New Formal Privacy Methods for Business Populations

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June 9, 2023

What will be covered…

- Outreach Plans & Outstanding Research
- County Business Patterns (CBP) Background
- High-level Overview of Per-Record Differential Privacy (PRDP)
- Accuracy & Privacy
- Second-Stage Noise
- Parameter Selection
- Demonstration Tables

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Outreach Plans & Outstanding Research

A Look into Planned Outreach Activities & Outstanding Research

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Outreach Plans

- Internal presentations for:
  - Senior leadership
  - Data Stewardship Executive Policy Committee
  - Disclosure Review Board
  - Methodology & Standards Council

- Demonstration Tables
  - Two planned releases with Federal Register Notices
  - Webinars

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Outstanding Research

- Protecting sample-based estimates
- Privacy-conserving approaches for firm counts
- Implications for benchmarking
- Privacy-protection algorithms for functions of the data other than sums
- Required privacy protections for product-level statistics

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County Business Patterns

A Brief Overview on the Program and Current Disclosure Avoidance Methodology

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Program Background

- Includes the following estimates
  - Counts
    - Establishments
  - Magnitude
    - Employment during the week of March 12
    - First quarter payroll
    - Annual payroll
- Data is useful for studying the economic activity in small areas
- Current methodology: multiplicative noise

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A Look into Per-Record DP

How to handle heavy-tailed distributions

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The Challenge & Takeaways

- Accurately release key economic indicators from heavy-tailed distributions with modernized privacy protection

- Differential privacy (DP) provides strong privacy protection but does not handle heavy-tailed distributions very well.
- “Per-Record” DP (PRDP) provides high data utility and formal privacy protection, but the privacy protection is not as strong as differential privacy.

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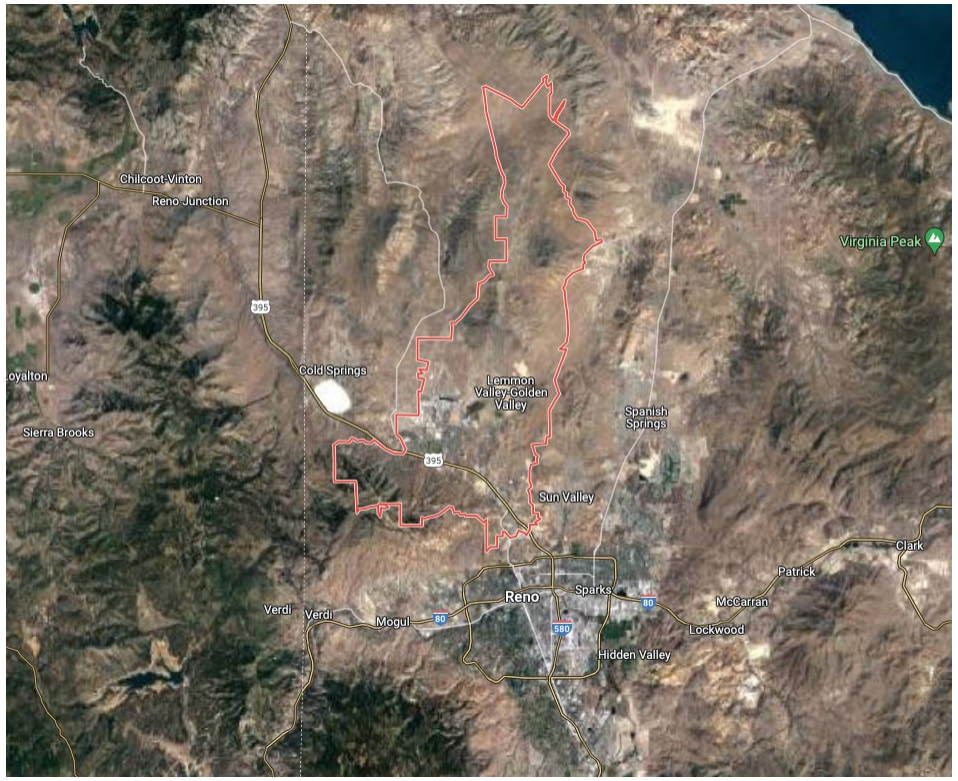
The challenge of applying DP to the CBP: How many employees work in 89506?



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Hiding large establishments

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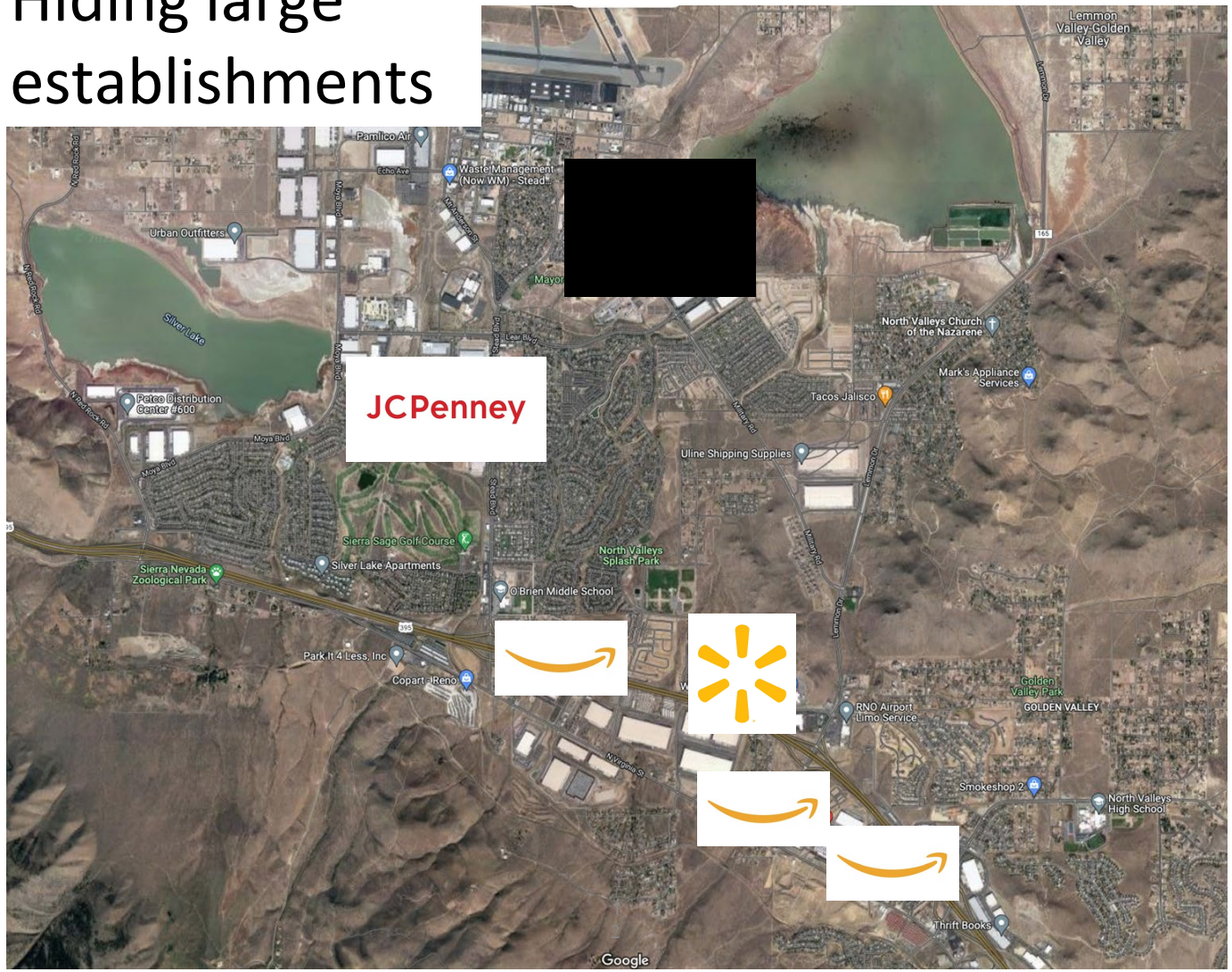
Hiding large establishments



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Overkill for small establishments

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Solution: Design a formal privacy framework that provides “sliding” protection to establishments.

Protection against “fact-of-filing”: adversaries should not be able to easily infer whether an establishment is represented in the CBP dataset.

Protection against exact inference: adversaries should not be able to deterministically infer exact attributes about an establishment, such as employee size or payrolls.

Protection for firms: the privacy properties of firms (i.e., collections of related establishments) should be inherited from the privacy properties of their individual establishments.

“Sliding” establishment protection: Allow the privacy guarantees to vary by establishment. In particular, allow privacy guarantees to degrade as the influence of an establishment grows.

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Hide small establishments?

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Fully hide small establishments

Hide large establishments?

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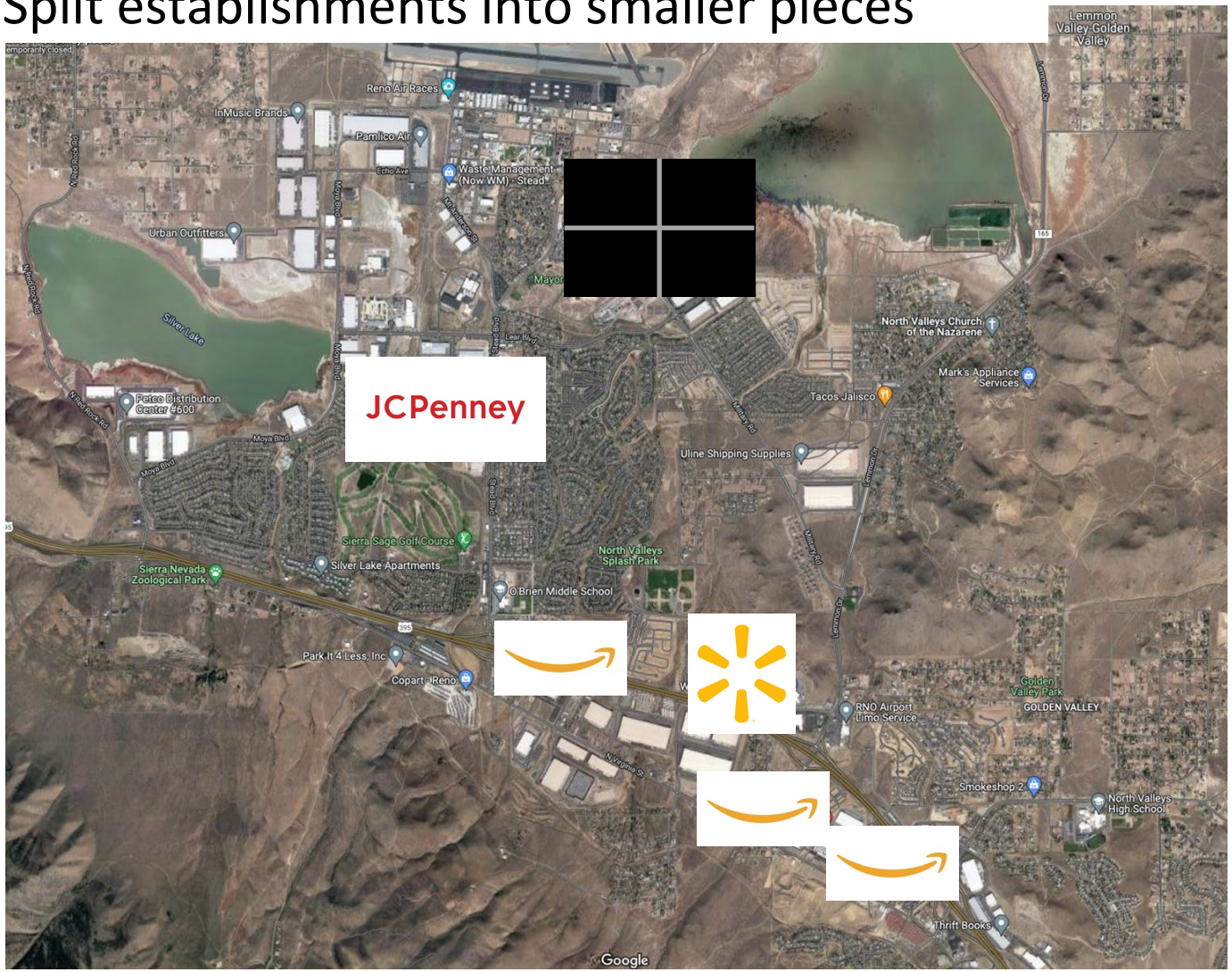
Split establishments into smaller pieces



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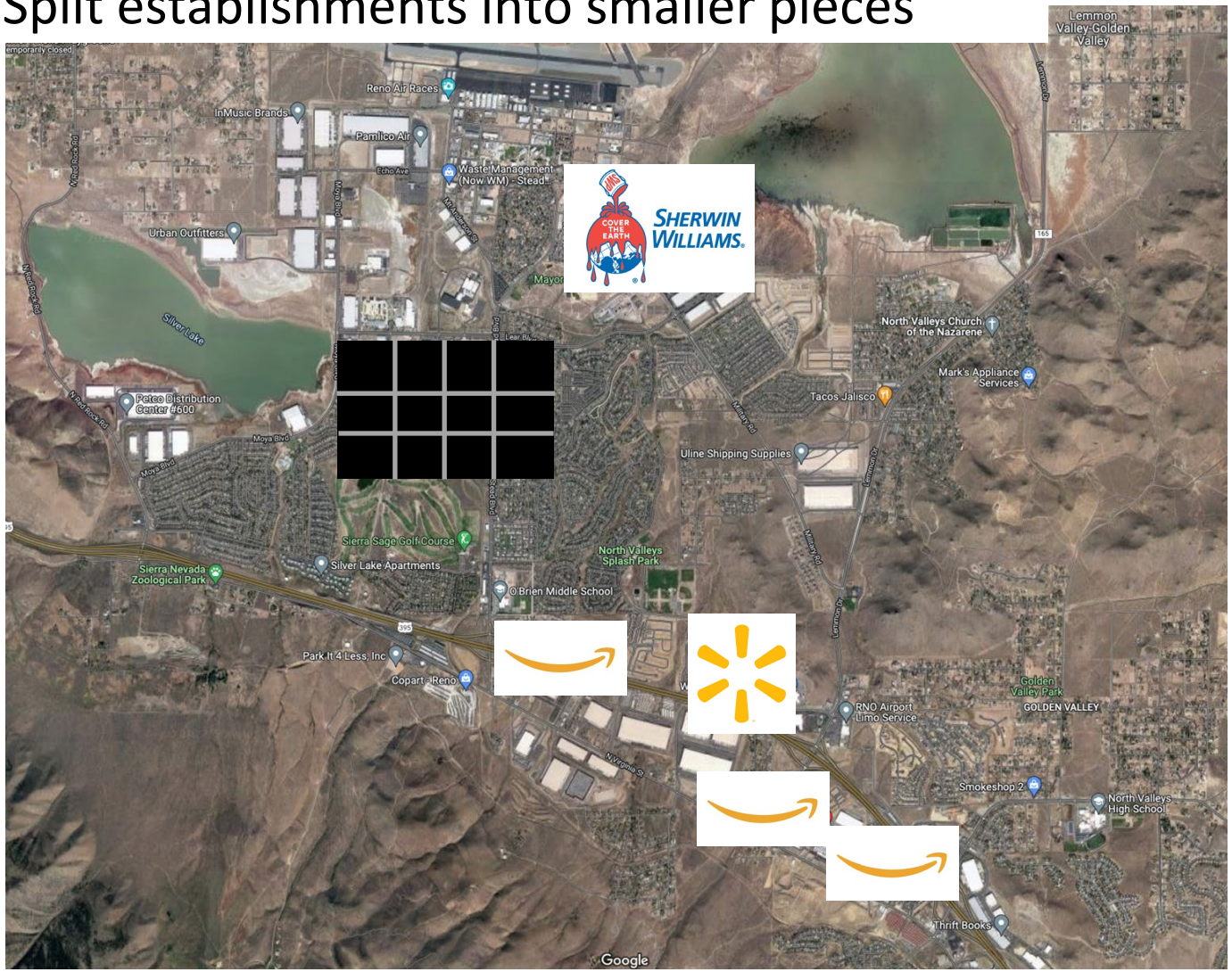
Split establishments into smaller pieces



Group Privacy for ε-DP Algorithms

- ε-DP algorithm privacy guarantee extends to groups of size *k*

- When input databases differ by adding or removing up to *k* records:
  - Output distributions are bounded by *k* x ε

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PRDP for Establishments

- When input databases differ by adding or removing a particular record, r
  - Output distributions are bounded by a function P(r)

- With establishment splitting A followed by DP mechanism M
  - $P(r) = |A(r)| \times \varepsilon$ where $|A(r)|$ is the number of pieces record r gets split into

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Data Utility Comparison

No establishment splitting

- Bias-variance trade off
- Outliers drive noise requirements
- Outliers dominate a large share of the aggregations

Establishment splitting

- No bias
- Noise requirements can be calibrated based on smaller establishments

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Accuracy and Privacy

Overview & Approach

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Accuracy and Privacy

- **The tradeoff between accuracy and privacy remains.**

  Less privacy for establishments → More accurate estimates
  More privacy for establishments → Less accurate estimates

- Challenge: Find a balance where quality is preserved, and all establishments are adequately protected.

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Median CV of County x 3-Digit NAICS Annual Payroll Estimates by Standard Deviation of Noise and Cell Size

Standard deviation of noise	All	Cell size (number of establishments)				
		a) 1-2	b) 3-9	c) 10-24	d) 25-99	e) 100+
10	0.00	0.03	0.01	0.00	0.00	0.00
20	0.01	0.07	0.02	0.00	0.00	0.00
50	0.02	0.17	0.04	0.01	0.00	0.00
100	0.04	0.35	0.08	0.02	0.01	0.00
200	0.09	0.69	0.16	0.04	0.01	0.00
500	0.22	>1.00	0.40	0.11	0.03	0.00
1,000	0.44	>1.00	0.80	0.22	0.06	0.01
2,000	0.88	>1.00	>1.00	0.44	0.13	0.02
5,000	>1.00	>1.00	>1.00	>1.00	0.31	0.04
10,000	>1.00	>1.00	>1.00	>1.00	0.63	0.09
20,000	>1.00	>1.00	>1.00	>1.00	>1.00	0.18
# of cells	187,446	53,264	61,799	32,569	26,901	12,913

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50	0.02	0.17	0.04	0.01	0.00	0.00
100	0.04	0.35	0.08	0.02	0.01	0.00
200	0.09	0.69	0.16	0.04	0.01	0.00
500	0.22	>1.00	0.40	0.11	0.03	0.00
1,000	0.44	>1.00	0.80	0.22	0.06	0.01
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Ensuring Adequate Protection

- PRDP with quality-preserving parameters will provide adequate protection for most establishments' magnitude data.
- Very large establishments will not have adequate protection.

Establishment	Employment
#1	75
#2	150
#3	30,000
Total	**30,225**

$$\xrightarrow[\text{and } \rho = 0.1]{\text{PRDP with } \theta = 10}$$

30,200 ± 37 (90% CI)

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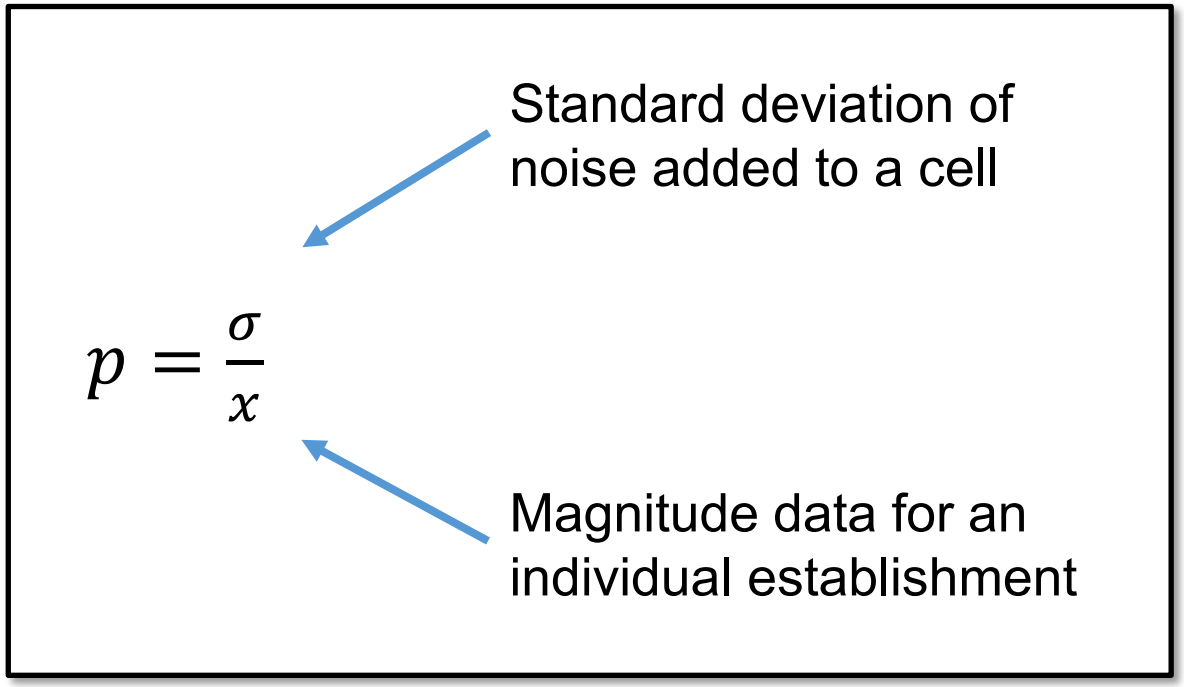
Relative Protection



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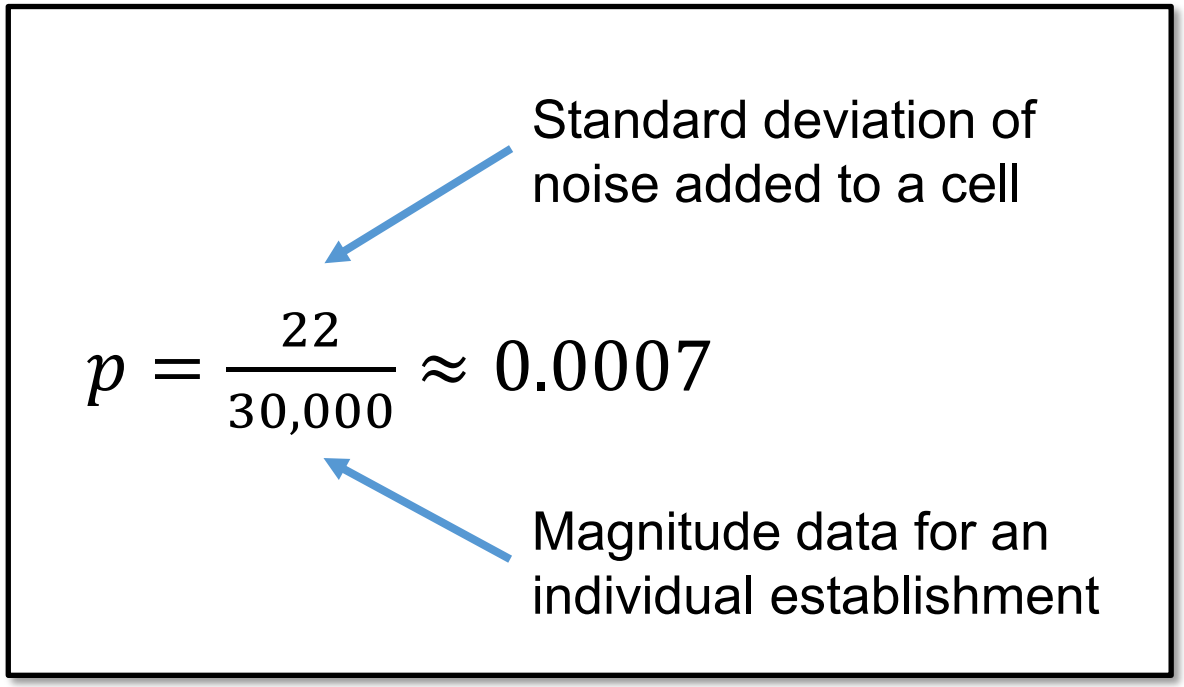

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Proportion of Establishments (N=7,960,386) with Relative Protection* Meeting or Exceeding Selected Levels

Standard deviation of noise	p ≥ 0.001	p ≥ 0.01	p ≥ 0.02	p ≥ 0.05	p ≥ 0.10	p ≥ 0.15	p ≥ 0.20	p ≥ 1.00
10	0.987	0.877	0.792	0.633	0.489	0.402	0.346	0.111
20	0.994	0.932	0.877	0.758	0.633	0.550	0.489	0.191
50	0.998	0.972	0.945	0.877	0.792	0.728	0.676	0.346
100	0.999	0.987	0.972	0.932	0.877	0.831	0.792	0.489
200	1.000	0.994	0.987	0.965	0.932	0.903	0.877	0.633
500	1.000	0.998	0.996	0.987	0.972	0.958	0.945	0.792
1,000	1.000	0.999	0.998	0.994	0.987	0.980	0.972	0.877
2,000	1.000	1.000	0.999	0.998	0.994	0.991	0.987	0.932
5,000	1.000	1.000	1.000	0.999	0.998	0.997	0.996	0.972
10,000	1.000	1.000	1.000	1.000	0.999	0.999	0.998	0.987
20,000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.994

* Relative protection for annual payroll

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Number of Establishments (N=7,960,386) with Relative Protection* Less than Selected Levels

Standard deviation of noise	p < 0.001	p < 0.01	p < 0.02	p < 0.05	p < 0.10	p < 0.15	p < 0.20	p < 1.00
10	103,250	982,779	1,655,356	2,920,852	4,067,289	4,761,364	5,205,203	7,074,254
20	45,312	542,070	982,779	1,926,842	2,920,852	3,585,832	4,067,289	6,439,113
50	14,304	221,237	441,006	982,779	1,655,356	2,168,765	2,578,852	5,205,203
100	5,651	103,250	221,237	542,070	982,779	1,346,866	1,655,356	4,067,289
200	2,169	45,312	103,250	278,455	542,070	774,739	982,779	2,920,852
500	502	14,304	34,458	103,250	221,237	334,079	441,006	1,655,356
1,000	147	5,651	14,304	45,312	103,250	162,836	221,237	982,779
2,000	42	2,169	5,651	18,995	45,312	73,773	103,250	542,070
5,000	6	502	1,549	5,651	14,304	23,987	34,458	221,237
10,000	2	147	502	2,169	5,651	9,766	14,304	103,250
20,000	1	42	147	737	2,169	3,785	5,651	45,312

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20,000	1	42	147	737	2,169	3,785	5,651	45,312

* Relative protection for annual payroll

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Second-Stage Noise

- Additional noise to increase relative protection
- Added post-PRDP
- Scaled to noisy sums
  - ***NOT*** the largest establishment in each cell
- Not formally private

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Second-Stage Noise

Establishment	Employment
#1	75
#2	150
#3	30,000
Total	**30,225**

$$\xrightarrow[\text{and } \rho = 0.1]{\text{PRDP with } \theta = 10}$$

30,200 ± 37 (90% CI)

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Second-Stage Noise

Establishment	Employment
#1	75
#2	150
#3	30,000
Total	**30,225**

PRDP with $\theta = 10$ and $\rho = 0.1$ → **30,200 ± 37 (90% CI)**

Additional noise to ensure $p \approx 0.10$

28,500 ± 4,688 (90% CI)

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Parameter Selection

A brief look at the parameter tuning approach

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Privacy Loss Budget (ρ) for PRDP

- Quality Target: 95% of cells with at least ***x*** establishments have a CV of 0.10 or less at each tabulation level

x	Establishments	Annual Payroll (θ = $100,000)	First Quarter Payroll (θ = $25,000)	Employment (θ = 4)	Total Privacy Loss Budget (ρ)
1	3160.55	7597.712	7219.692	5019.129	22997.083
10	30.821	7.666	9.537	19.804	67.828
25	5.066	1.381	1.702	3.909	12.058
100	0.342	0.133	0.158	0.375	1.008

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Privacy Loss Budget (ρ) for PRDP

- Quality Target: 95% of cells with at least **25** establishments have a CV of 0.10 or less at each tabulation level

x	Establishments	Annual Payroll (θ = $100,000)	First Quarter Payroll (θ = $25,000)	Employment (θ = 4)	Total Privacy Loss Budget (ρ)
1	3160.55	7597.712	7219.692	5019.129	22997.083
10	30.821	7.666	9.537	19.804	67.828
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100	0.342	0.133	0.158	0.375	1.008

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Second-Stage Noise

- Cells have a minimum CV via second-stage noise:

$$CV_{MINIMUM} = \max\left(0, \min\left(0.25, 0.25 - \frac{\#\text{ noisy establishments}}{100}\right)\right)$$

# of Noisy Establishments	Minimum CV
≤ 0	25%
1	24%
5	20%
15	10%
25+	0%

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Demonstration Tables

- All CBP tabulation levels
  - Non-noisy and noisy values
  - CVs/variances
- Summary table:
  - Mean absolute error (MAE)
  - Mean absolute percent error (MAPE)
  - Median coefficient of variation
  - 95th percentile coefficient of variation
  - A comparison to noise ranges in the published 2019 CBP tables (for rows with at least 3 establishments)

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Contact Us

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