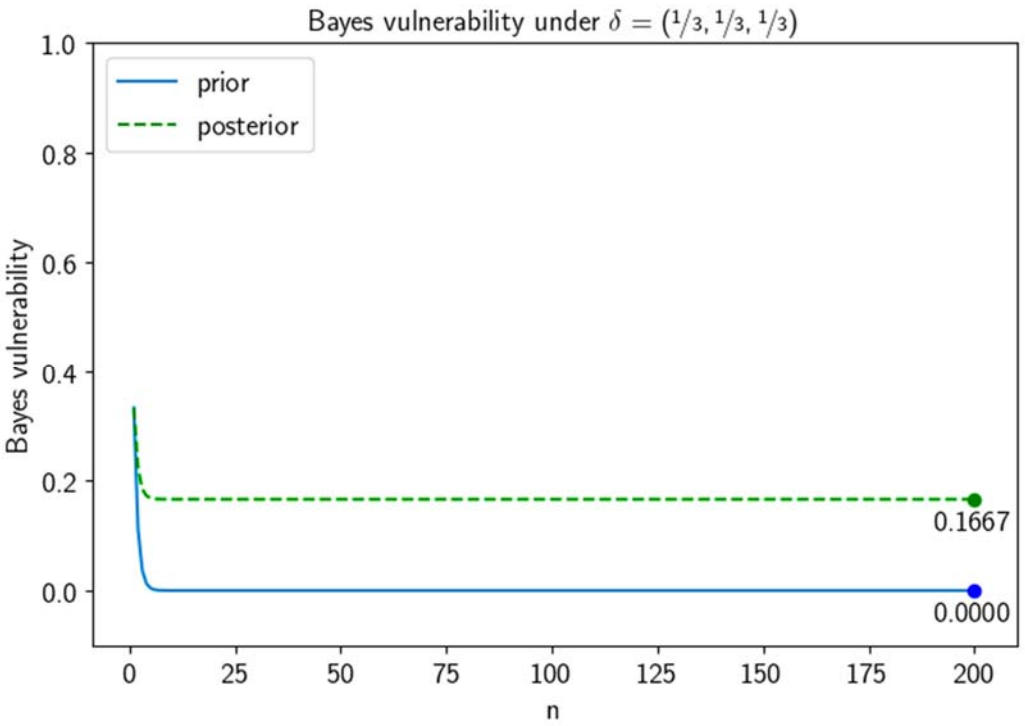

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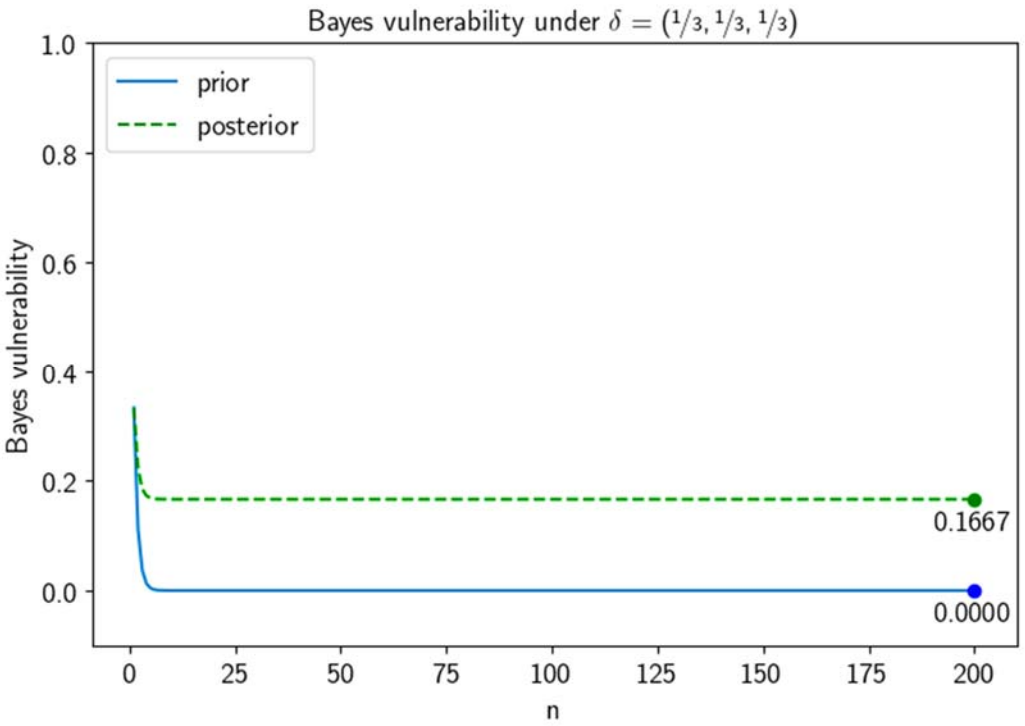

Prior Vulnerability:

When n = 1: ? $1/3$

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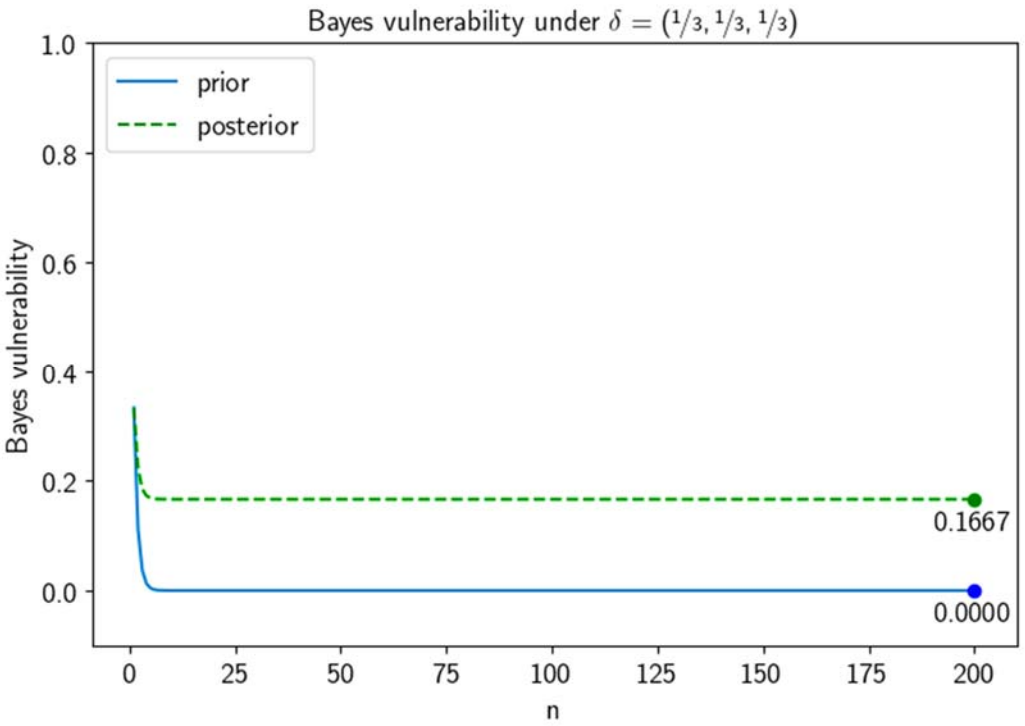

Prior Vulnerability:

When n = 1: ? $1/3$

When n is large: ? $1/3^n$

?

?

?

?

?

?

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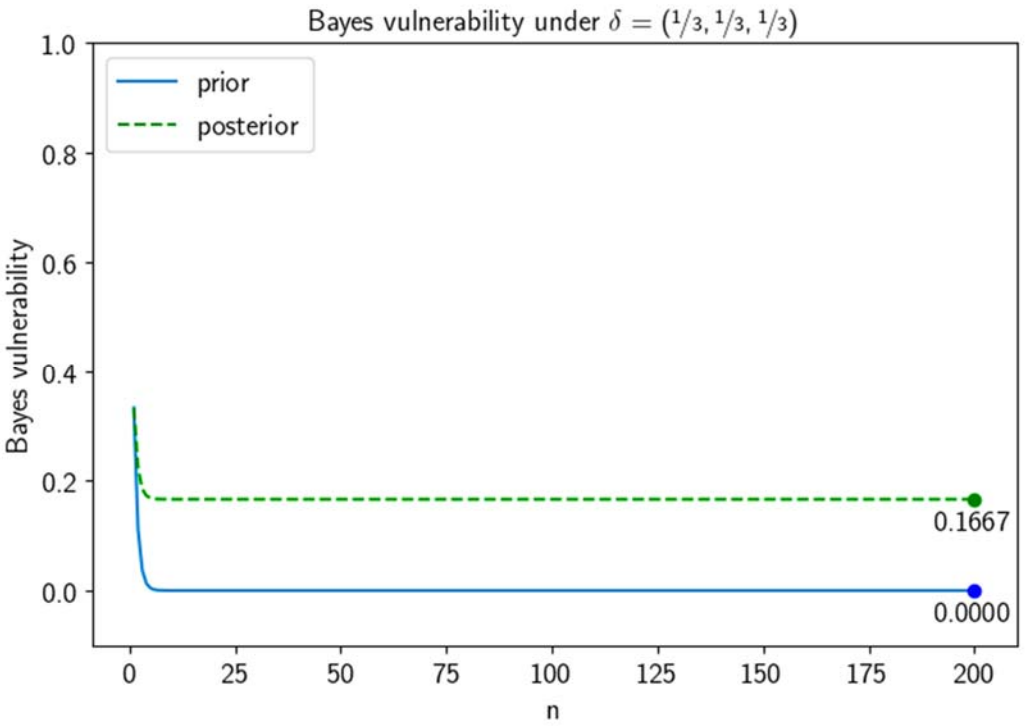

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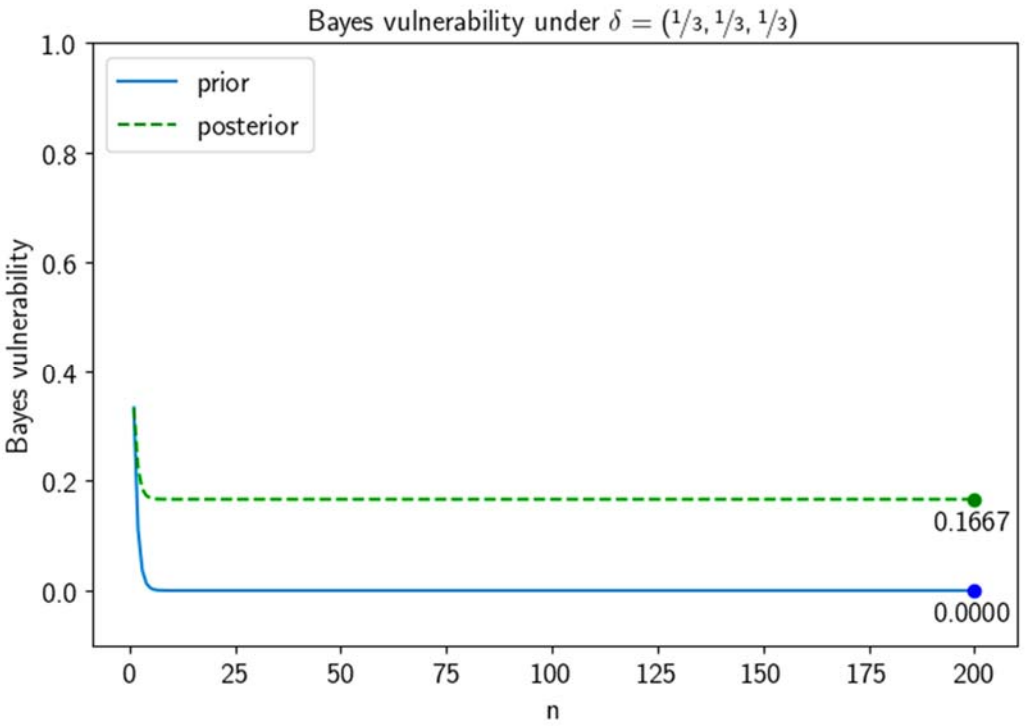
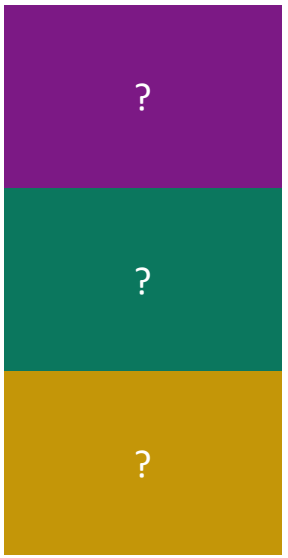


Posterior Vulnerability:

When n is large:



$1/6$

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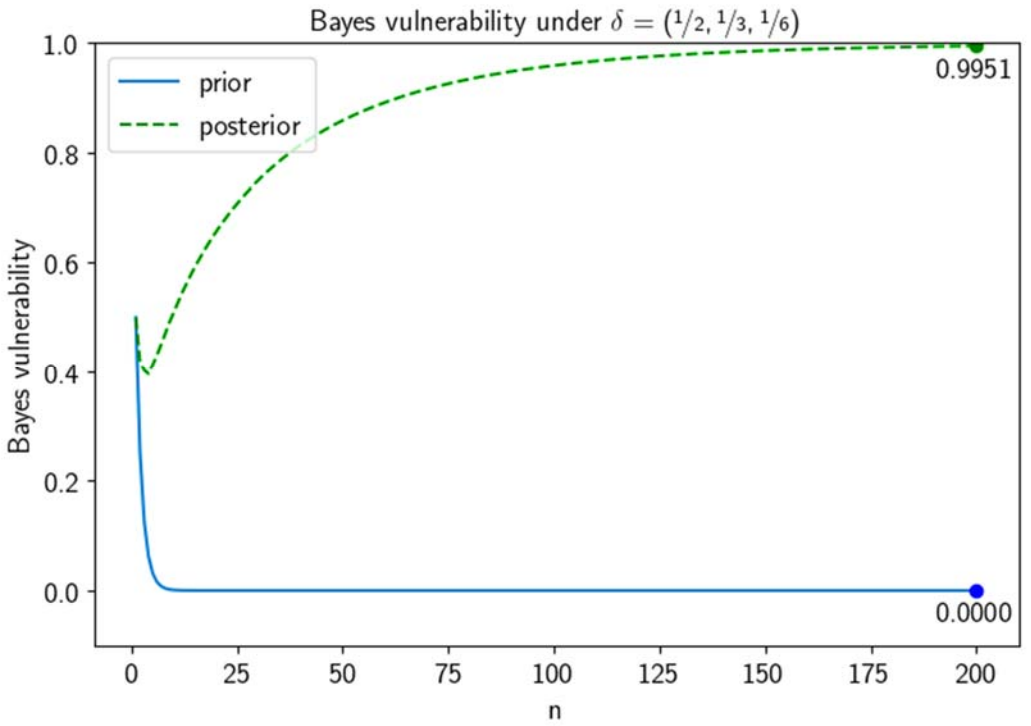

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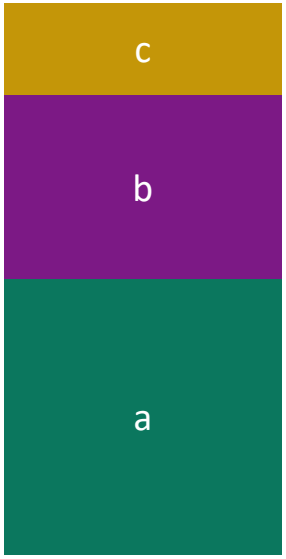

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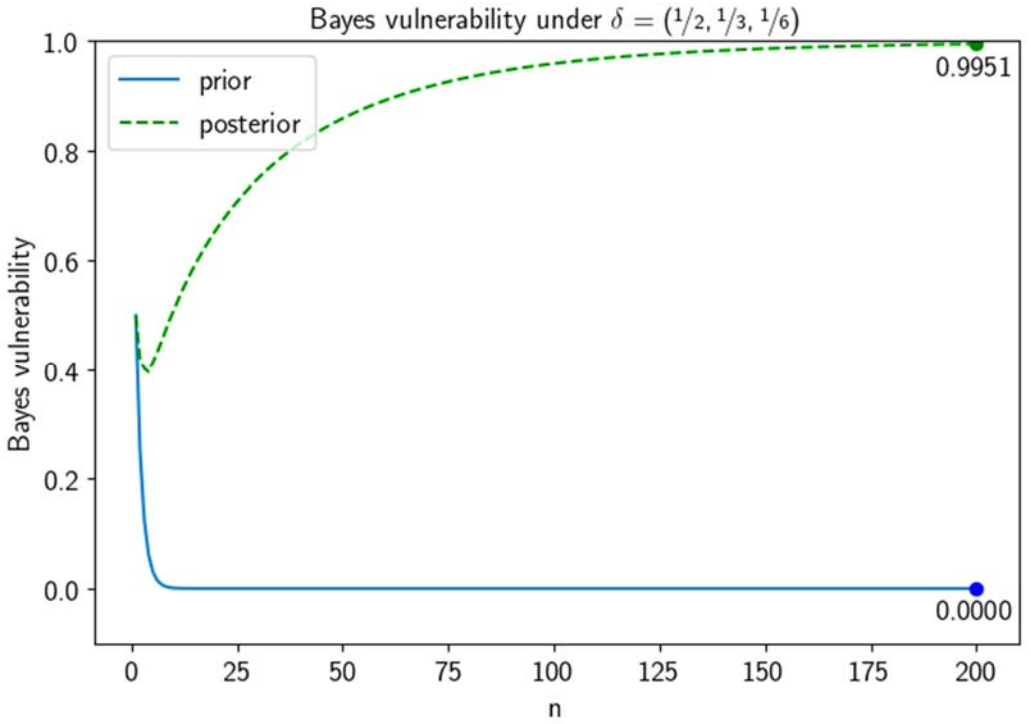

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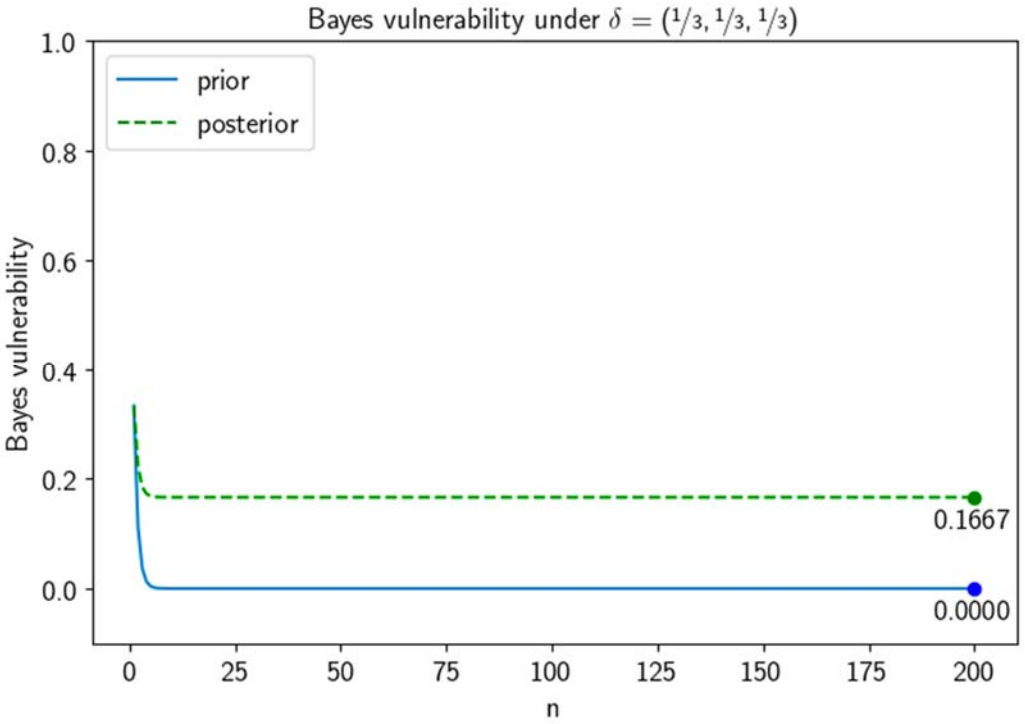

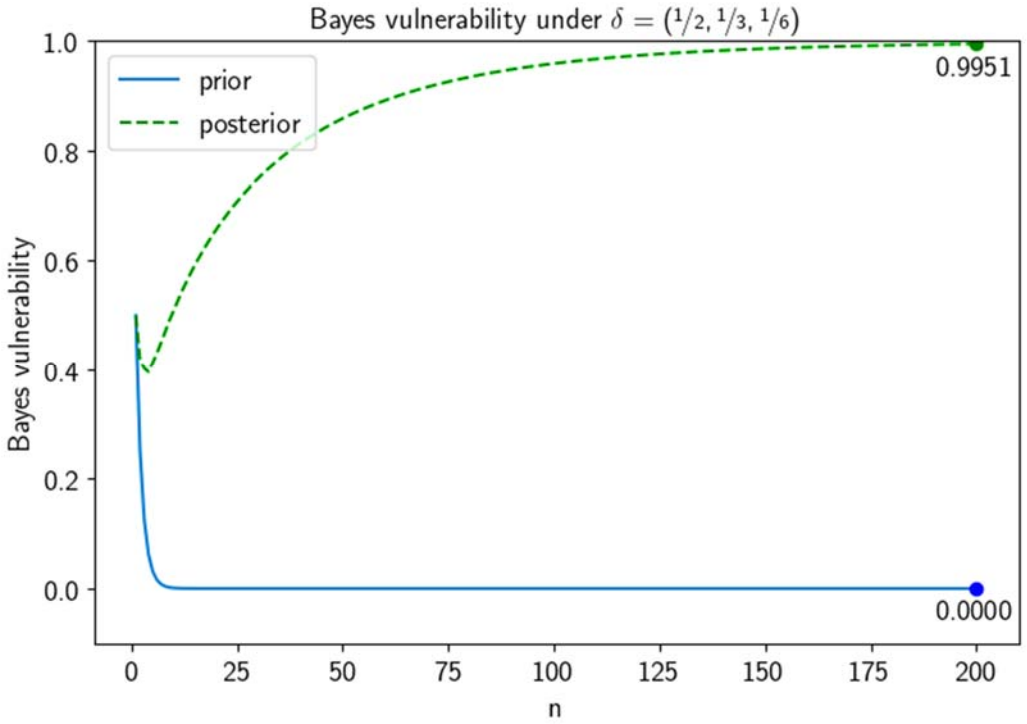

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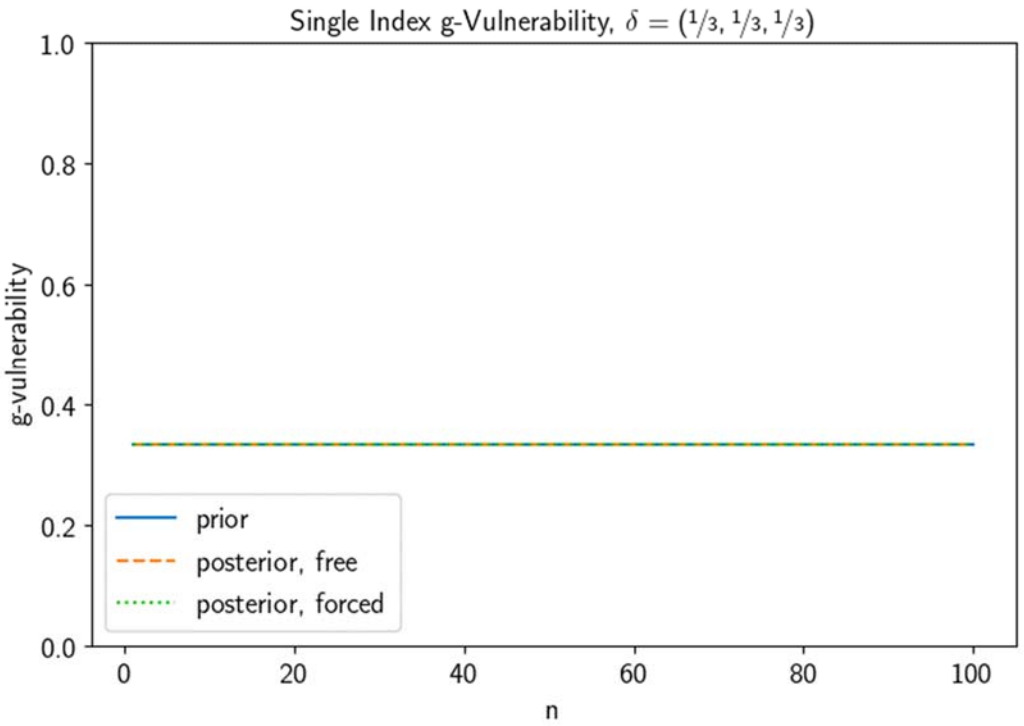

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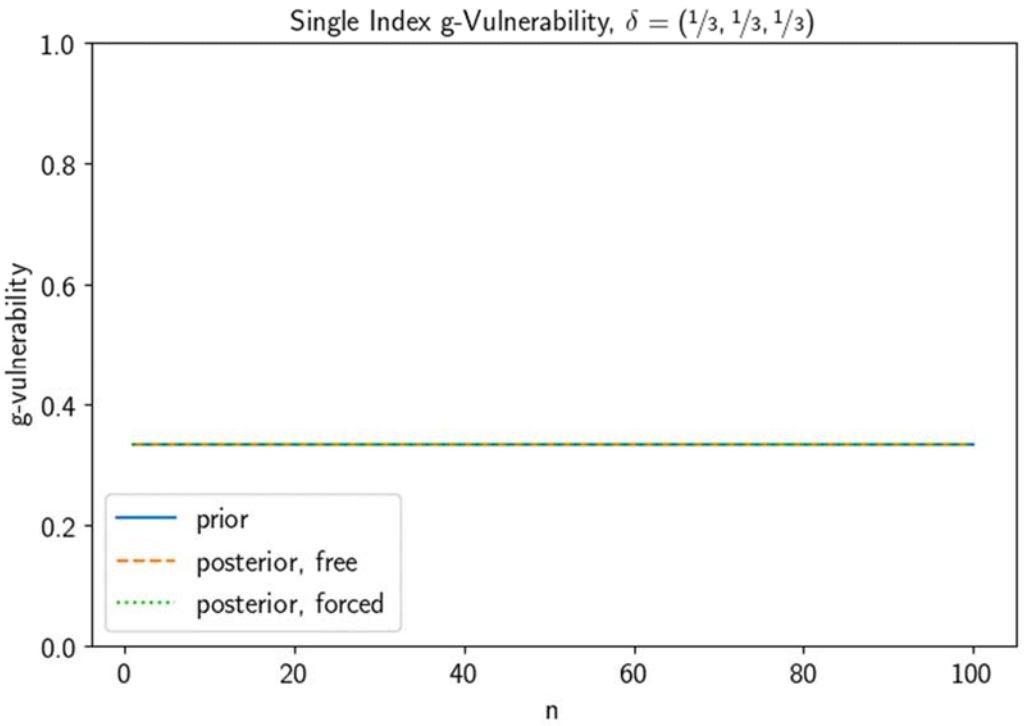
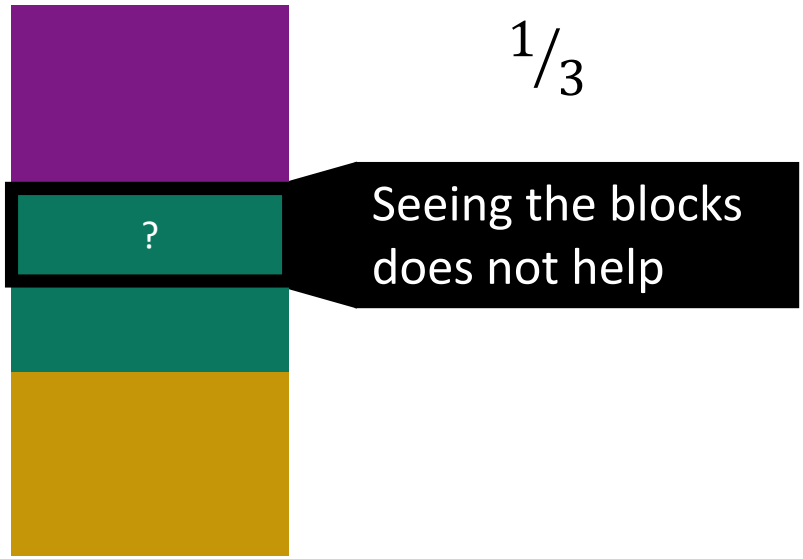


Posterior Vulnerability:



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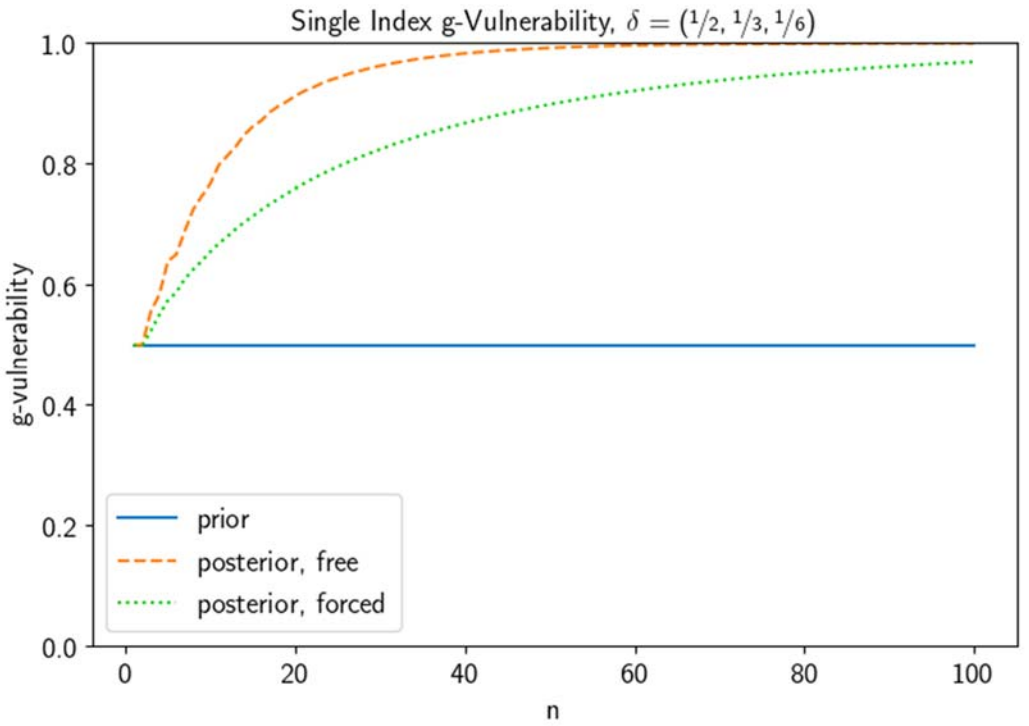

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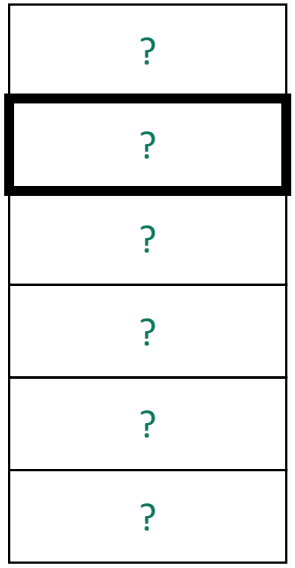
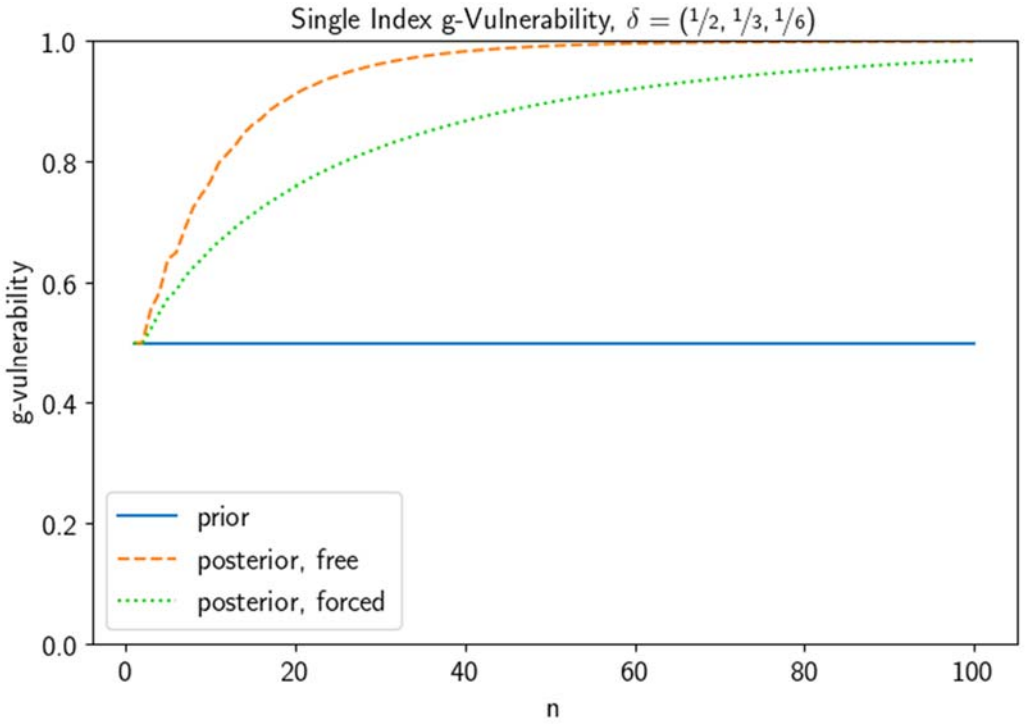


$1/2$



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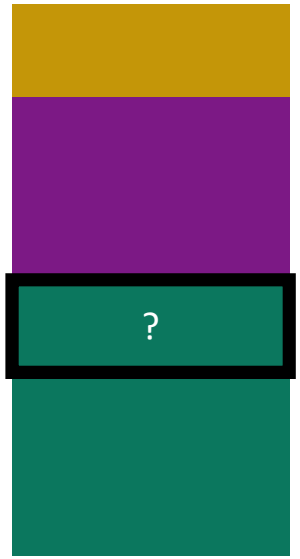
Posterior Vulnerability (free):



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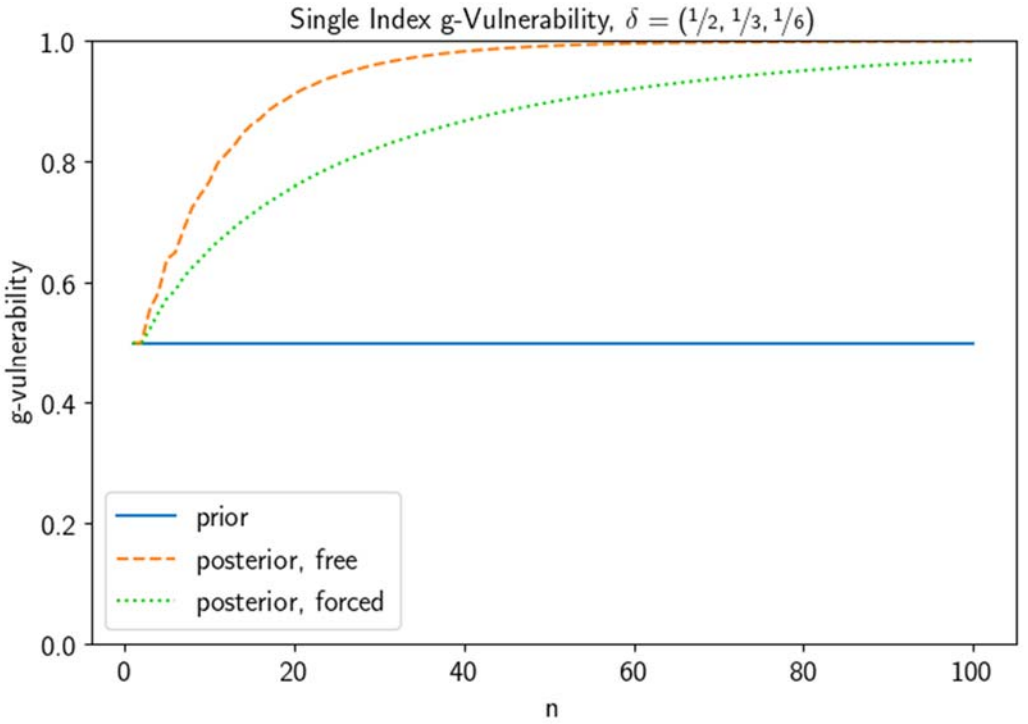

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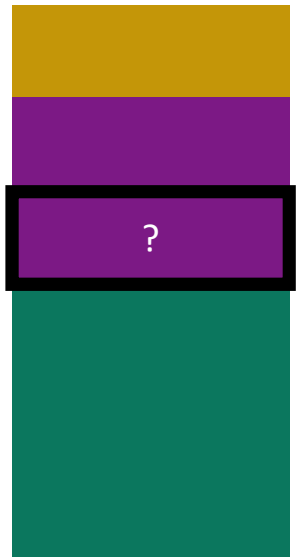
Posterior Vulnerability (forced):



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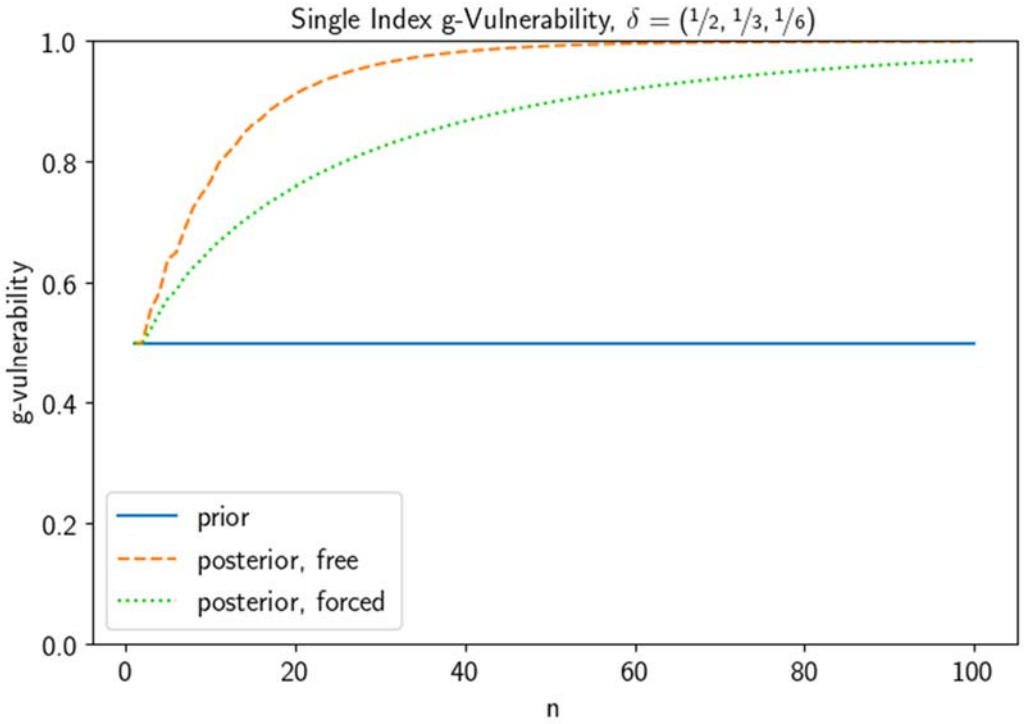

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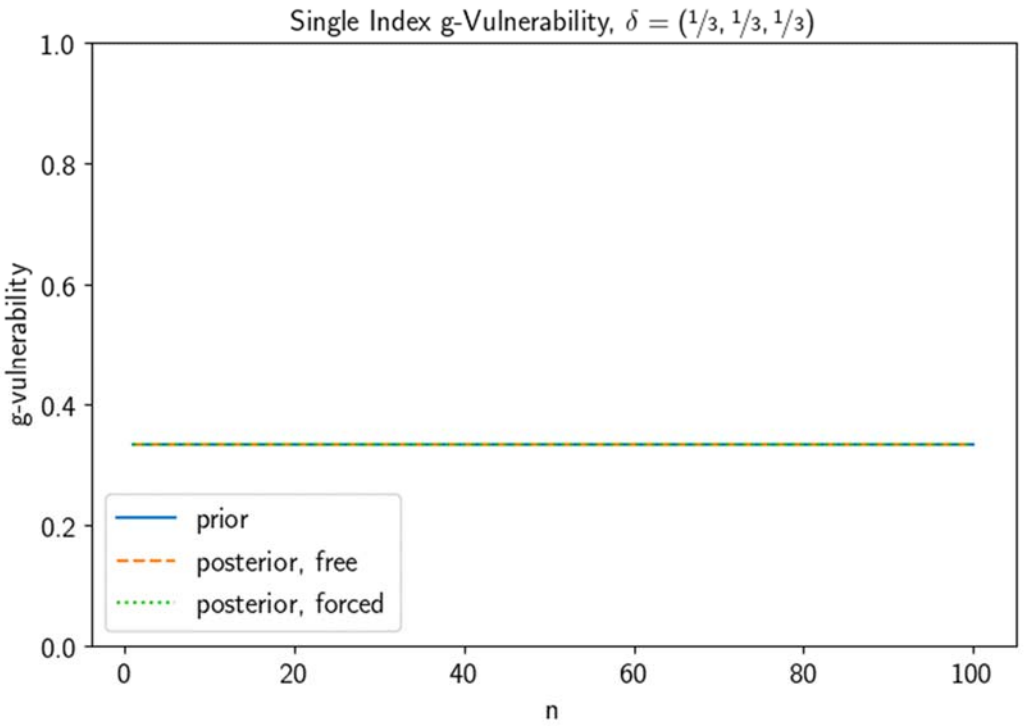
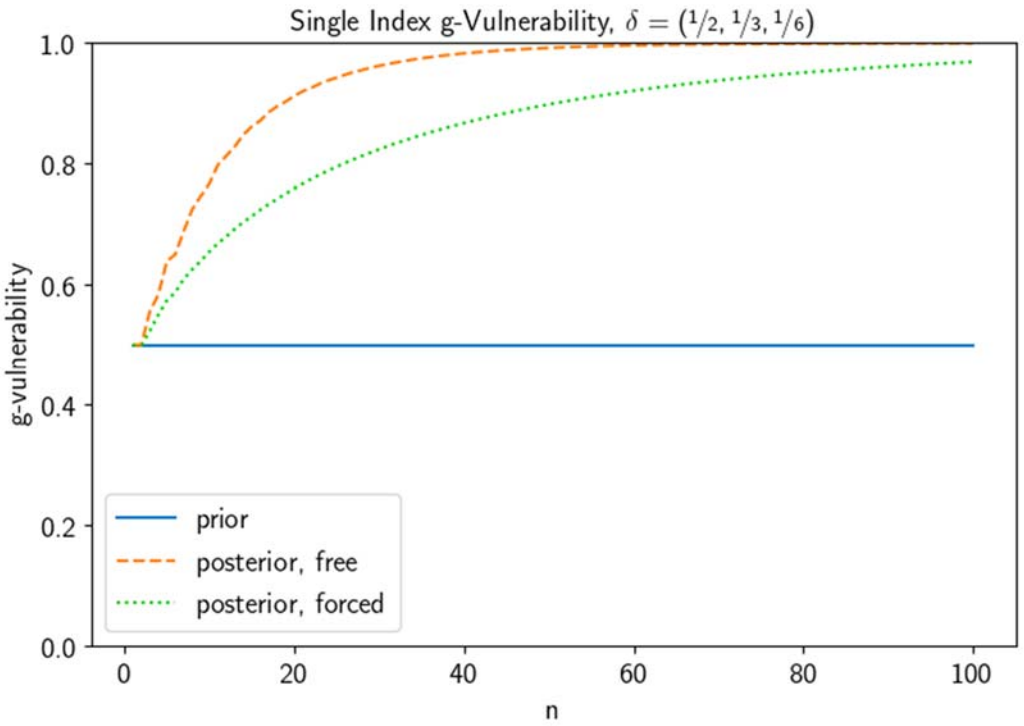
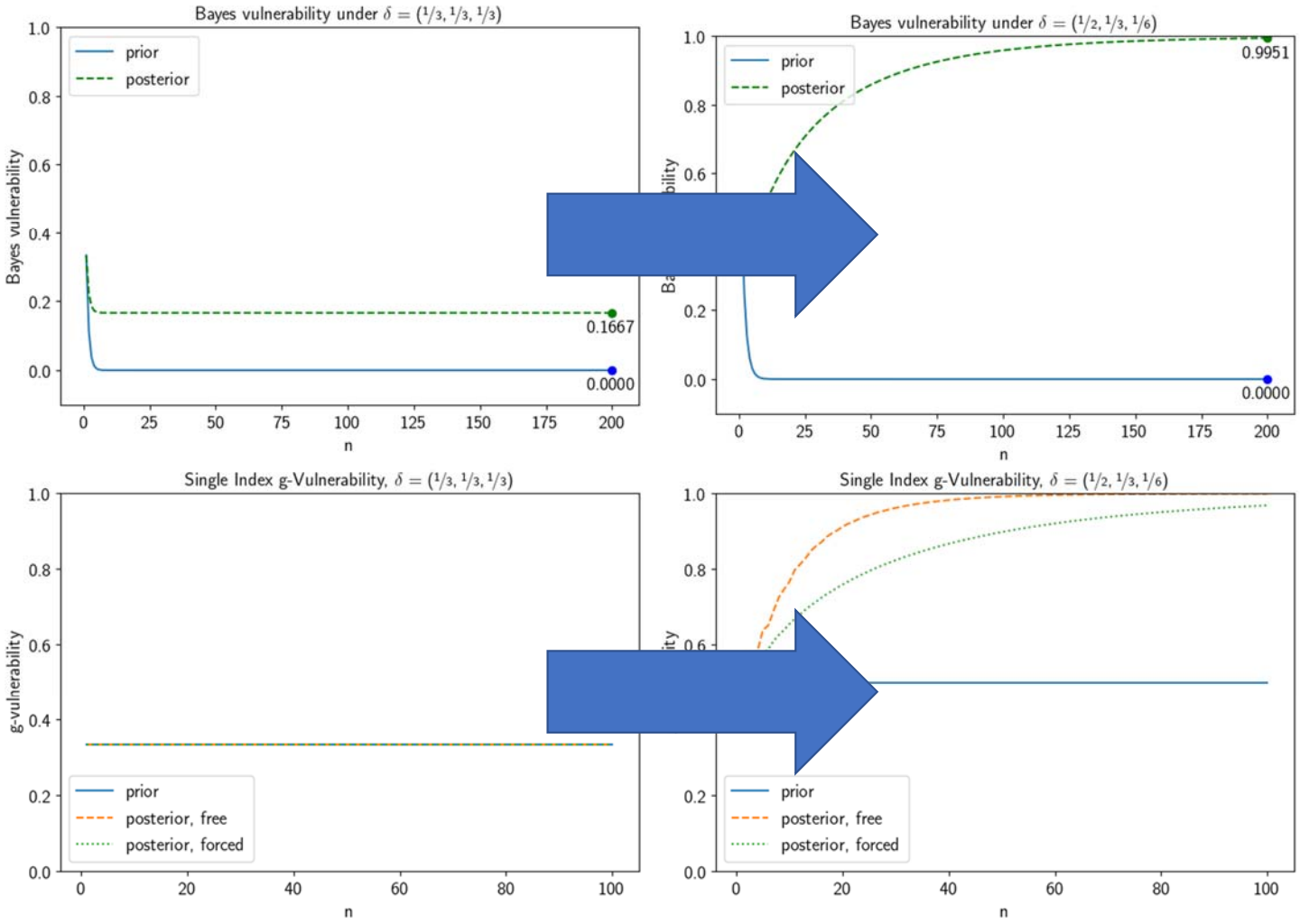
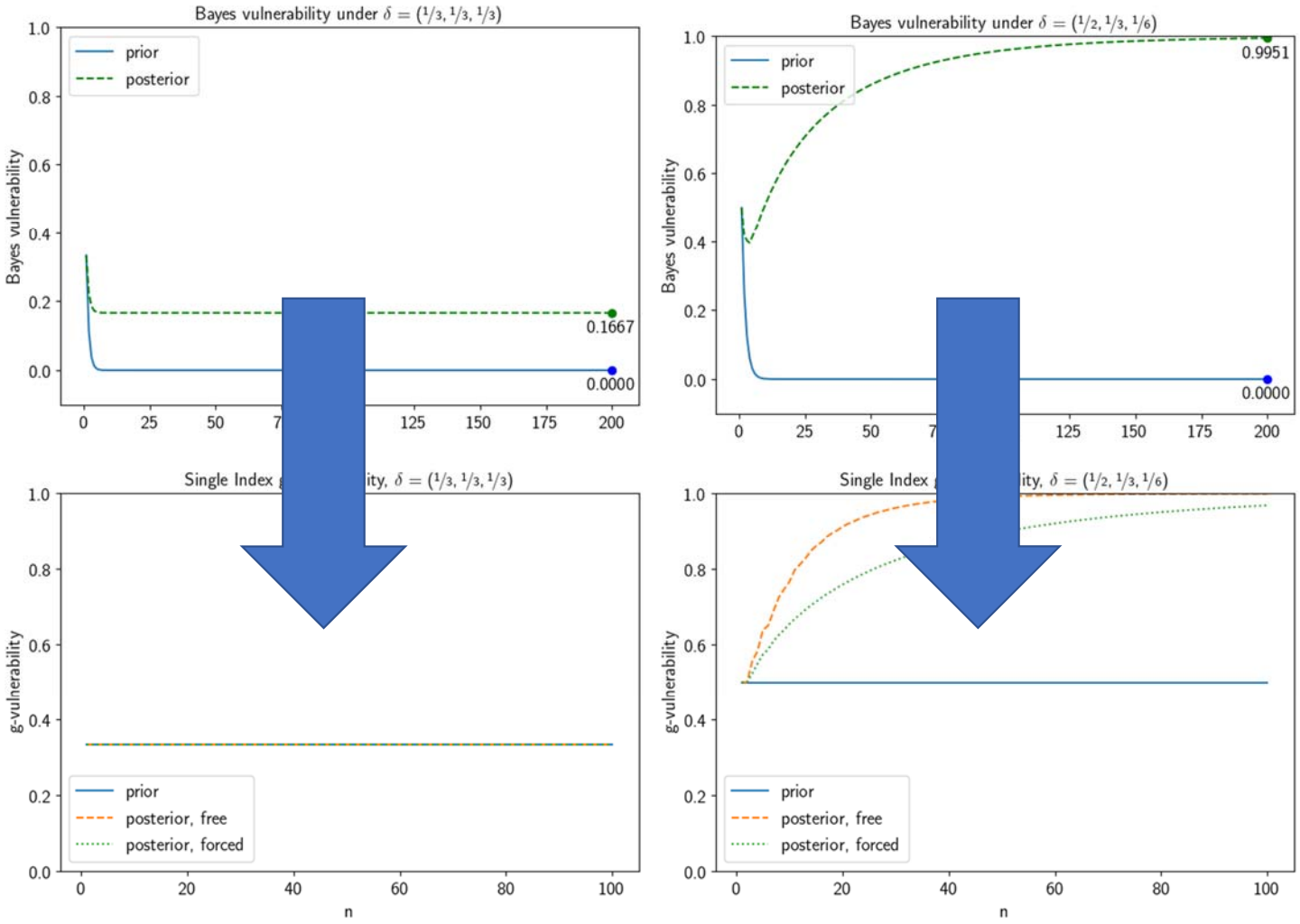






Leakage Depends on Prior and Operational Scenario



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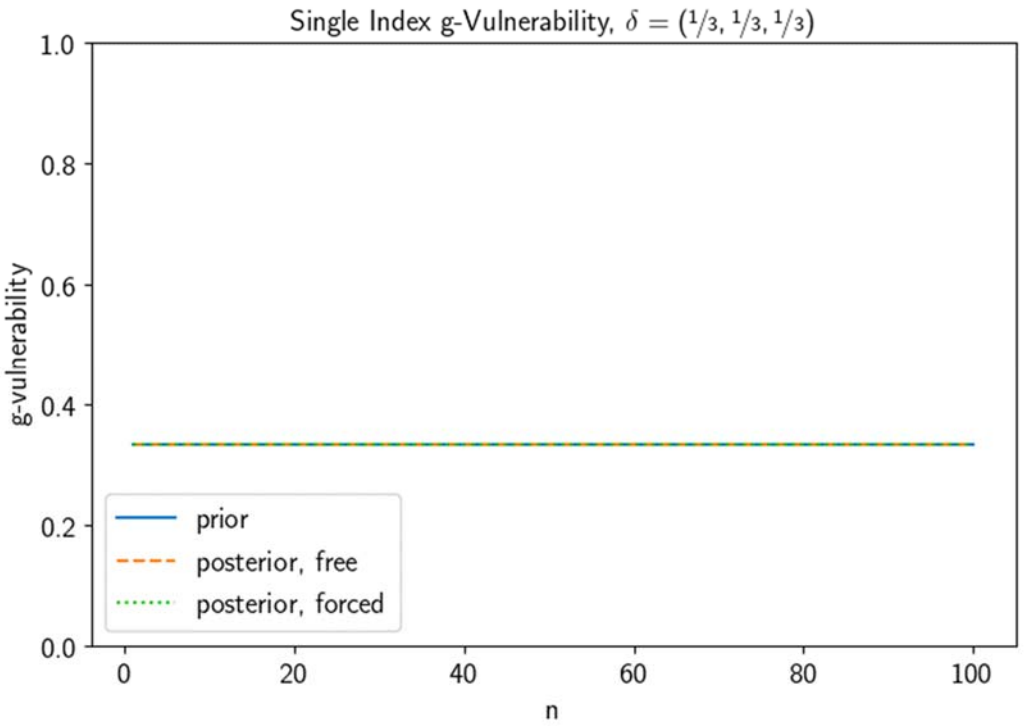

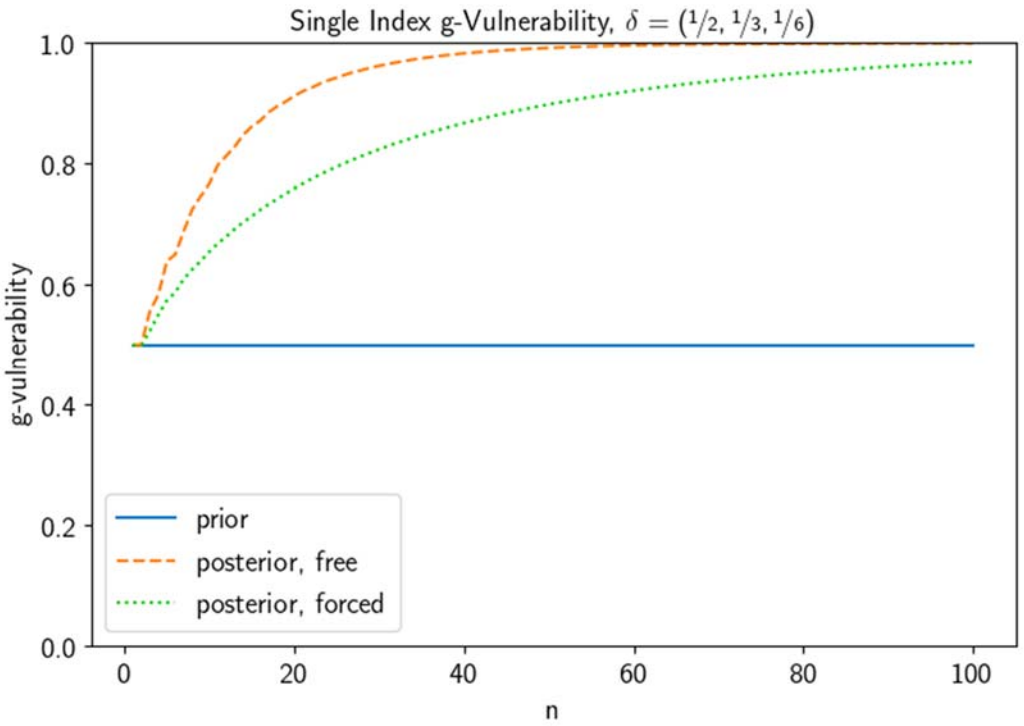

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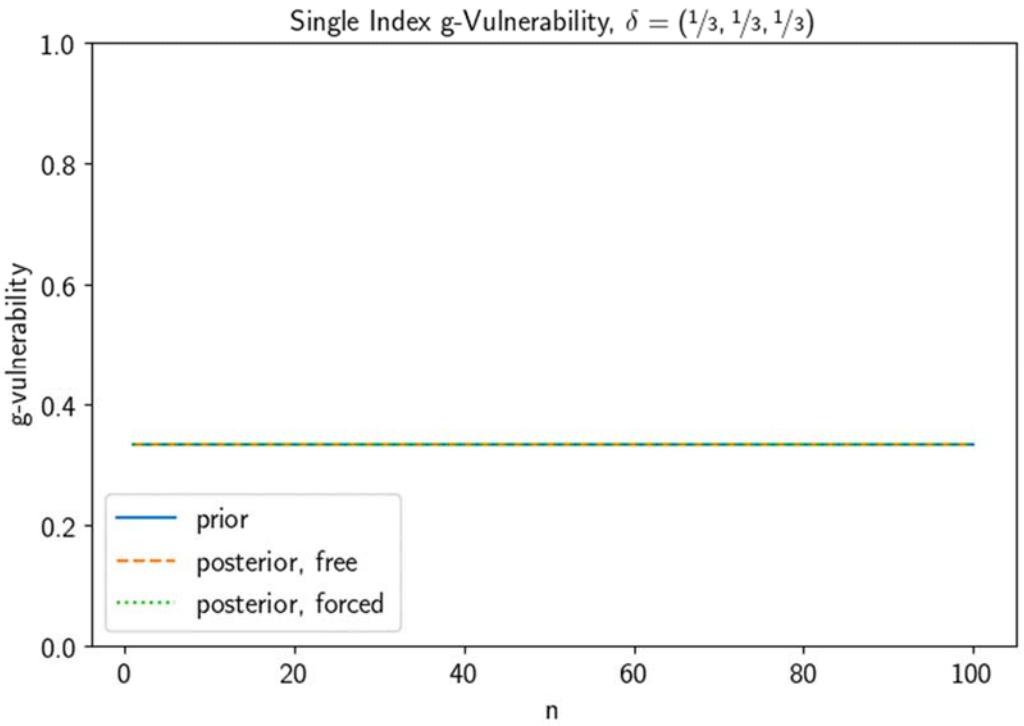
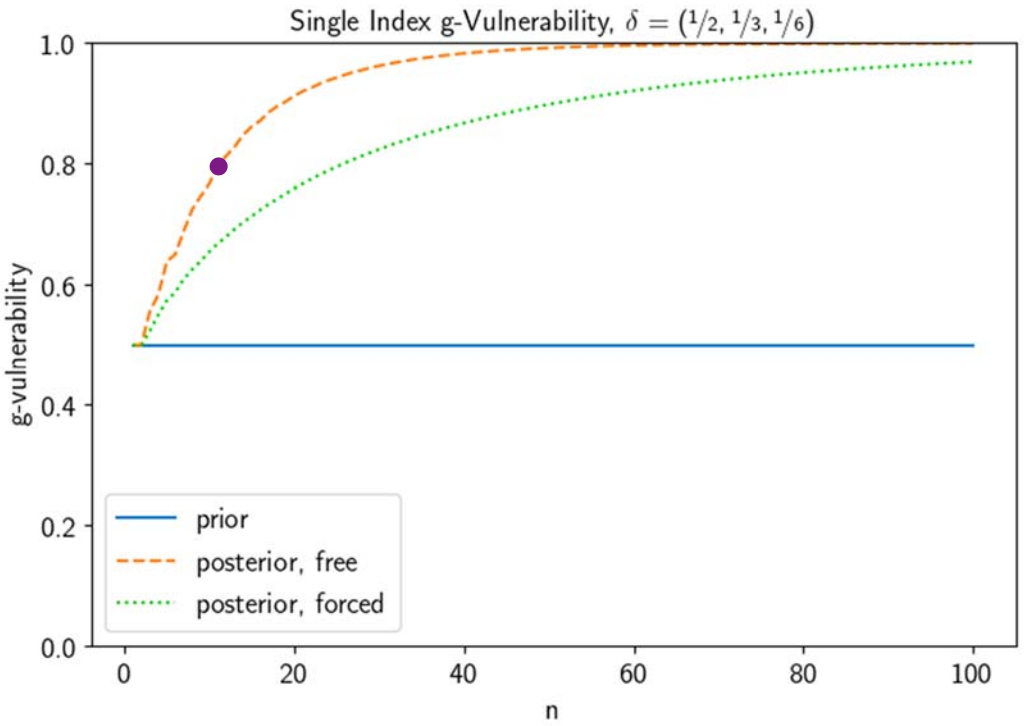
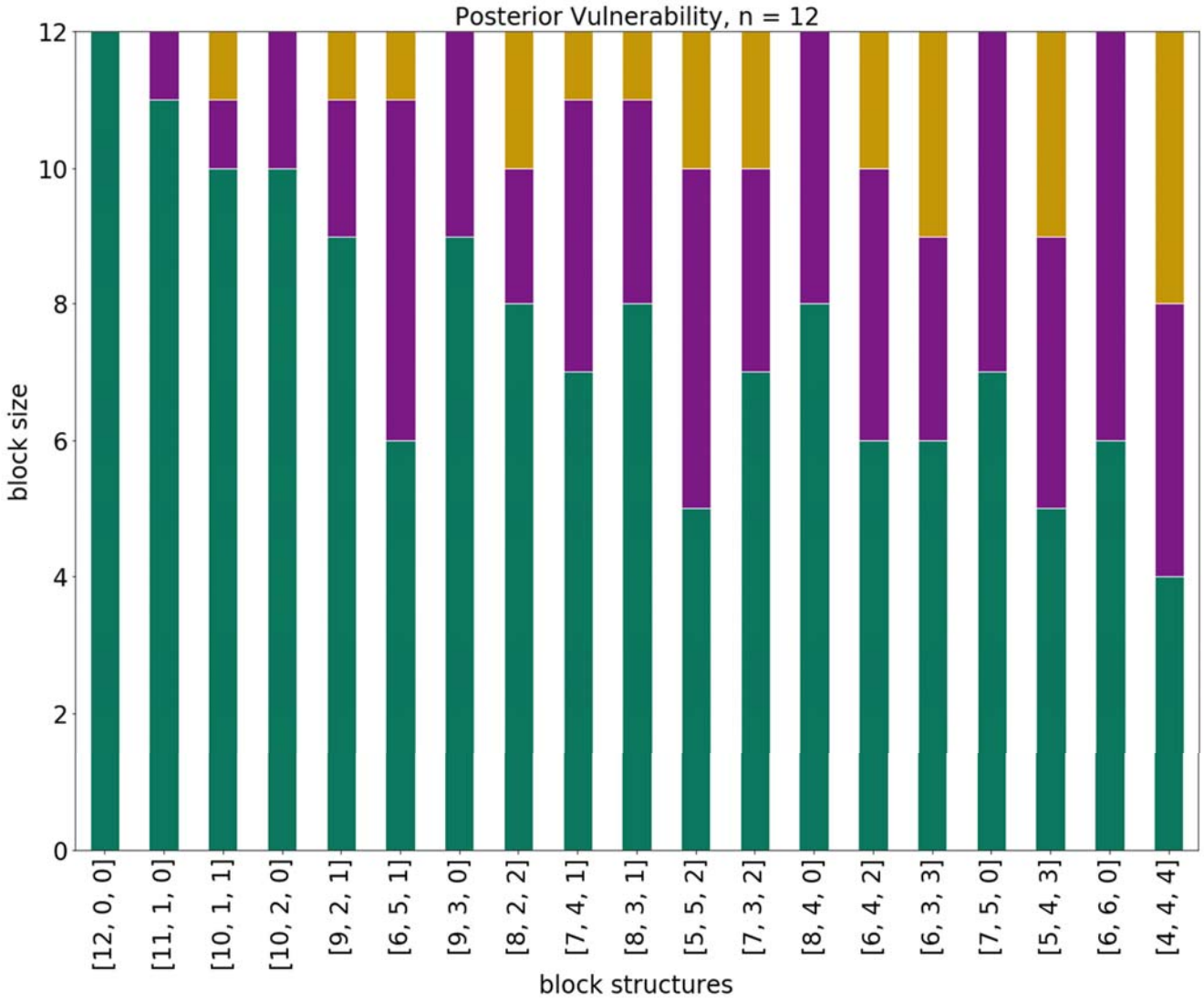




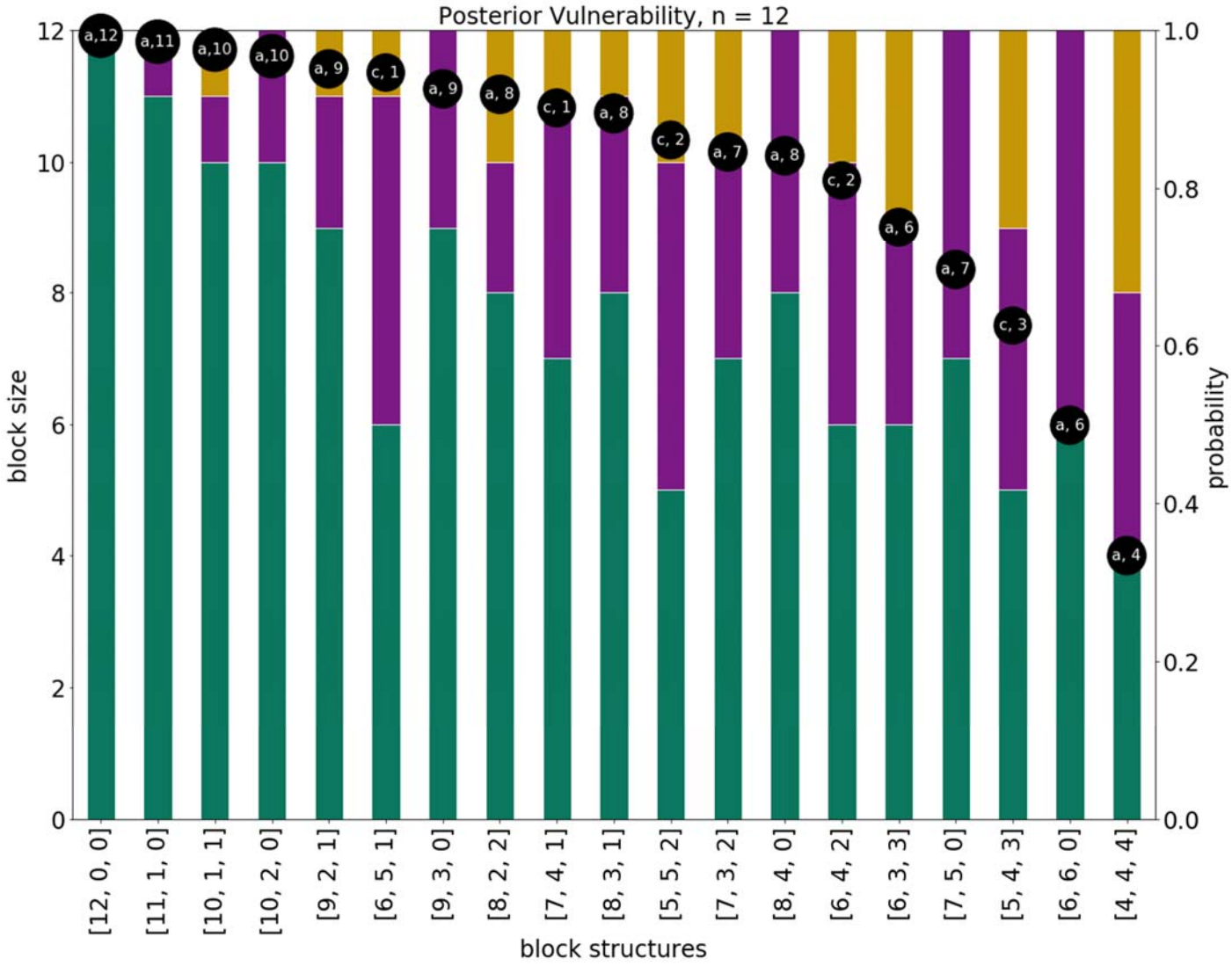
An In Depth View

- 19 possible block structures



An In Depth View

- 19 possible block structures
- Dots: the best guess and her probability of being correct



An In Depth View

- 19 possible block structures
- Dots: the best guess and her probability of being correct
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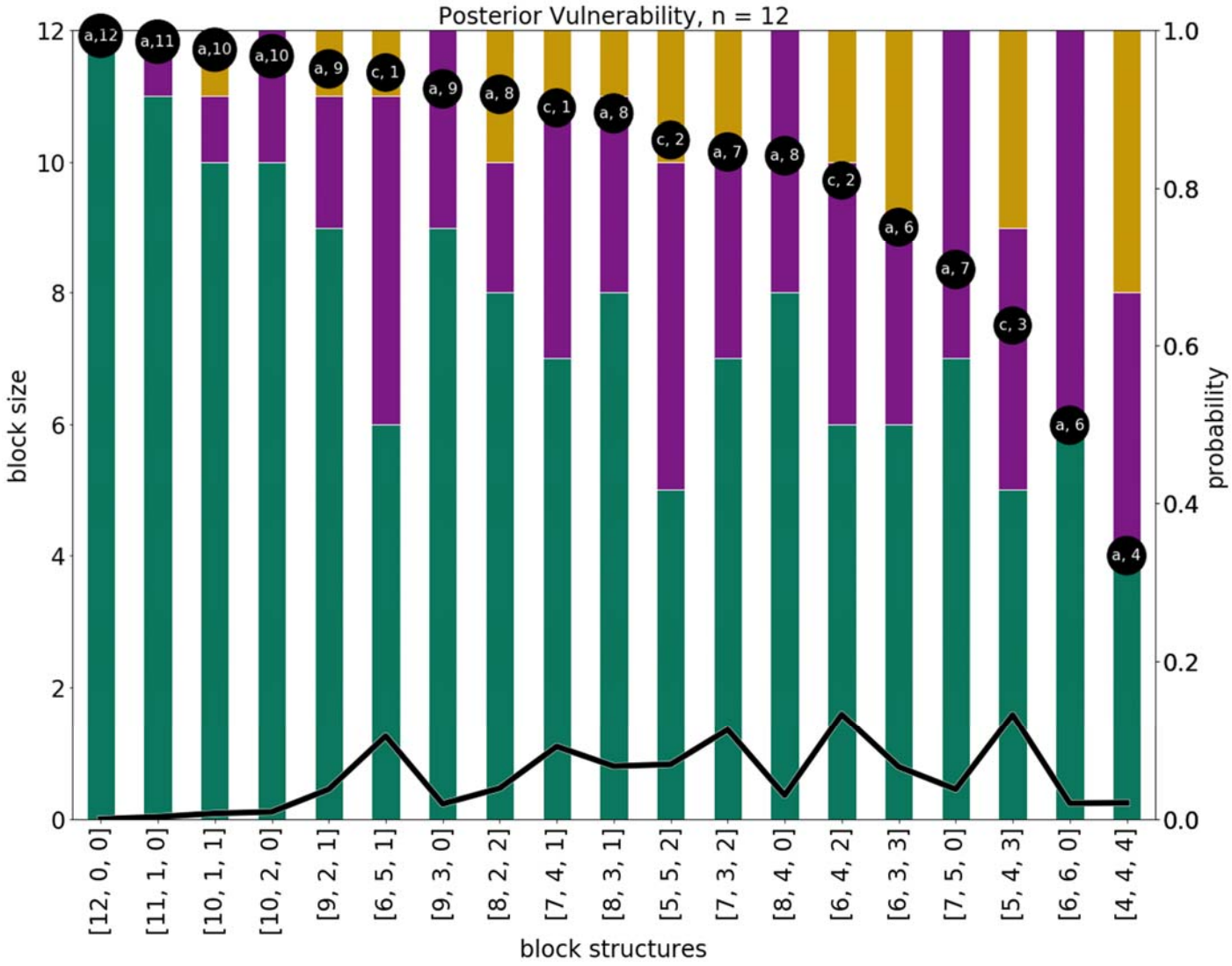

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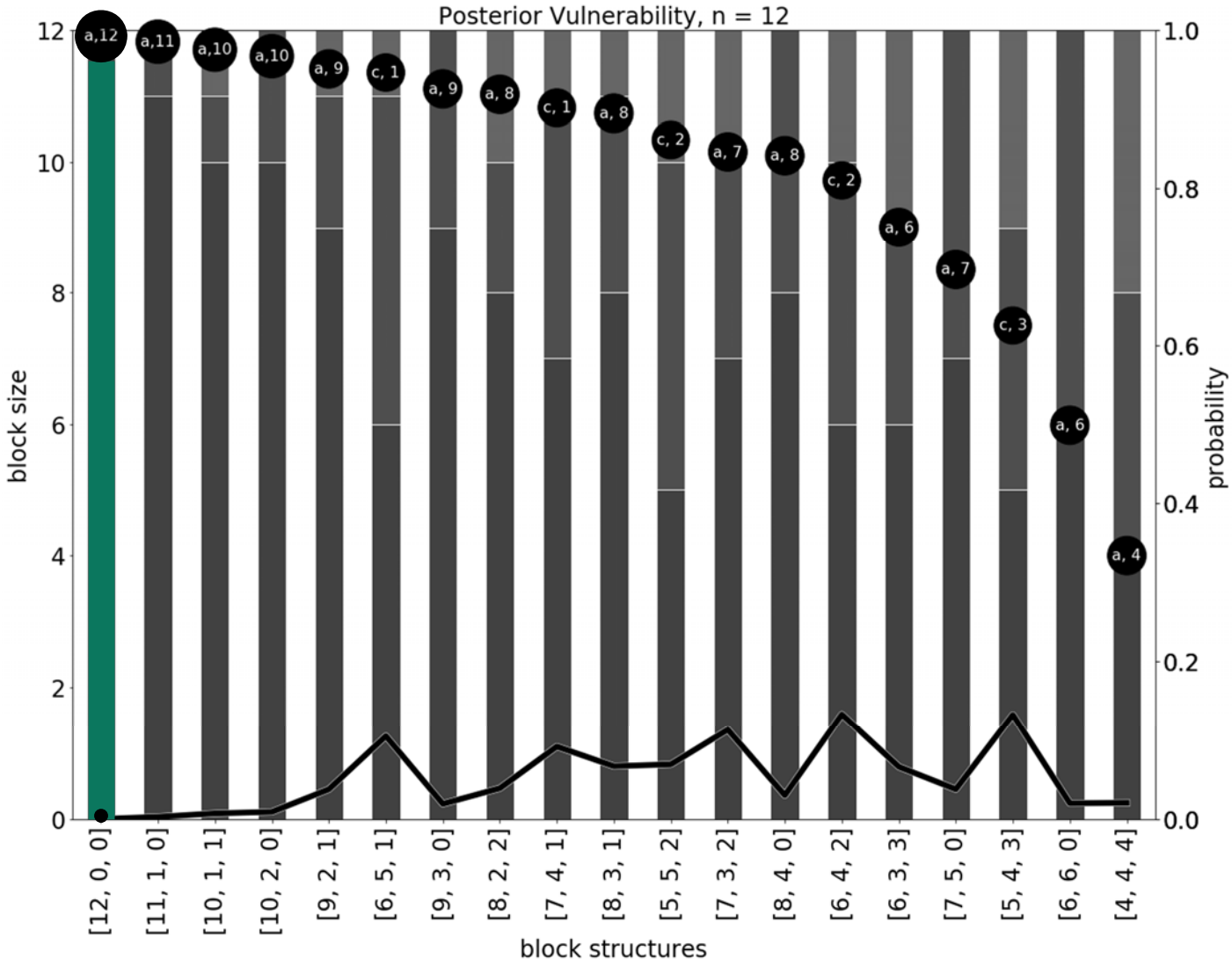

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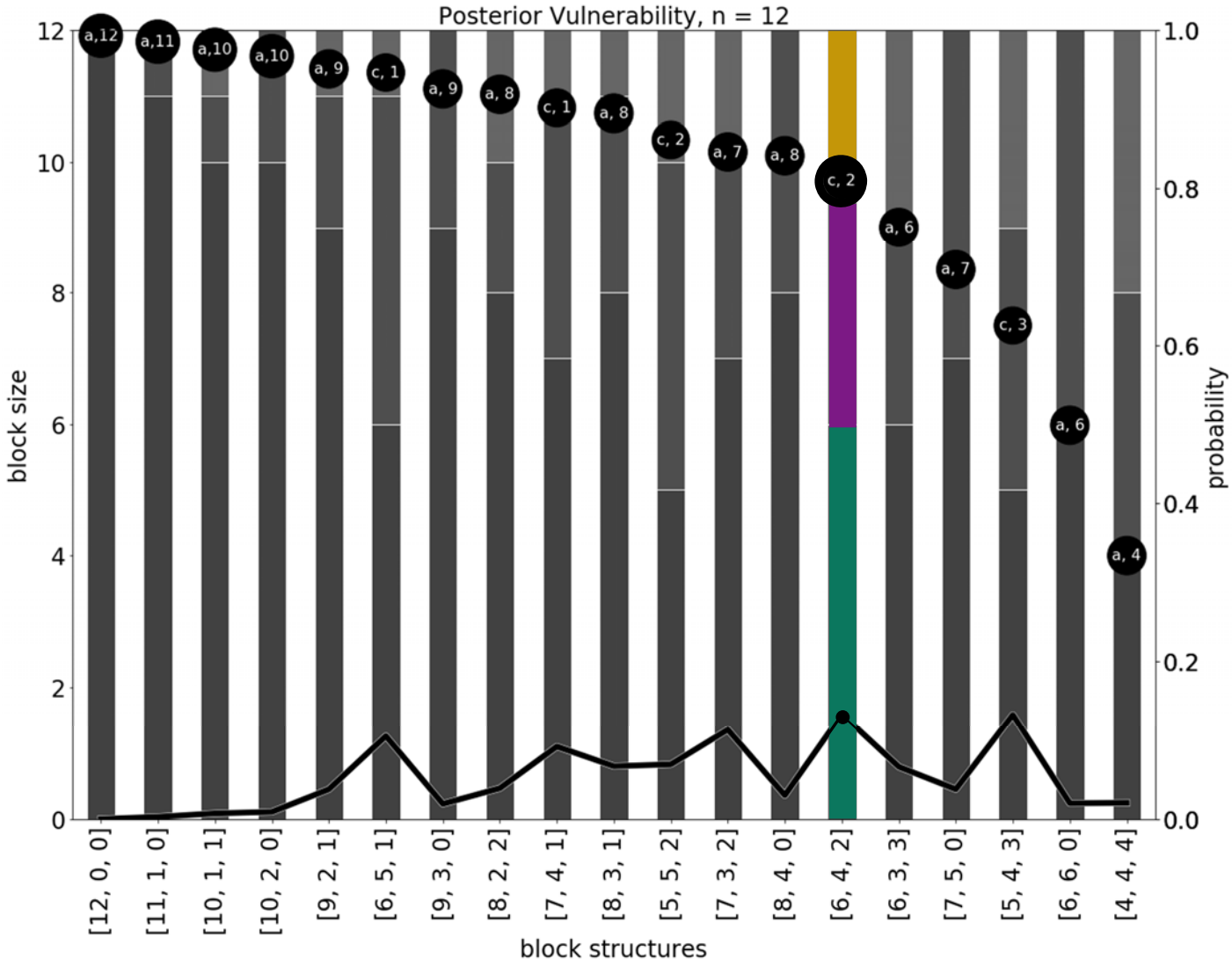

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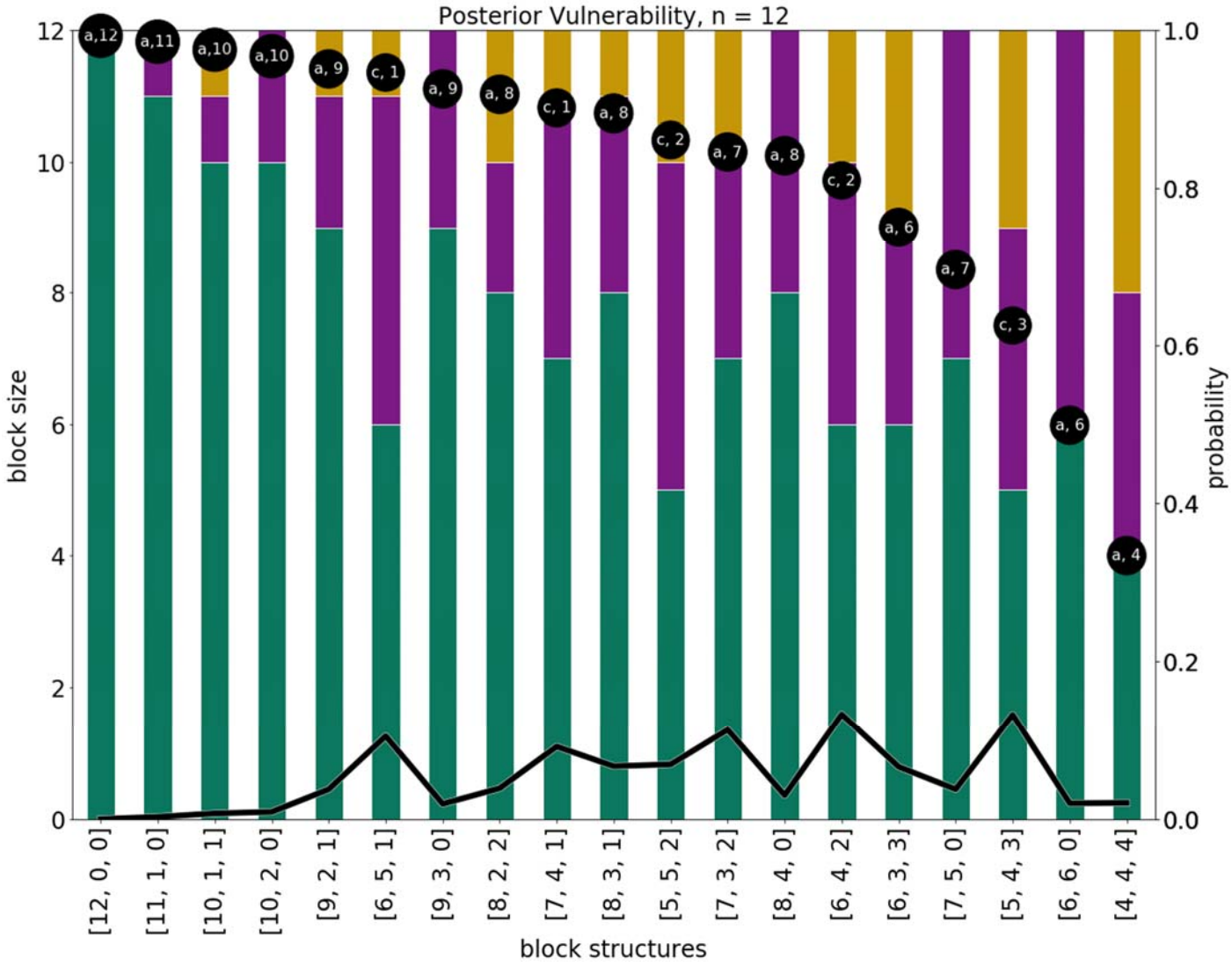
- **Posterior vulnerability: ~0.813**



Contributions

Revealed that there are scenarios where deterministic encryption is not safe even under a uniform prior.

Demonstrated a novel security framework by coupling the provable security approach of modern cryptography with QIF theory.

Illustrated that there is no one ‘right’ way to quantify leakage. Information flow depends on the operational scenario.