

Statistically Valid Inferences from Privacy Protected Data¹

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Webcast, Project TIER (Teaching Integrity in Empirical Research), 2/14/2020

¹Joint work with Georgina Evans, Margaret Schwenzfeier, Abhradeep Thakurta.

²[GaryKing.org/dp](https://garyking.org/dp)

Solving Political Problems Technologically

Differential Privacy & Inferential Validity

A General Purpose, Statistically Valid DP Algorithm

The Algorithm in Practice

Convincing Facebook to Make Data Available

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Solving a Political Problem Technologically (via “constitutional design”)

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- [New Problem](#): **Sharing data without it leaving Facebook**

Data Sharing Regime \rightsquigarrow Data Access Regime

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 - *no* uncertainty estimates

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Theories of Inference: Statistics vs. CS

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Population

:

Michele

Daniel

Georgie

Gary

Meg

Abhradeep

Scott

Larsy

Keith

Elise

Mean
income:

\$48

Quantity
of Interest

Theories of Inference: Statistics vs. CS

	Population	Sample
	:	X
	Michele	✓
	Daniel	✓
	Georgie	✓
	Gary	✓
	Meg	✓
	Abhradeep	✓
	Scott	✓
	Larsy	✓
	Keith	✓
	Elise	✓
Mean income:	\$48	

Quantity
of Interest

Theories of Inference: Statistics vs. CS

Population	Sample	\$
:	X	
Michele	✓	76
Daniel	✓	122
Georgie	✓	145
Gary	✓	96
Meg	✓	86
Abhradeep	✓	127
Scott	✓	72
Larsy	✓	132
Keith	✓	95
Elise	✓	134

Mean
income:

\$48

Classical
Inference

\$108

Quantity
of Interest

Usually
no direct
relevance

Theories of Inference: Statistics vs. CS

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Mean
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Quantity
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Theories of Inference: Statistics vs. CS

Population	Sample	\$	+Privacy
:	X		
Michele	✓	76	Noise & Censoring
Daniel	✓	122	
Georgie	✓	145	
Gary	✓	96	
Meg	✓	86	
Abhradeep	✓	127	
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Scott	✓	72		101
Larsy	✓	132		128
Keith	✓	95		83
Elise	✓	134		201

Mean income:

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Classical Inference

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Query-Response

\$111

Quantity of Interest

Usually no direct relevance

No direct relevance

Theories of Inference: Statistics vs. CS

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Mean
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Differential Privacy and its Inferential Challenges

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- Estimators

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- Estimators
 - Classical Statistics: Apply statistic s to dataset D , $s(D)$

Differential Privacy and its Inferential Challenges

- Estimators

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- **DP Mechanism:** $M(s, D)$, with **noise** & **censoring**

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- **Statistical properties:** usually biased, no uncertainty estimates

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 - **Can address with:** careful software design & education

Solving Political Problems Technologically

Differential Privacy & Inferential Validity

A General Purpose, Statistically Valid DP Algorithm

The Algorithm in Practice

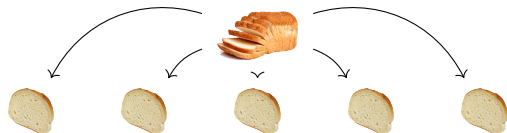
A Differentially Private Estimator

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Private data

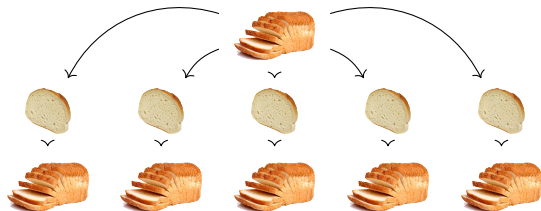
A Differentially Private Estimator



Private data

Partition

A Differentially Private Estimator

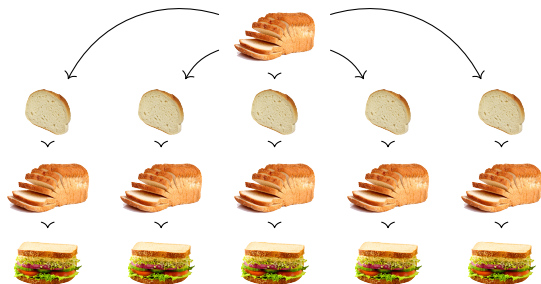


Private data

Partition

Bag of little bootstraps

A Differentially Private Estimator



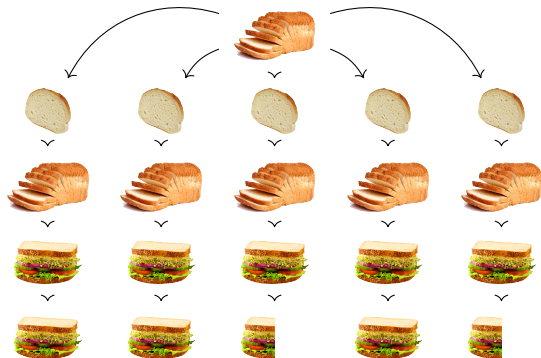
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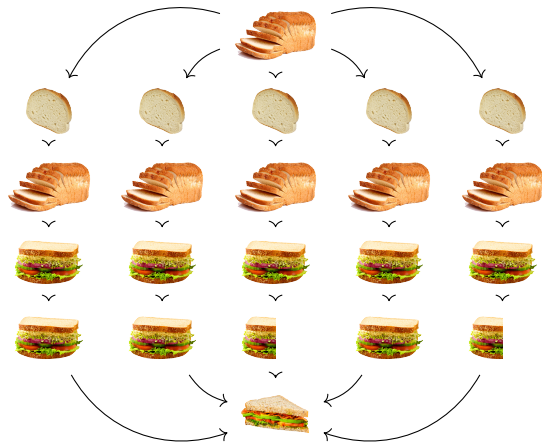
Partition

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Censor

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Private data

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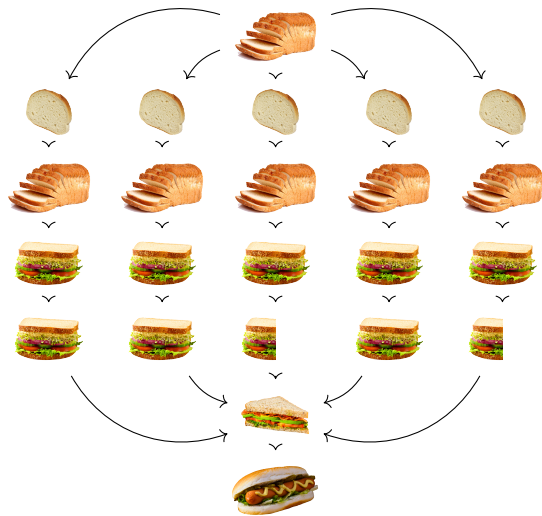
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Private data

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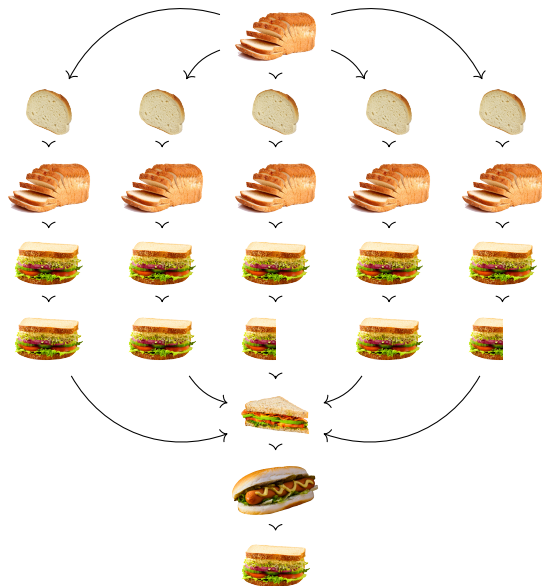
Estimator

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Noise

A Differentially Private Estimator



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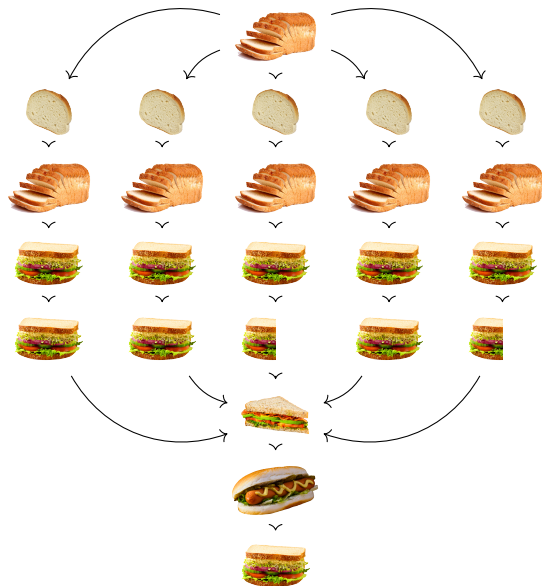
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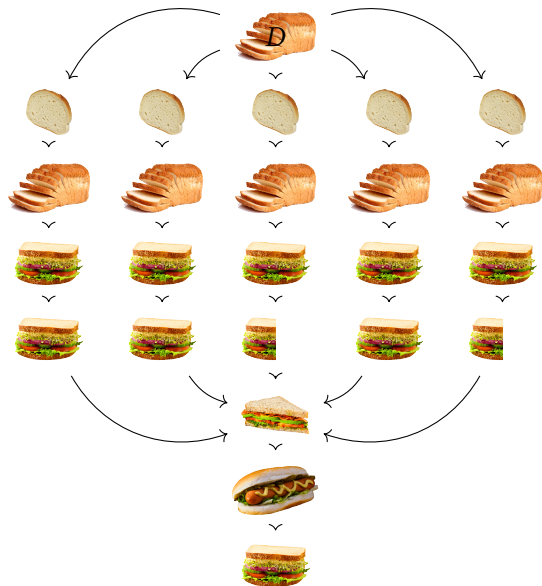
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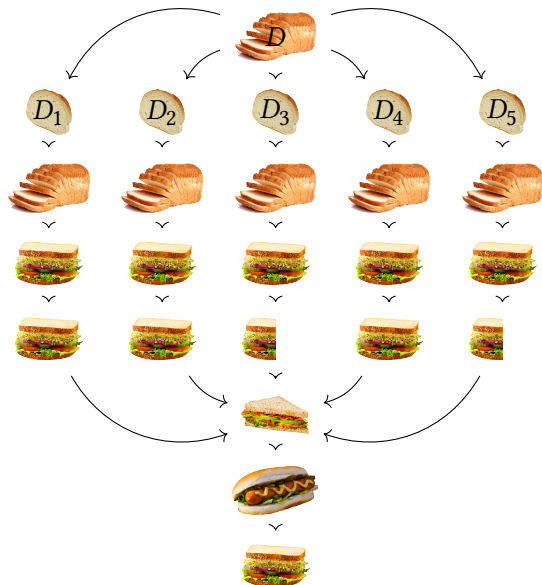
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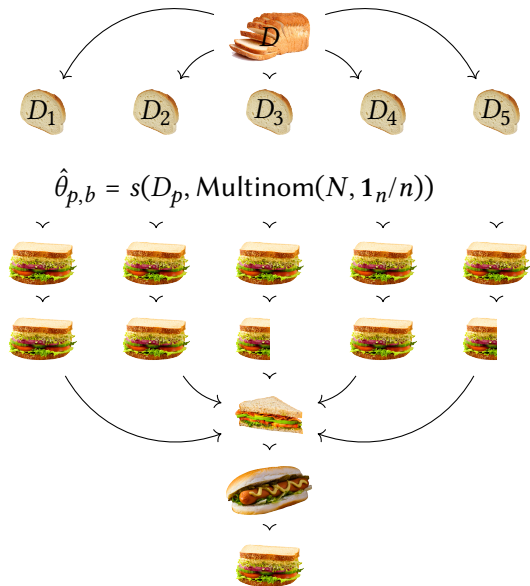
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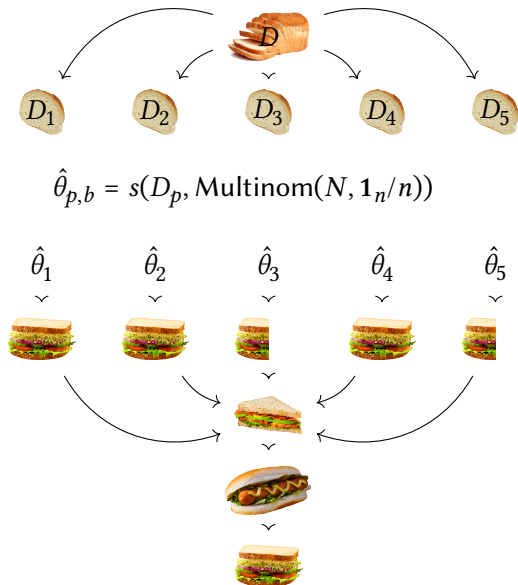
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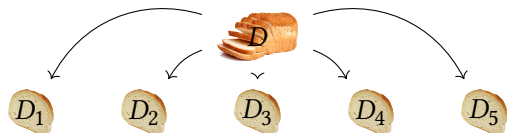
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$$\hat{\theta}_{p,b} = s(D_p, \text{Multinom}(N, \mathbf{1}_n/n))$$

Bag of little bootstraps

$$\hat{\theta}_1 \quad \hat{\theta}_2 \quad \hat{\theta}_3 \quad \hat{\theta}_4 \quad \hat{\theta}_5$$

Estimator

$$\hat{\theta}^{\text{dp}} = \frac{1}{P} \sum_{p=1}^P c(\hat{\theta}_p, \Lambda) + N\left(0, \frac{8\Lambda}{P\epsilon}\right)$$

Censor

Average

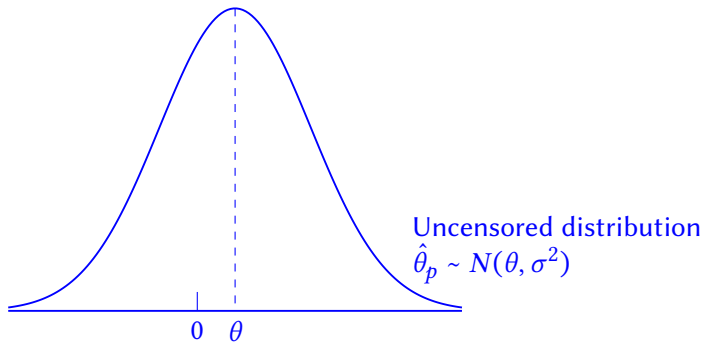
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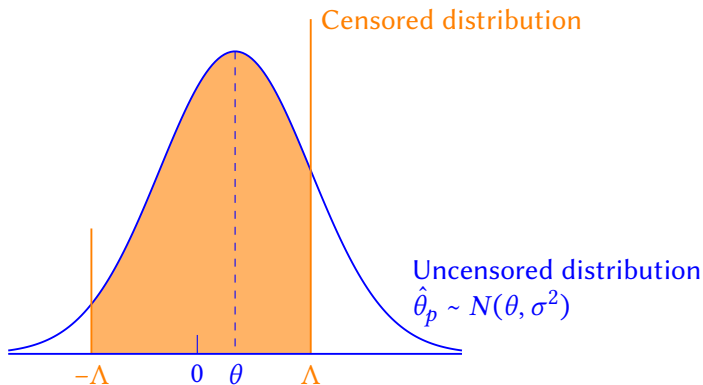
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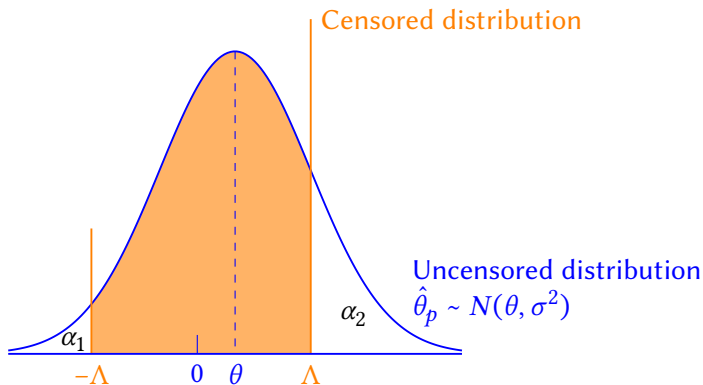
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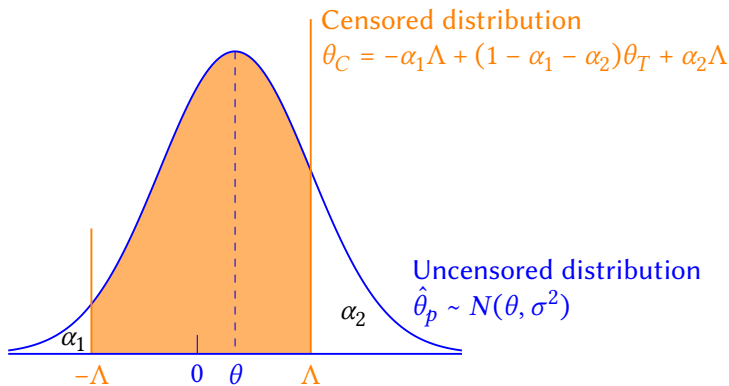
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$$\int_{-\infty}^{-\Lambda} N(t | \theta, \sigma^2) dt$$

$$\int_{\Lambda}^{\infty} N(t | \theta, \sigma^2) dt$$

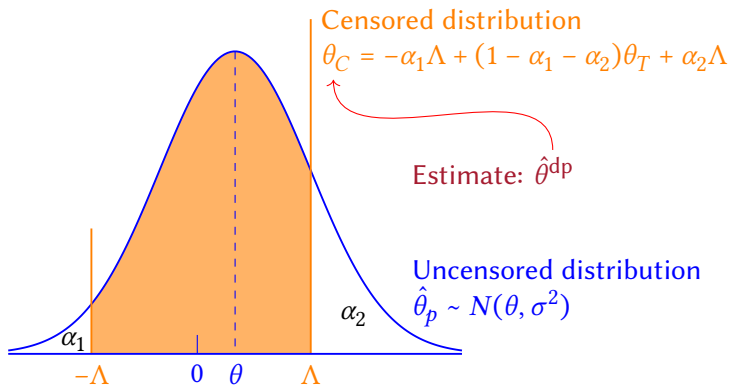
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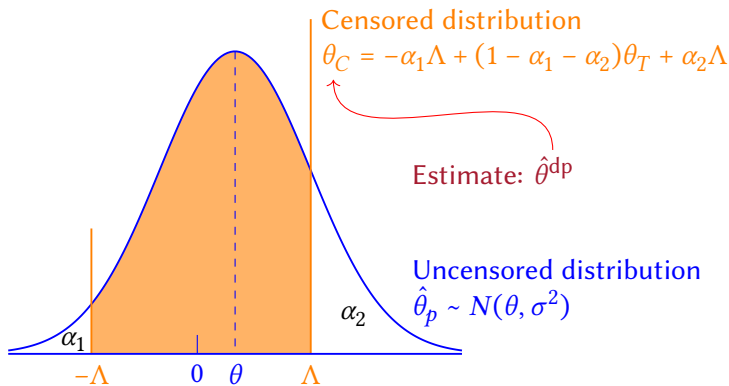
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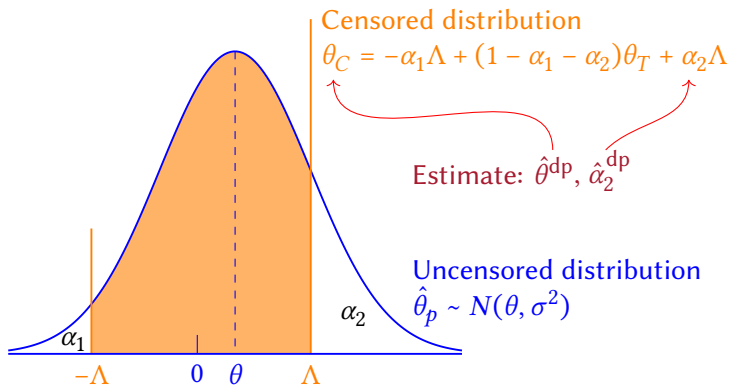


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3 eqns, 4 unknowns $\theta, \sigma^2, \alpha_1, \alpha_2$

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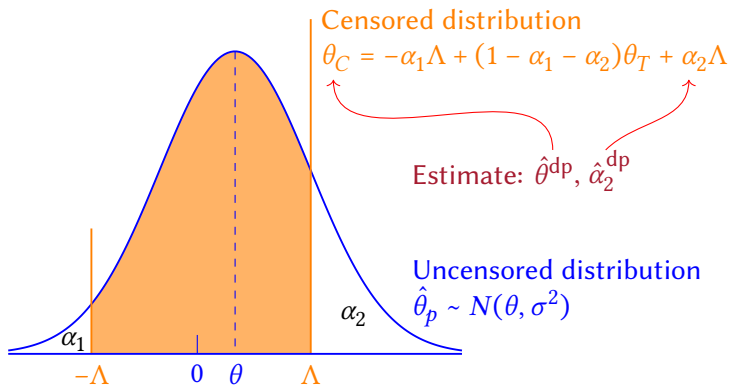


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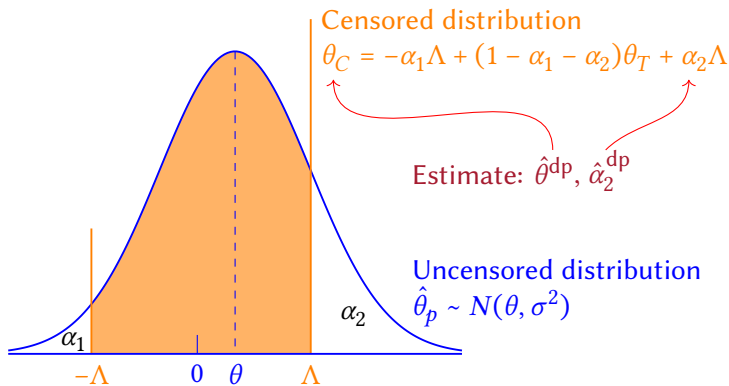


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 Solve for θ (and σ^2, α_1)

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- Standard error: Standard deviation of $\tilde{\theta}^{\text{dp}}(i)$ over i
- Bias correction: reduces bias *and* variance:

$$E(\tilde{\theta}^{\text{dp}}) \approx \theta, \quad V(\tilde{\theta}^{\text{dp}}) \lesssim V(\hat{\theta}^{\text{dp}})$$

Solving Political Problems Technologically

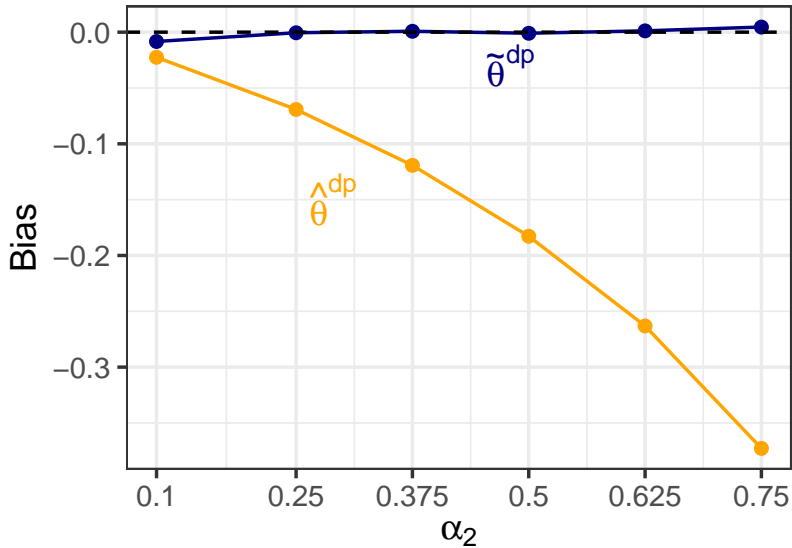
Differential Privacy & Inferential Validity

A General Purpose, Statistically Valid DP Algorithm

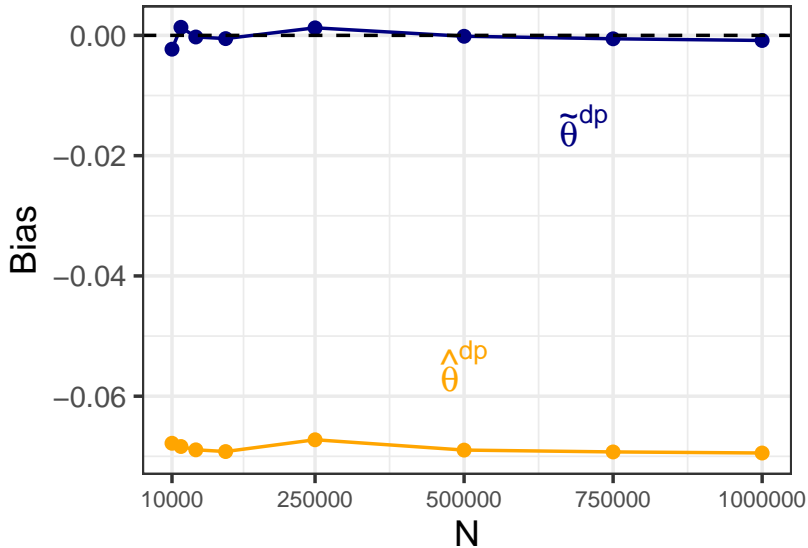
The Algorithm in Practice

Simulations: Finite Sample Evaluation

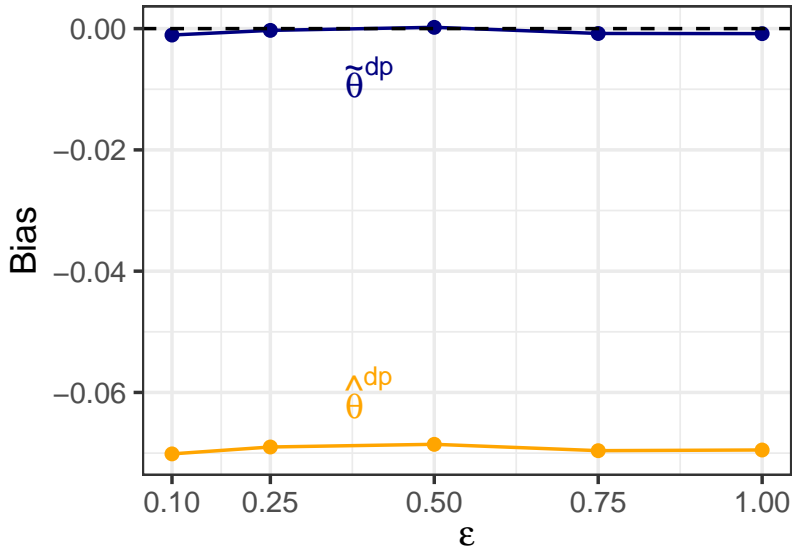
Simulations: Finite Sample Evaluation



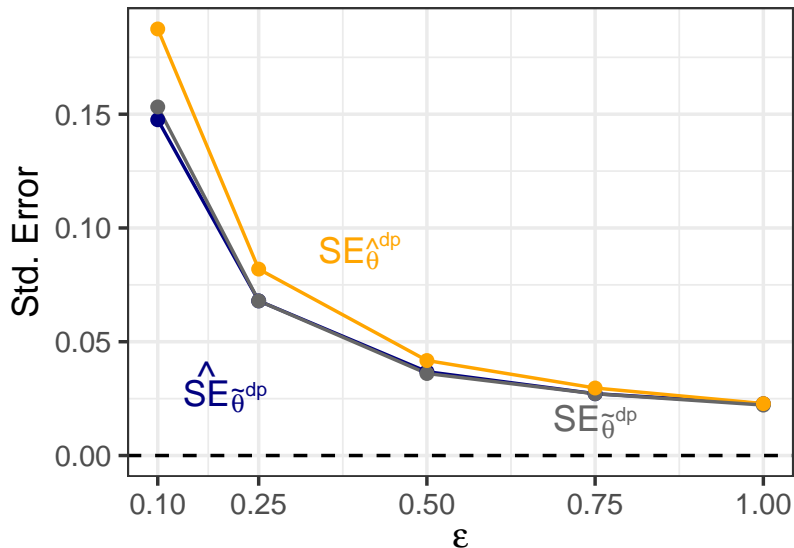
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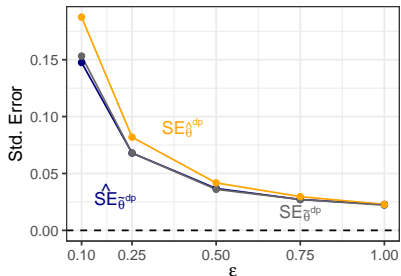
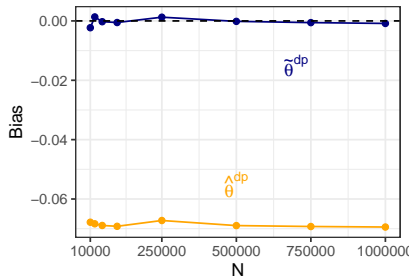
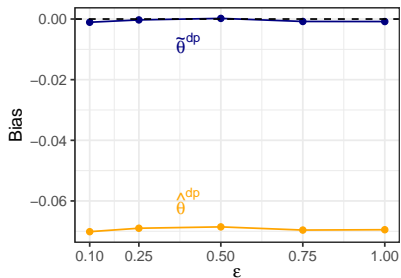
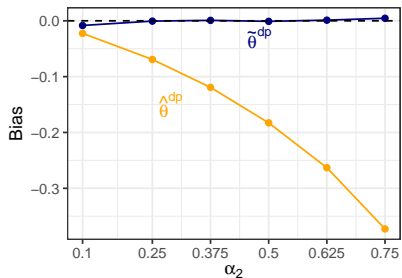
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For more information



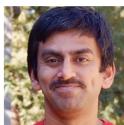
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