Differential Privacy and Accuracy

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Background

Census Bureau is implementing new Disclosure Avoidance System

- More control over accuracy vs privacy
  - Differential Privacy adds noise
  - Post-processing makes all values non-negative and consistent
    - Can also affect accuracy
- Neither accuracy nor privacy is easily quantified
  - costs of less accuracy depend on use cases
- Stakeholder involvement to help find right balance

Definition of accuracy

From Statistics Canada:

Accuracy refers to the extent to which the data correctly describes the phenomenon they are supposed to measure.

- Accuracy is often decomposed into **precision**, which measures how similar are repeated measurements of the same thing, and **bias**, which measures any systematic departures from reality in the data.

Demonstration products

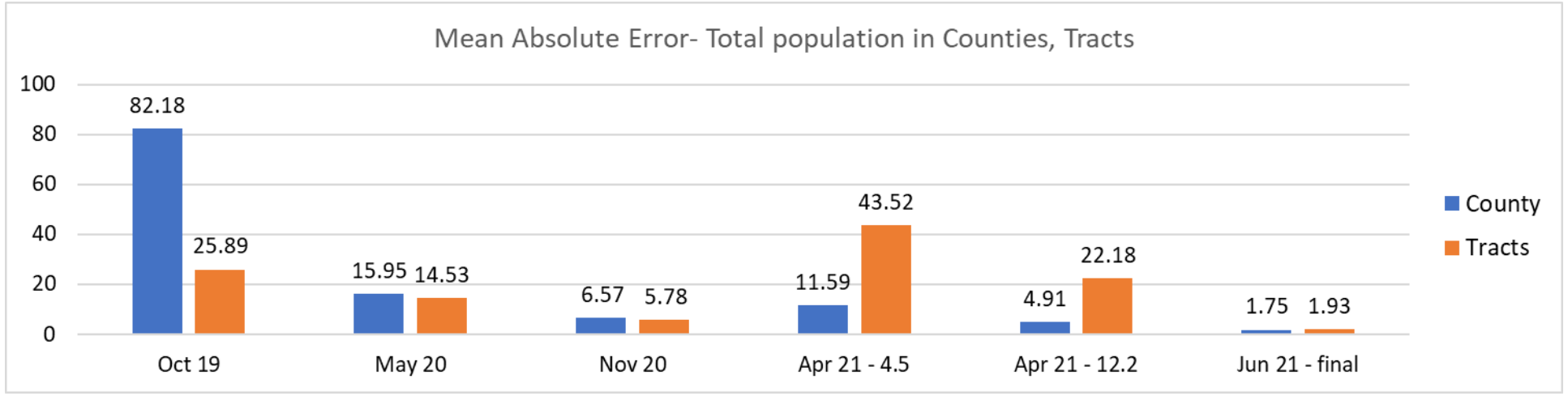
1. October 2019
   - Included most variables, ε = 6 (p:4 + hu:2)
2. May 2020
   - Included only person variables, ε = p:4
3. September/November 2020
   - Only PL variables, ε = 4.5 (p:4 + hu:0.5)
4. April 2021 (2 sets)
   - Only PL variables, ε = 4.5, ε = 12.2 (p:10.3 + hu:1.9)
5. June 2021 (production code)
   - Only PL variables, ε = 19.61 (p:17.14 + hu:2.47)

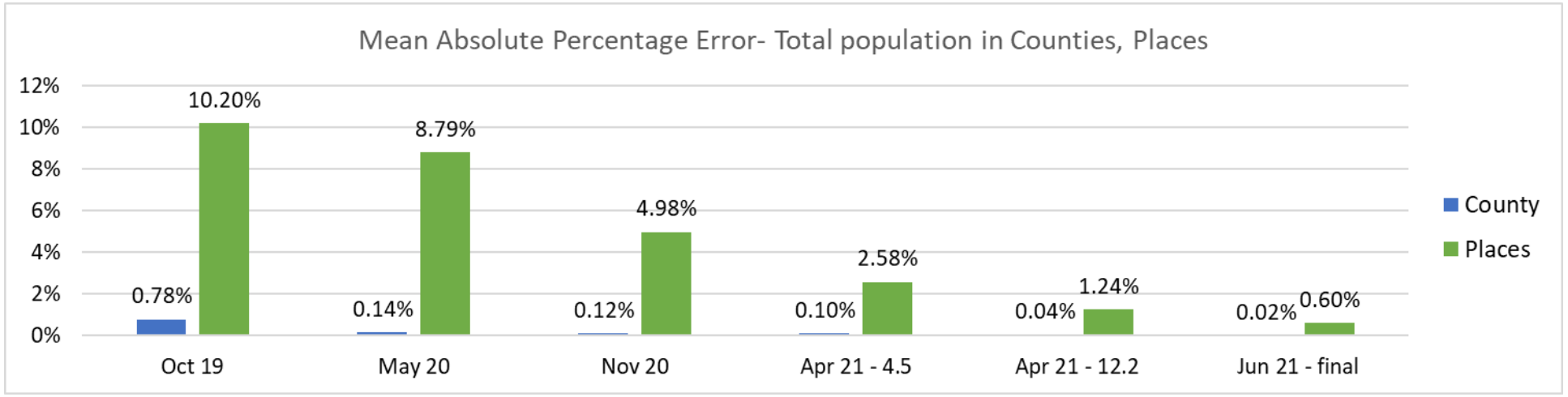
Metric tables

Produced for each demonstration product

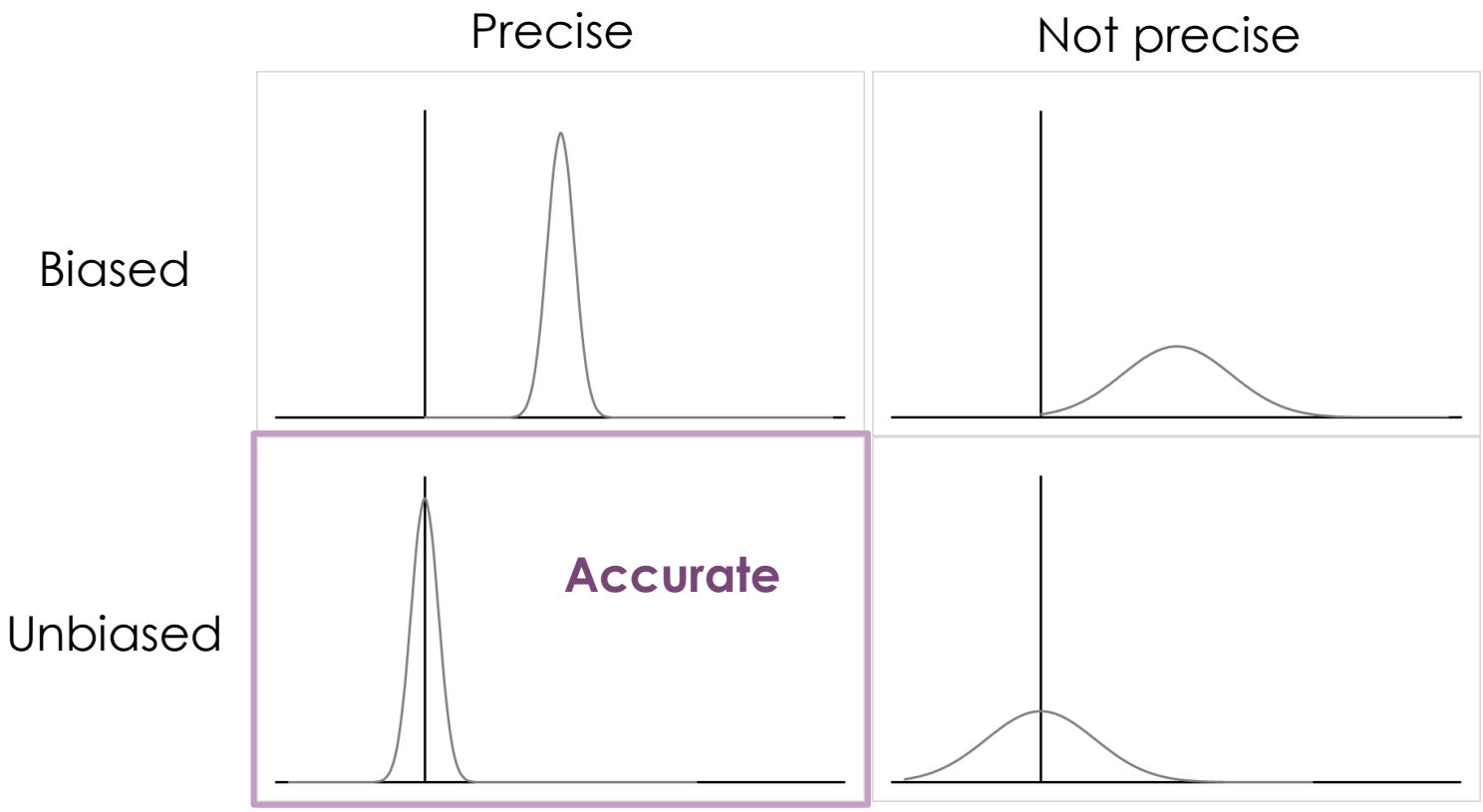
- Type of metrics
  - Mean errors, Mean Absolute Errors, Mean Percentage Errors, Mean Absolute Percentage Error, Frequency of outliers
- For different geographies
  - Sometimes also size categories
- For different race groups
- Goal: to be able to see the progress of DAS development

Metrics tables

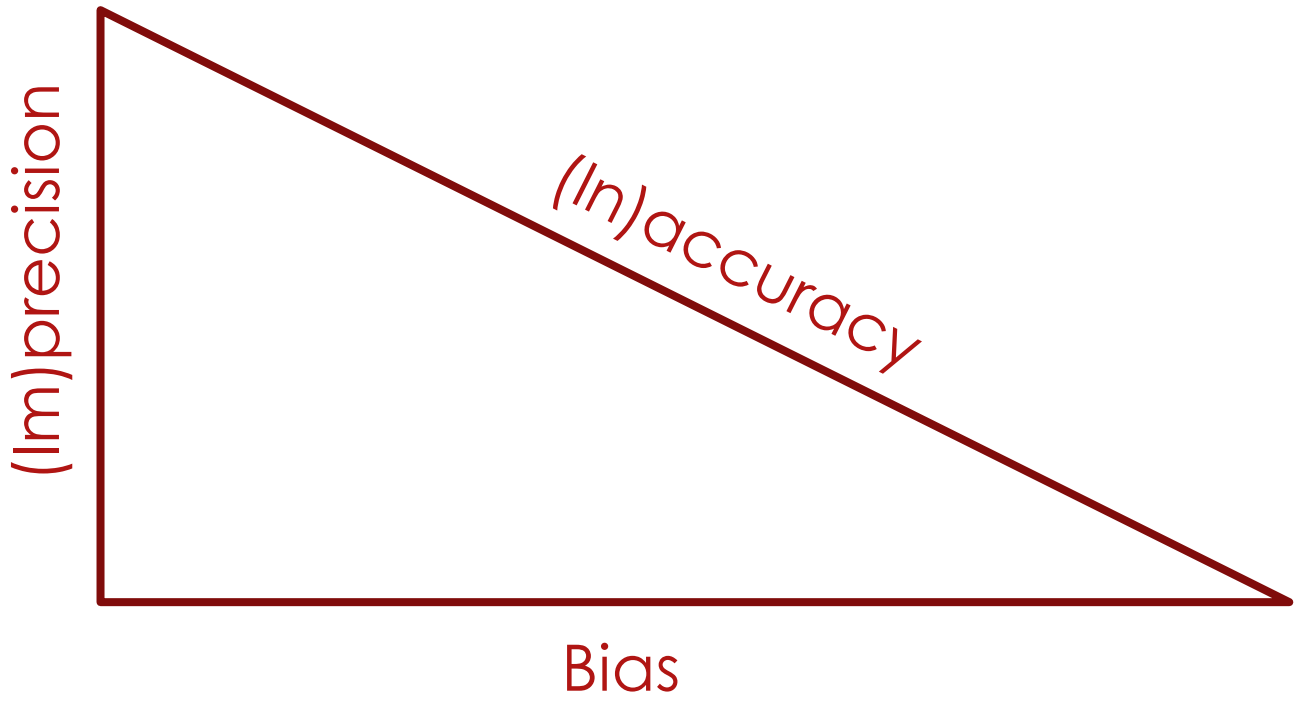




Bias, Precision and Accuracy



Bias, Precision and Accuracy



Final Demonstration Product: Total population in NY places

Total population

Group	N	SF1	DP	Difference in total	Count differences: Bias ME		Count differences: Precision StdDev	Count differences: Accuracy MAE	Percent differences: Bias MALPE		Percent differences: Precision StdDev	Percent differences: Accuracy MAPE	Extreme percent diff: APE >= 5%	Extreme percent diff: APE >= 10%
0 - 499	160	50,223	49,832	-391	-2.4	*	14.7	11.9	0.7%		14.5%	5.7%	49	16
500 - 4999	683	1,304,192	1,298,032	-6,160	-9.0	**	28.3	19.5	-0.6%	**	2.1%	1.4%	27	1
5000 - 49999	327	4,486,164	4,484,000	-2,164	-6.6	**	26.4	14.1	-0.1%	**	0.4%	0.2%	0	0
>=50000	19	9,867,359	9,867,405	46	2.4		15.2	12.4	0.0%		0.0%	0.0%	0	0
Cities	61	2,235,187	2,235,181	-6	-0.1		8.9	6.4	0.0%		0.0%	0.0%	0	0
Villages	556	10,080,714	10,074,725	-5,989	-10.8	**	27.4	17.9	-0.4%		7.2%	1.8%	30	8
CDPs	570	3,372,319	3,369,662	-2,657	-4.7	**	26.0	17.1	-0.3%		3.7%	1.6%	46	9
All places	1189	15,707,938	15,699,269	-8,669	-7.3	**	26.3	16.9	-0.3%		5.5%	1.6%	76	17
Remainder	1	3,670,164	3,678,833	8,669	8669.0	-	-	8669.0	0.2%	-	-	0.2%	0	0

Final Demonstration Product: Population by voting age in NY places

Voting age population

Group	N	SF1	DP	Difference in total	Count differences: Bias ME		Count differences: Precision StdDev	Count differences: Accuracy MAE	Percent differences: Bias MALPE		Percent differences: Precision StdDev	Percent differences: Accuracy MAPE	Extreme percent diff: APE >= 5%	Extreme percent diff: APE >= 10%
0 - 499	160	38,727	38,720	-7	0.0		9.7	7.7	0.9%		9.5%	4.4%	45	9
500 - 4999	683	1,012,832	1,010,241	-2,591	-3.8	**	18.3	13.0	-0.3%	**	1.8%	1.2%	17	1
5000 - 49999	327	3,438,660	3,437,563	-1,097	-3.4	*	24.2	17.2	-0.1%	**	0.3%	0.2%	0	0
>=50000	19	7,715,015	7,714,784	-231	-12.2		42.4	35.2	0.0%		0.1%	0.1%	0	0
All places	1189	12,205,234	12,201,308	-3,926	-3.3	**	19.9	13.8	-0.1%		3.8%	1.4%	62	10
Remainder	1	2,847,939	2,851,868	3,929	3929.0	-	-	3929.0	0.1%	-	-	0.1%	0	0

Non voting age population

Group	N	SF1	DP	Difference in total	Count differences: Bias ME		Count differences: Precision StdDev	Count differences: Accuracy MAE	Percent differences: Bias MALPE		Percent differences: Precision StdDev	Percent differences: Accuracy MAPE	Extreme percent diff: APE >= 5%	Extreme percent diff: APE >= 10%
0 - 499	160	11,496	11,112	-384	-2.4	**	9.3	7.5	19.2%		199.1%	35.1%	114	77
500 - 4999	683	291,360	287,791	-3,569	-5.2	**	17.0	12.7	-1.1%	*	13.0%	5.0%	203	77
5000 - 49999	327	1,047,504	1,046,437	-1,067	-3.3	**	21.1	15.3	0.4%		8.5%	1.3%	4	2
>=50000	19	-4,342,696	-4,345,122	-2,426	14.6		38.6	34.6	0.1%		0.2%	0.2%	0	0
All places	1189	3,502,704	3,497,961	-4,743	-4.0	**	18.1	13.1	2.1%		73.9%	7.9%	321	156
Remainder	1	822,225	826,965	4,740	4740.0	-	-	4740.0	0.6%	-	-	0.6%	0	0

Final Demonstration Product: Total population in NY Cities/Towns

Total population

Group	N	SF1	DP	Difference in total	Count differences: Bias ME		Count differences: Precision StdDev	Count differences: Accuracy MAE	Percent differences: Bias MALPE		Percent differences: Precision StdDev	Percent differences: Accuracy MAPE	Extreme percent diff: APE >= 5%	Extreme percent diff: APE >= 10%
City	61	2,235,187	2,235,181	-6	-0.1		8.9	6.4	0.0%		0.0%	0.0%	0	0
Town	932	8,958,225	8,958,233	8	0.0		4.3	3.1	0.0%		0.5%	0.1%	1	1
Village (part)	632	1,905,581	1,899,598	-5,983	-9.5	**	25.8	16.4	0.6%		15.3%	3.5%	60	25
CDP (part)	632	3,372,319	3,369,662	-2,657	-4.2	**	24.4	15.9	0.6%		11.3%	2.6%	70	19
Remainder of town	911	3,660,607	3,669,272	8,665	9.5	**	26.4	15.6	0.6%	**	4.4%	0.9%	15	2

Average errors in block groups by diversity index quintiles

	April, 12.2 Mean error	Final Mean error
20% with lowest diversity	5.05	1.43
Group 2	4.24	1.67
Group 3	0.99	0.67
Group 4	-2.22	-0.60
20% with highest diversity	-8.07	-3.11

Census blocks

Limited Privacy Loss Budget assigned to blocks

- Much noise added
- Big impact of post-processing
  - Many instances where count + noise < 0
  - Number have to be made consistent
    - Within block, e.g. Hispanic + Non Hispanic = Total
    - With higher levels of geography:
      sum of blocks in block group = block group

If noise is random, noise get cancelled out in aggregation

Number of living quarters was held invariant (no noise added)

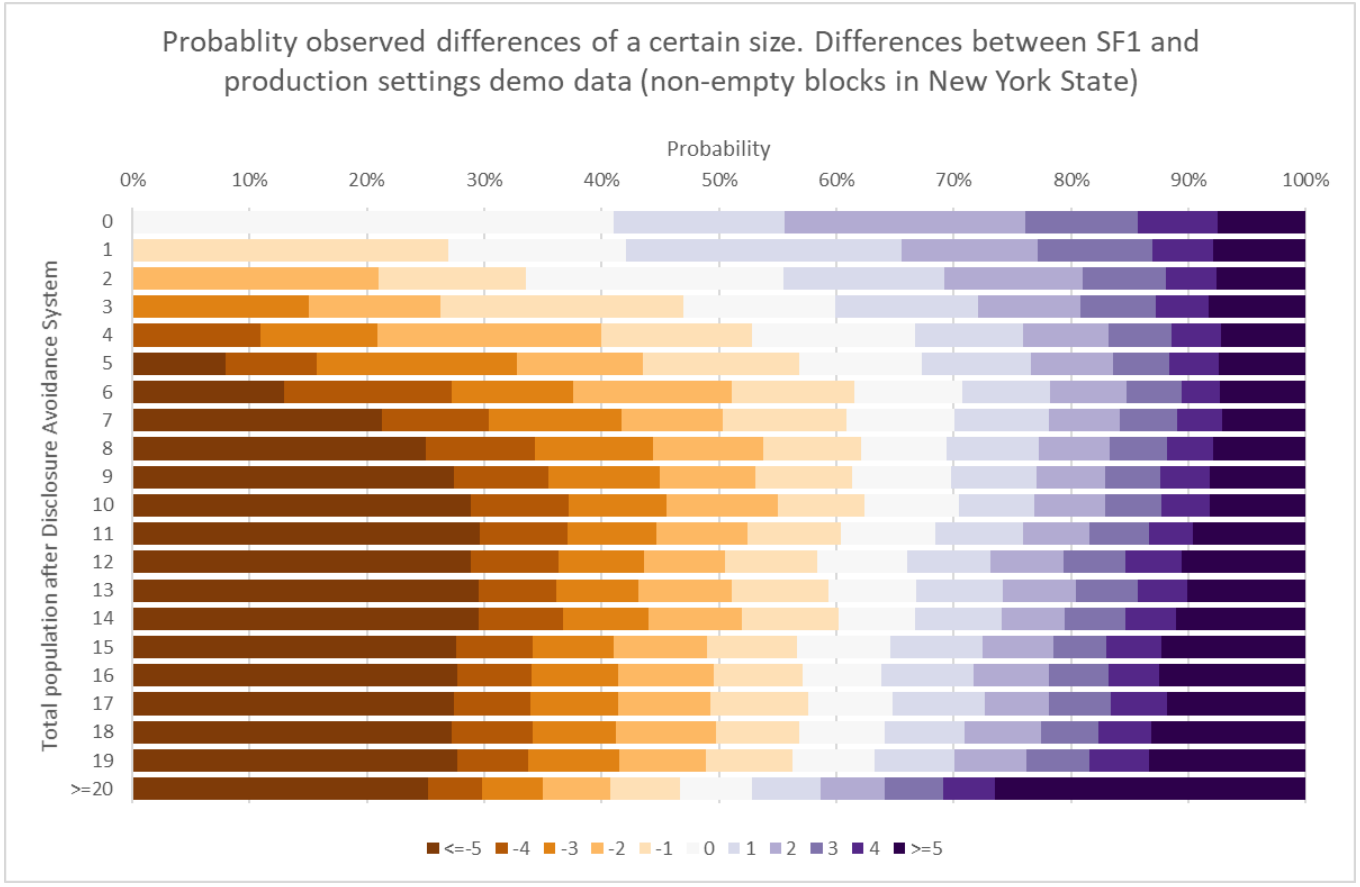
My block - 2010

1. SF1
   - **8 NH white adult + 1 NH White youth**
2. October 2019
   - 10 NH White adult
3. May 2020
   - 5 NH White adult
4. November 2020
   - 9 NH White adult + 8 NH Black adult
5. April 2021, ε = 4.5
   - 18 NH White adult + 4 NH White+Asian adult + 2 NH Black youth
6. April 2021, ε = 12.2
   - 8 NH white adult + 1 Hisp Other youth
7. June 2021 (production code)
   - 8 NH white adult + 1 Hisp White adult + 1 NH Asian adult + 1 NH Asian youth

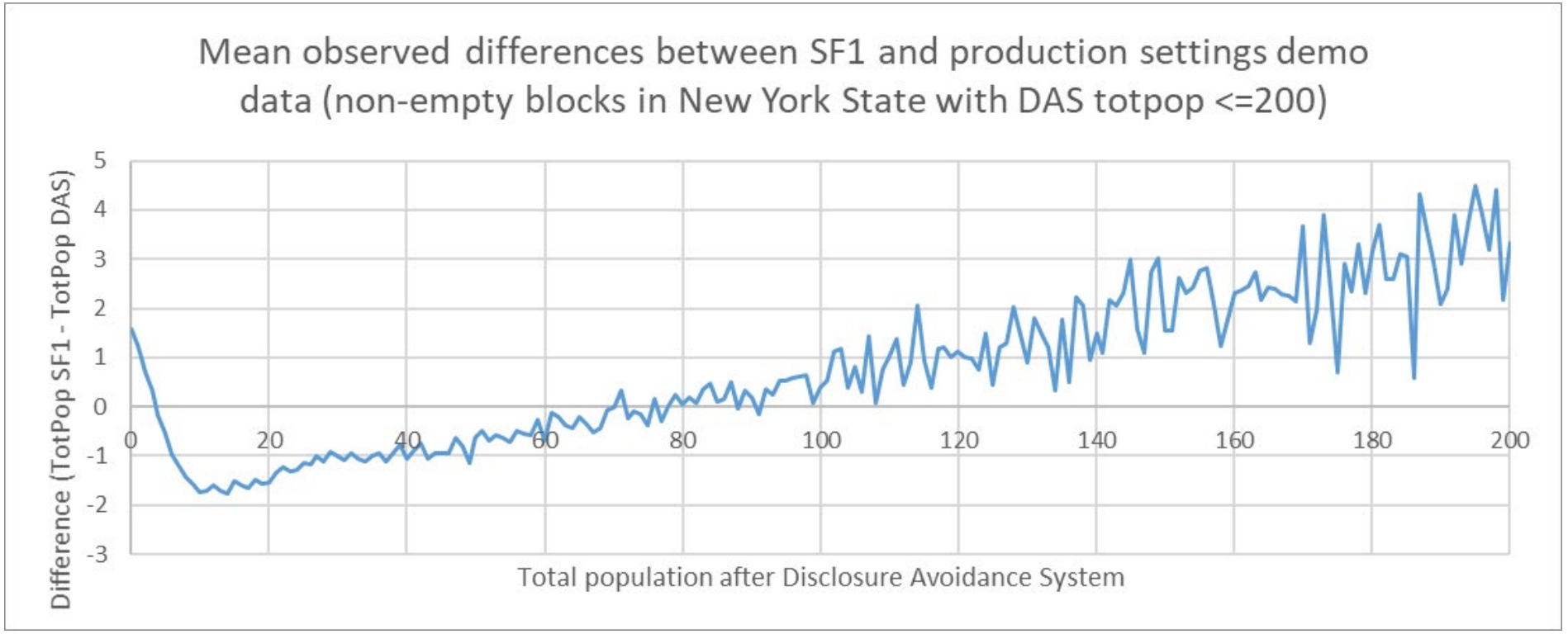
My block - 2020

1. My own count
   - **7 NH white adult + 4 NH White youth**
2. Published PL94-171
   - 4 NH White adults + 6 NH White youth + 3 NH Asian youth

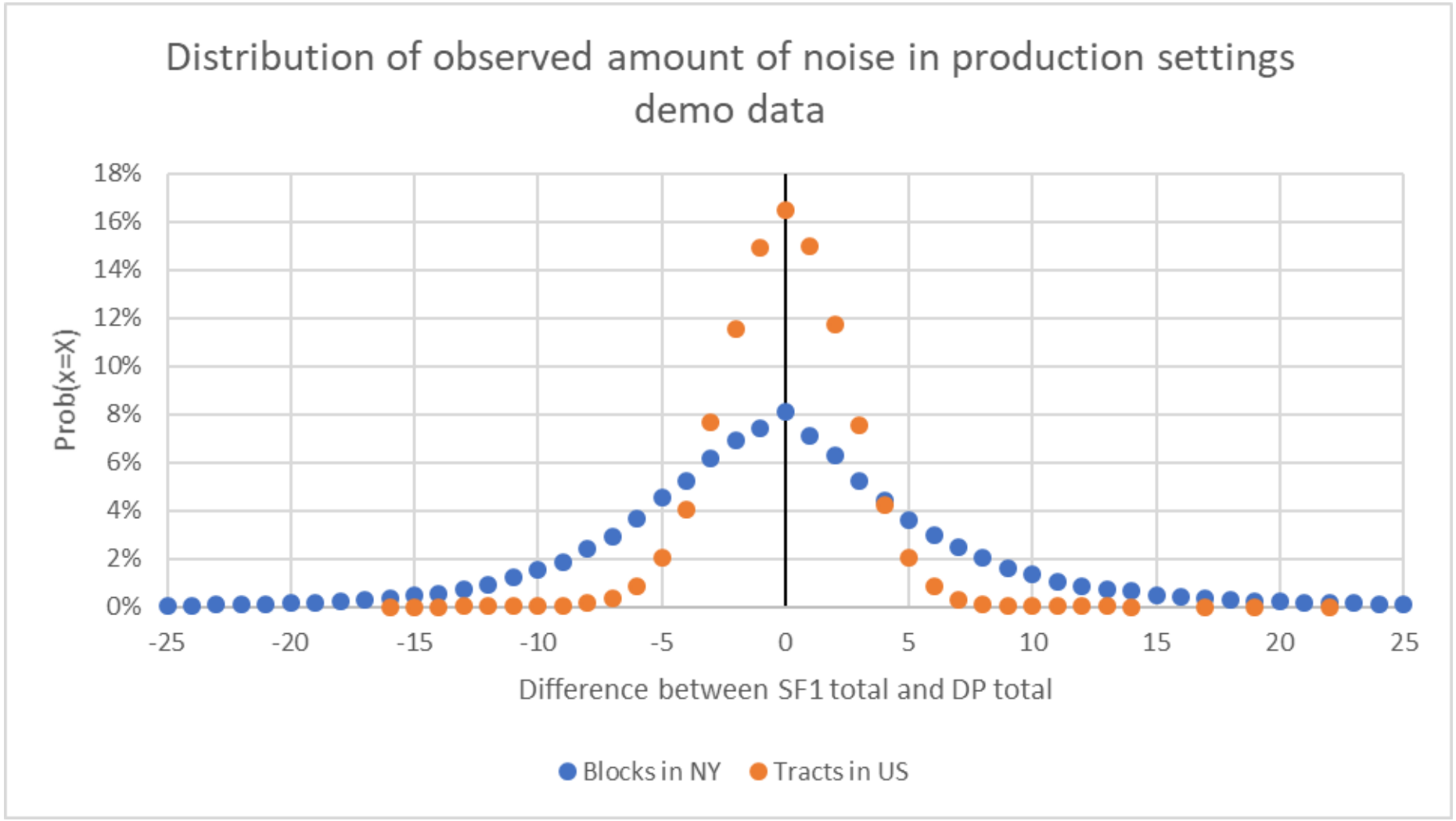
Block count differences



Differences in block counts



Error distribution (tracts and blocks)



Impossible and improbable blocks

	2010		2020	
	Count	% of all	Count	% of all
Non empty blocks	250,070		233,182	
Households (occupied houses) and household population				
Household population > 0, but occupied houses = 0	Impossible in 2010		14,276	6.1%
Household population < occupied houses (Persons per household < 1)			5,764	2.5%
Household population = 0, but occupied houses > 0			1,834	0.8%
PPH > 10	53	0.0%	4,510	1.9%
Youth only				
Only 0-17	21	0.0%	2,808	1.2%
Without GQ and only 0-17	1	0.0%	2,795	1.2%

Accuracy in future products

DAS for Demographic and Housing Characteristics (DHC) file is in development

- 2 Demonstration products
  - National workshop (CNSTAT)
- Consistency not decided yet
- Tables and geographic details not decided yet
  - GIVE FEEDBACK!
- Current time line indicates publication in summer 2022

Accuracy in future products

DAS for Detailed Demographic and Housing Characteristics (Detailed DHC) file is in development

- Not Top-Down
- Probably not consistent with other products
- Tables and geographic details not decided yet

GIVE FEEDBACK!

Handbooks and Guidance

The Census Bureau asked Population Reference Bureau (PRB) to produce handbooks that explain what Differential Privacy is

- Expected soon!

Census Bureau is looking into producing some guidance as far as uncertainty of a certain count