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Lessons learned from censuses of the 2020 round

Evaluating the demographic quality of the United States 2020 Census

Note by United States Census Bureau*

Summary

The U.S. Census Bureau conducted the United States 2020 Census during the Covid-19 Global Pandemic. Although this created significant challenges, the U.S. Census Bureau was able to collect and process the once-a-decade enumeration of population and housing in the United States. In this paper, we evaluate the demographic quality of the 2020 Census. We present results from two coverage measurement programs, comparisons of the 2020 Census results to demographic benchmarks, and evaluations of the internal demographic consistency of the census data. The findings show that the demographic quality of the 2020 Census is different compared to past censuses, but that the data are still fit for some important uses.

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I. Introduction

1. In this paper, we examine the quality of the 2020 Census in the United States using several different evaluation techniques. Examining multiple evaluation techniques provides a broad picture of the quality of the 2020 Census.

2. The demographic quality of the decennial census data is vital to the Federal Statistical System in the United States. The data are used for the apportionment of seats in congress and for the redistricting of the boundaries for congressional districts. In addition, the decennial census data, and the subsequent postcensal population estimates, are used to allocate hundreds of billions of dollars in federal funds each year, as population controls for household surveys, as denominators for vital rates, and as inputs to other official statistics.

3. Because the decennial census is a full enumeration of the population, it provides more detailed information than a household survey. This is especially important for small population groups and sparsely-populated geographic areas Similarly, the decennial census gives us the most detailed demographic data for the U.S. population by age, sex, race, and Hispanic origin.

4. The Census Bureau has implemented a modern Disclosure Avoidance System (DAS) for the 2020 Census. The DAS protects respondent's information from unlawful disclosure. The DAS infuses noise into the census data using a statistical method called Differential Privacy. While the noise infusion impacts the accuracy of the 2020 Census data, the loss of precision is necessary to protect the privacy of people who responded to the census.

II. Coverage Error

5. Coverage error is an important indicator of quality in a census. The U.S. Census Bureau uses two methods to estimate net coverage error in the decennial census. One approach is Demographic Analysis (DA), which uses current and historical vital records, data on international migration, and Medicare Enrolment records to produce estimates of the population. The population estimates are independent of the census being evaluated. The DA results are compared to the census counts to produce estimates of net coverage error. The DA estimates are not produced using a survey; therefore, we cannot produce standard errors or other variance measures. We produced a range of estimates—Low, Middle, High—to reflect uncertainty in the data and methods used to produce the DA estimates.

6. The second approach used to estimate net coverage error in the 2020 Census was dual-system estimation with a post-enumeration survey (PES). The PES in-person interviews were conducted after data collection was completed for the 2020 Census. The PES results were matched to the census results to produce dual-system estimates of the population. The PES did not include the population living in group quarters (e.g., college dormitories, correctional facilities, and nursing homes) or the population living in Remote Alaska. However, group quarters account for roughly 3 per cent of the total population and the population in Remote Alaska is also relatively small.[1]

7. Both DA and PES produce estimates of net coverage error. Because they are a "net" measure, they can include both undercounts and overcounts for the same population group. However, populations with large undercounts usually do not have large overcounts as well.

[1] Stempowski, Debbie and James Christy. 2021. "2020 Census Group Quarters." Random Samplings Blog: https://www.census.gov/newsroom/blogs/random-samplings/2021/03/2020-census-group-quarters.html

The PES also produces estimates of the components of coverage error, which can break the net coverage error estimates into estimates of omissions (undercounts) and erroneous enumerations (overcounts).

8. The national-level results of DA and PES for 2010 and 2020 are presented in Table 1. For 2020, the PES did not find a statistically different undercount or overcount for the total U.S. population. The DA estimates of net coverage error found an overcount of 0.22 per cent for the Low series and undercounts in the Middle (-0.35 per cent) and High (-1.21 per cent) series. The main differences between the series are the estimates of international migration.

Table 1
Post-Enumeration Survey and Demographic Analysis National Estimates of Net Coverage Error for People: 2010 and 2020

Year	PES		DA		
	Net Coverage Error	Standard Error	Low Series	Middle Series	High Series
2010 Census	0.01	0.14	1.00	0.13	-1.27
2020 Census	-0.24	0.25	0.22	-0.35	-1.21

Source: U.S. Census Bureau, 2010 and 2020 Post-Enumeration Survey and Demographic Analysis Estimates.

A. Demographic Analysis

9. The DA net coverage error estimates are produced by detailed demographic characteristics including single year of age, sex, race, and Hispanic origin. For this paper, we focus on the 2020 DA net coverage error estimates by age and sex, which were released in March 2022. The DA net coverage error estimates by race and Hispanic origin will be released in 2023.

1. DA Results

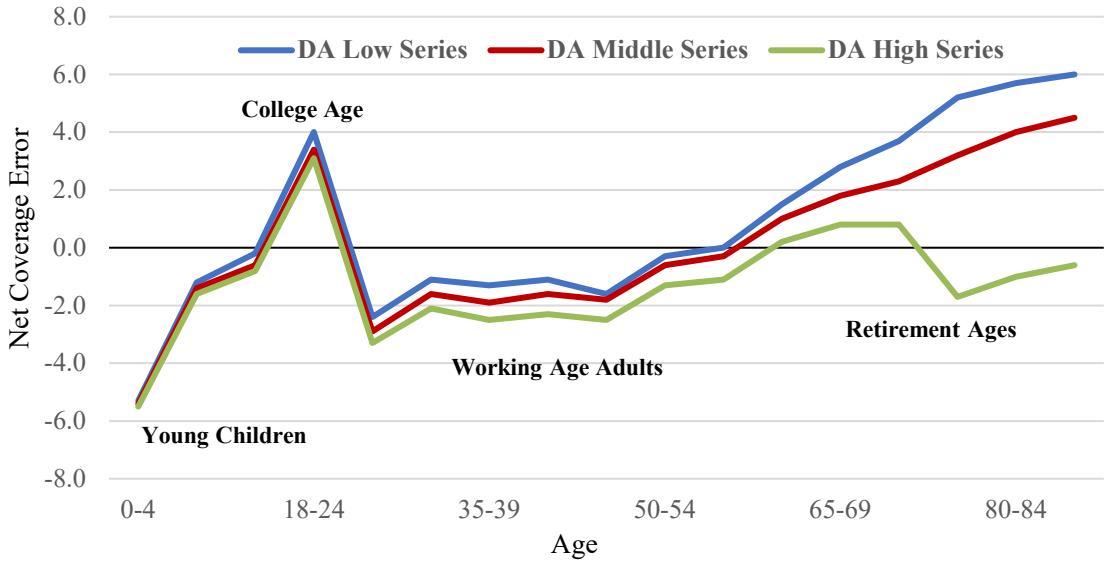
10. Figure 1 shows the three series of DA net coverage error estimates for the 2020 Census by five-year age groups. The largest undercount was for young children aged 0 to 4, which is a persistent issue that we find in the decennial census.[2] We also find undercounts for the 5-9 and 10-17 age groups, but the undercounts for these ages were not as large as they were for young children.

11. We see a large overcount for the 18-24 age group, which is the college-aged population. Many colleges and universities closed during the Covid-19 pandemic and some students may have moved home with their parents. The 2010 DA also showed an overcount

[2] O'Hare, W. P. (2015). *The undercount of young children in the US Decennial Census*. Springer International Publishing.

for this population. This overcount was mostly likely caused by students being counted at both their university address and another address.

Figure I
2020 Demographic Analysis Net Coverage Error Estimates for Selected Age Groups by



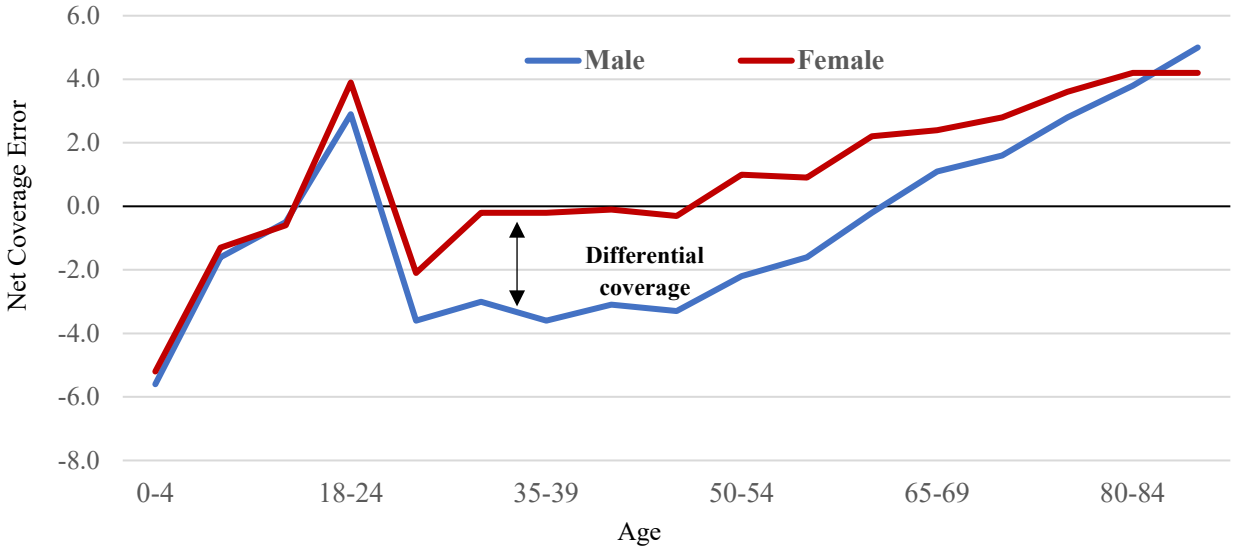
Source: U.S. Census Bureau, Population Division, 2020 Demographic Analysis (December 2020 release), and 2020 Census special tabulation (DRB Approval Number: CBDRB-FY22-DSEP-001).

12. The DA net coverage error estimates showed an undercount for the population between the ages 25 and 59. For the oldest ages, we see overcounts in the DA low and middle series but undercounts in the high series. The DA population estimates for the oldest ages are produced using Medicare Enrolment records and the different series were developed by varying assumptions about the coverage in the administrative records.

13. A strength of DA is that it can be used to highlight differential coverage in the census by demographic characteristics. Figure II shows the DA net coverage errors by five-year age groups and sex. The previous graph showed that DA estimated relatively large undercounts for working-age adults in the 2020 Census. This graph shows that those undercounts were mainly for the males in those ages. In fact, females showed full coverage or even an overcount for many of the ages between 25 and 64. We will also look at differential patterns in coverage by race once the 2020 Census Modified Race data are available.

14. The relatively high undercounts for some racial and ethnic groups in the 2020 Census is concerning. In response, the Census Bureau organized the Base Evaluation and Research Team, which is a group of Census Bureau experts tasked with researching the feasibility of taking coverage measures from the DA and PES into account in the development of the official population estimates. The team is comprised of subject-matter experts in the areas of population estimates, age and sex statistics, coverage measurement, race and ethnicity, demography, and disclosure avoidance.

Figure II
2020 Demographic Analysis Middle Series Net Coverage Error Estimates for Selected Age



Source: U.S. Census Bureau, Population Division, 2020 Demographic Analysis (December 2020 release), and 2020 Census special tabulation (DRB Approval Number: CBDRB-FY22-DSEP-001).

B. Post-Enumeration Survey

15. The 2020 PES produced estimates of net coverage error and the components of coverage for the 2020 Census. For this paper, we focus on the PES estimates of net coverage error by age, sex, race, Hispanic origin, and state of residence. Additional results from the 2020 PES can be accessed using the following link: https://www.census.gov/programs-surveys/decennial-census/about/coverage-measurement/pes.html.

1. Results of PES

16. Unlike DA which has limited race groups, the PES can measure coverage for all the race and ethnicity groups. In 2020, the PES results show there was an overcount for the non-Hispanic White group and for Asians. The PES measured an undercount of 3.30 per cent for Blacks, 5.64 per cent for American Indians living on Reservation, 4.34 per cent for Some Other Race, and 4.99 per cent for Hispanics. The findings for 2020 are consistent with the PES results for 2010. However, the undercount rates for Some Other Race and Hispanics were significantly higher in 2020 than in 2010.

Table 2
Post-Enumeration Survey Net Coverage Error Rates for the Household Population in the United States by Race and Hispanic Origin (In per cent)

Race or Hispanic Origin	2020		2010	
	Estimate	Standard Error	Estimate	Standard Error
Total	-0.24	0.25	0.01	0.14
Race alone or in combination with one or more other races				
White	0.66*	0.21	0.54*	0.14
Non-Hispanic White Alone	1.64*	0.21	0.83*	0.15
Black or African American	-3.30*	0.61	-2.06*	0.50
Asian	2.62*	0.77	0.00	0.52
American Indian Alaskan Native	-0.91*	0.54	-0.15	0.71
On Reservation	-5.64*	2.72	-4.88*	2.37
American Indian Areas Off Reservation	3.06	2.72	3.86	2.99
Balance of the United States	-0.86*	0.47	0.05	0.58
Native Hawaiian or Other Pacific Islander	1.28	2.11	-1.02	2.06
Some Other Race	-4.34*	0.49	-1.63*	0.31
Hispanic or Latino	-4.99*	0.53	-1.54*	0.33

* Denotes a (per cent) net coverage error that is significantly different from zero.
Note: A person can be included in more than one row. A negative (positive) estimate of net coverage error indicates an undercount (overcount).
Source: U.S. Census Bureau, Decennial Statistical Studies Division, 2020 Post-Enumeration Survey (March 2022 Release) and 2010 Census Coverage Measurement Survey.

C. Comparing PES and DA Results

17. DA and PES both produce independent estimates of coverage error in the 2020 Census; However, they use different methodologies. DA produces population estimates that are used as benchmarks to evaluate the census while PES matches the results of an independent survey to the results of the census to produce dual-system estimates of net coverage error. There are additional differences that may cause the results to be different. For example, there are differences in the universe being estimates. DA produced estimates for the total population living in the United States on April 1, 2020. PES did not include estimates for the population living in group quarters and Remote Alaska.

18. Comparing the PES and DA results by age and sex show that, for the most part, the results are consistent. Both programs show undercounts for young children and over counts for people aged 50 and over. We see a discrepancy for those aged 18 to 29. The PES indicates an undercount for those age groups while DA indicates an overcount. More specifically, DA shows an overcount in all series for both males and females aged 18 to 24. These are prime college ages, and it could be that families could incorrectly reported their children who were at university as living at home while they were also counted at their university. This may have been compounded by the pandemic as many universities closed in late March of 2020.

Table 3
Post-Enumeration Survey and Demographic Analysis Estimates of Net Coverage Error by Age and Sex: April 1, 2020

Age and Sex	2020 Post-Enumeration Survey		2020 Demographic Analysis		
	Net Coverage Error Estimate (%)	Standard Error (%)	Low Series (%)	Middle Series (%)	High Series (%)
U.S. Total	**-0.24**	**0.25**	**0.2**	**-0.3**	**-1.2**
0 to 17	-0.84*	0.38	-1.8	-2.1	-2.3
0 to 9	-1.40*	0.49	-3.2	-3.4	-3.5
0 to 4	-2.79*	0.64	-5.3	-5.4	-5.5
5 to 9	-0.10	0.56	-1.2	-1.4	-1.6
10 to 17	-0.21	0.43	-0.2	-0.6	-0.8
18 to 29 Males	-2.25*	0.57	0.7	0.1	-0.3
18-24 Males			3.6	2.9	2.6
25-29 Males			-3.2	-3.6	-4.1
18 to 29 Females	-0.98*	0.58	1.8	1.3	0.9
18-24 Females			4.4	3.9	3.6
25-29 Females			-1.7	-2.1	-2.5
30 to 49 Males	-3.05*	0.35	-2.8	-3.2	-3.9
30 to 49 Females	0.10	0.36	0.3	-0.2	-0.8
50+ Males	0.55*	0.25	1.1	0.2	-1.4
50+ Females	2.63*	0.25	3.1	2.2	0.5

* Denotes a (per cent) net coverage error that is significantly different from zero.

Note: A negative (positive) estimate of net coverage error indicates an undercount (overcount).

Source: U.S. Census Bureau,2020 Post-Enumeration Survey and Demographic Analysis (March 2022 Release).

III. Demographic Benchmarks

19. The Census Bureau's official population estimates also can be used as benchmarks to evaluate the quality of the 2020 Census. These data are produced each year using a cohort-component method to estimate components of population change since the last census. The estimates start with the latest decennial census as a base to which births are added and deaths are subtracted. The Census Bureau uses tax records to estimate domestic migration and data from the American Community Survey to estimate international migration. The population estimates are produced for the nation, states, and counties disaggregated by age, sex, race, and Hispanic origin. The Census Bureau also produces population totals for cities and towns.

20. After the decennial census, the Census Bureau conducts an error-of-closure analysis between the population estimates and the new census results. This analysis is called the Estimates Evaluation (E2) and the results are used to make improvements to the population estimates for the coming decade.

21. There are three sources of error or difference when we compare the population estimates to the census. First, there could be errors in the prior census which was used as the base population for the V2020 estimates, in this case the 2010 Census. Next, there could be error in the data and methods used to produce the population estimates during the postcensal period. Finally, there could be error in the new census data. When comparing the population estimates to the 2020 Census counts, it is important to remember that differences are caused by all three sources of error, and not just data quality issues in the 2020 Census.

22. For this paper, we are using the population estimates as the benchmark to evaluate the quality of the 2020 Census. We subtract the estimates from the census results to calculate numeric differences and use the estimates as the denominator when calculating per cent differences. The equation for calculating the per cent difference is presented below:

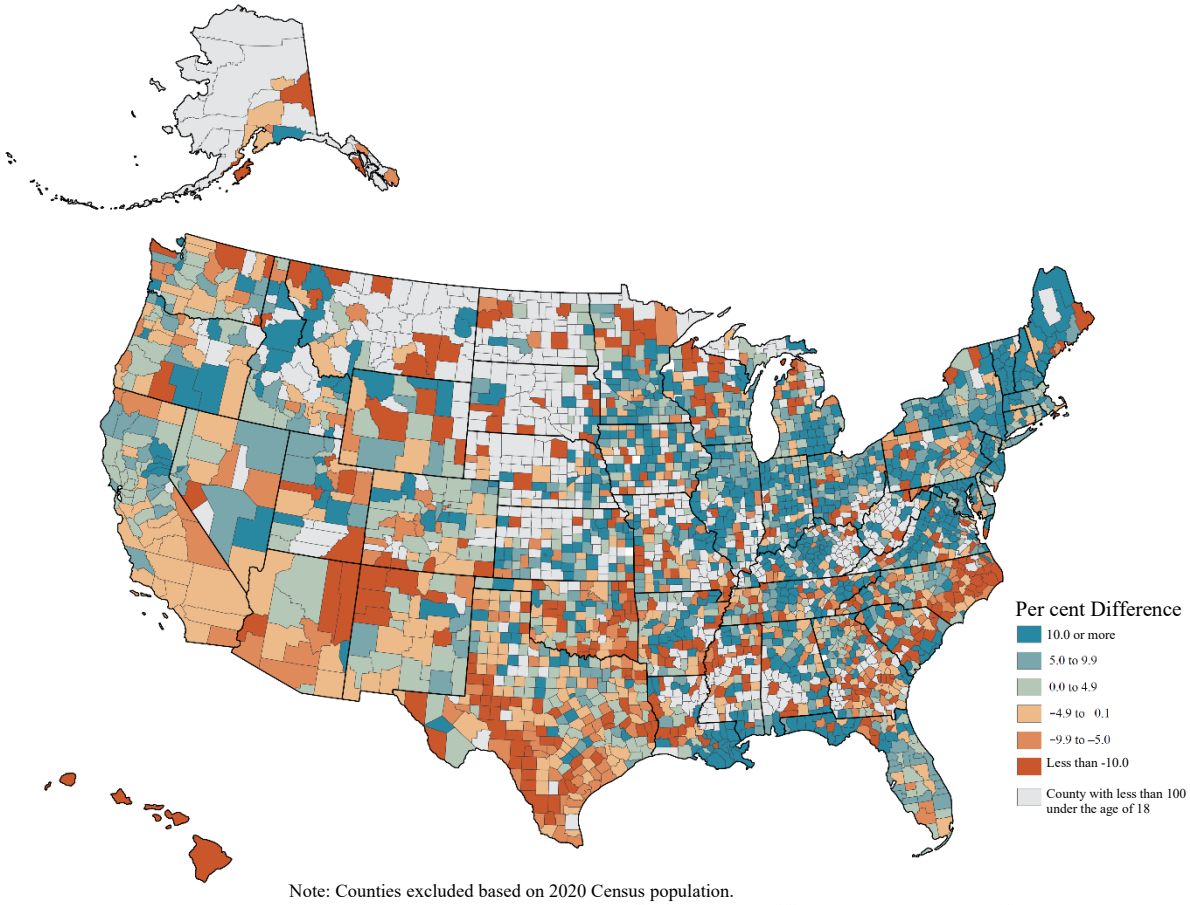
$$Percent\ Difference\ =\ 100\left(\frac{2020\ Census\ -\ V2020\ Estimates}{V2020\ Estimates}\right)$$

A. Results

23. Figure III shows a county map with per cent differences for the Hispanic or Latino population under 18 years between the 2020 Census and the Vintage 2020 population estimates. We see regional patterns where the census results are higher than the population estimates in the Northeast and Midwest; whereas, the census counts were lower than the population estimates in the West and Southwest.

24. Some of the highest values are in areas with lower Hispanic or Latino populations. For these, relatively small numeric differences can turn into large percentage differences because the population used as the denominator to calculate the percentage difference is small. To overcome this small population problem, we look at both numeric and per cent differences when comparing the 2020 Census to the V2020 population estimates and use professional judgment when assessing the quality of census data for small population groups.

Figure III
2020 Census Counts Compared to Vintage 2020 Population Estimates of Hispanic Population Under 18 Years of Age: April 1, 2020

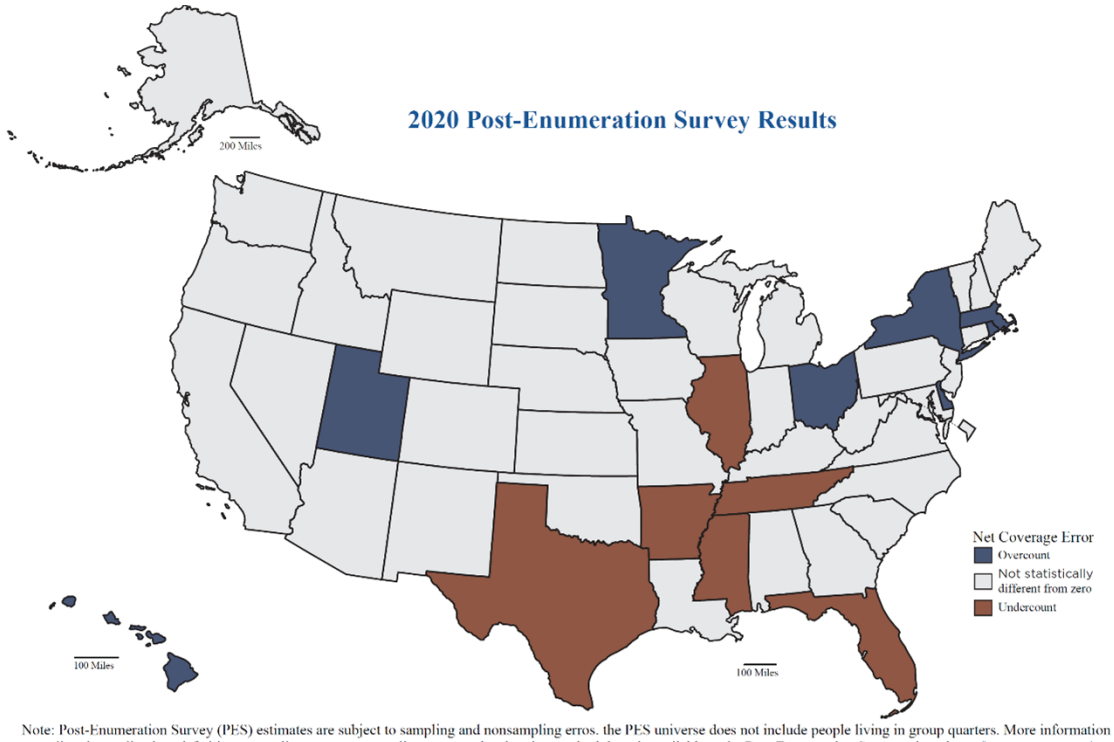


Note: Counties excluded based on 2020 Census population.
Source: U.S. Census Bureau, 2020 Census Redistricting Data (Public Law 94-171) Summary File; Vintage 2020 Population Estimates.

25. The Census Bureau uses PES results and population estimates to evaluate the census counts for states. In 2020, the PES measured an undercount or overcount in 14 states. For 12 of those states, the population estimates also showed an undercount or overcount consistent with the PES results. For one state, Illinois, the PES showed an undercount of 1.97 per cent while the population estimates suggested on overcount of 1.56 per cent. The comparison of the census counts with population estimates also shows some states with overcounts; Alabama (2.1 per cent) New Jersey (4.48 per cent), and Rhode Island (3.72 per cent) while the PES did not find a significant overcount in these states. The population estimates comparison also indicate undercounts in Arizona (-3.28 per cent) and the District of Columbia (-3.18 per cent) whereas the PES did not show undercounts in these states.

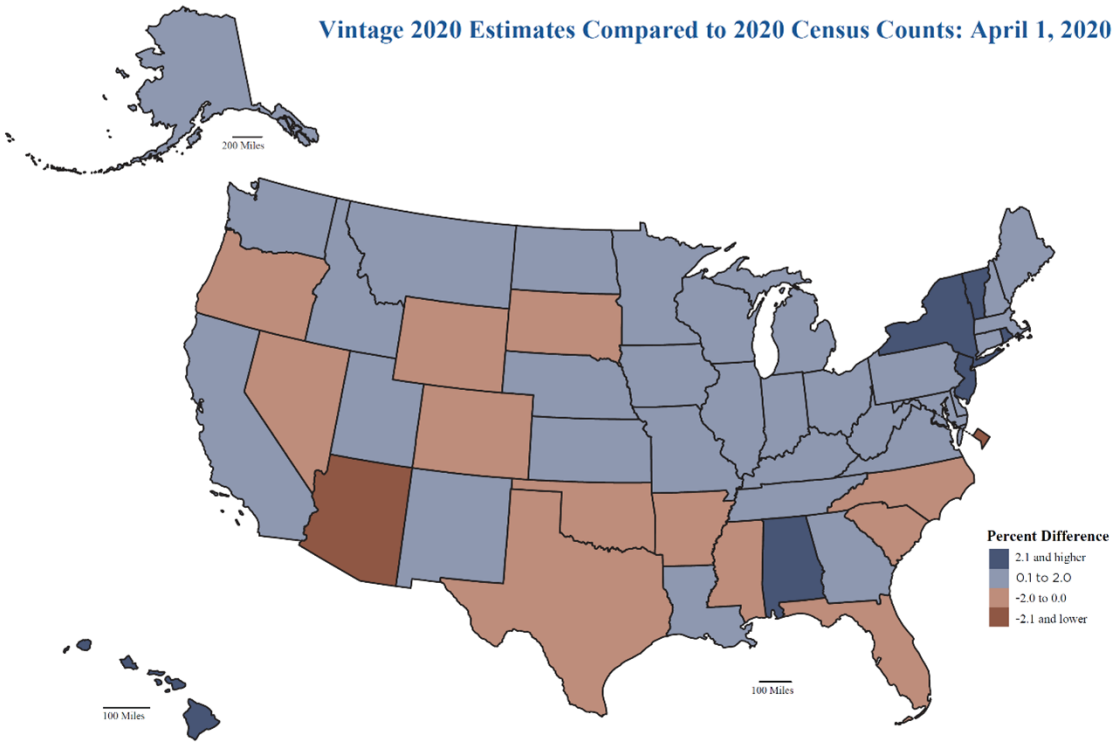
Figure IV

Post-Enumeration Survey Results and Vintage 2020 Population Estimates Compared to 2020 Census by State: April 1, 2020



Note: Post-Enumeration Survey (PES) estimates are subject to sampling and nonsampling erros. the PES universe does not include people living in group quarters. More information regarding data collection, definitions, sampling error, nonsampling error, and estimation methodology is available at the Post-Enumeration Surveys site. <https://www.census.gov/programs-surveys/decennial-census/about/coverage-measurement/pes.2020.html>

Source: U.S. Census Bureau, 2020 Post-Enumeration Survey



Source: U.S. Census Bureau, 2020 Census and Vintage 2020 Population Estimates

26. The PES included estimates of net coverage error by state. DA does not produce state-level estimates, but we can compare the per cent difference between the population estimates and the Census with the PES results (Figure IV). While there was some overlap between the PES and population estimates, there were also differences. The PES state results show the states where there was a significant undercount or overcount in the 2020 Census for the household population. The population estimates analysis shows the per cent difference between the V2020 estimates and the 2020 Census. We do not produce measures of uncertainty for the population estimates; therefore, we cannot say if the difference is statistically significant. Instead, we highlight the magnitude of difference.

27. The 2020 PES found that six states—Arkansas, Florida, Illinois, Mississippi, Tennessee, and Texas—had a statistically significant undercount in the 2020 Census. Of those states, Illinois and Tennessee were the only ones where the population estimate was higher than the 2020 Census count. Arizona and the District of Columbia were the states (and state equivalent) with the highest negative per cent difference (population estimate was higher than the census) but these states did not have a statistically significant undercount or overcount in the PES results.

28. The PES found that eight states— Delaware, Hawaii, Massachusetts, Minnesota, New York, Ohio, Rhode Island, and Utah—had a statistically significant overcount in the 2020 Census. For all of these states, the population estimate was lower than the census count indicating an overcount. Alabama and New Jersey had a relatively large positive per cent difference between the estimates and the census counts, but the PES did not show a statistically significant difference for these states.

B. Internal Demographic Consistency

29. A final approach for evaluating the demographic quality of the 2020 Census is to analyse the internal demographic consistency of the data. Specifically, we analyse age distributions, sex ratios, and the percentage of cohort change in the 2020 Census results. We also compare these indicators to the results from the 2010 and 2000 Censuses.

1. Age distributions

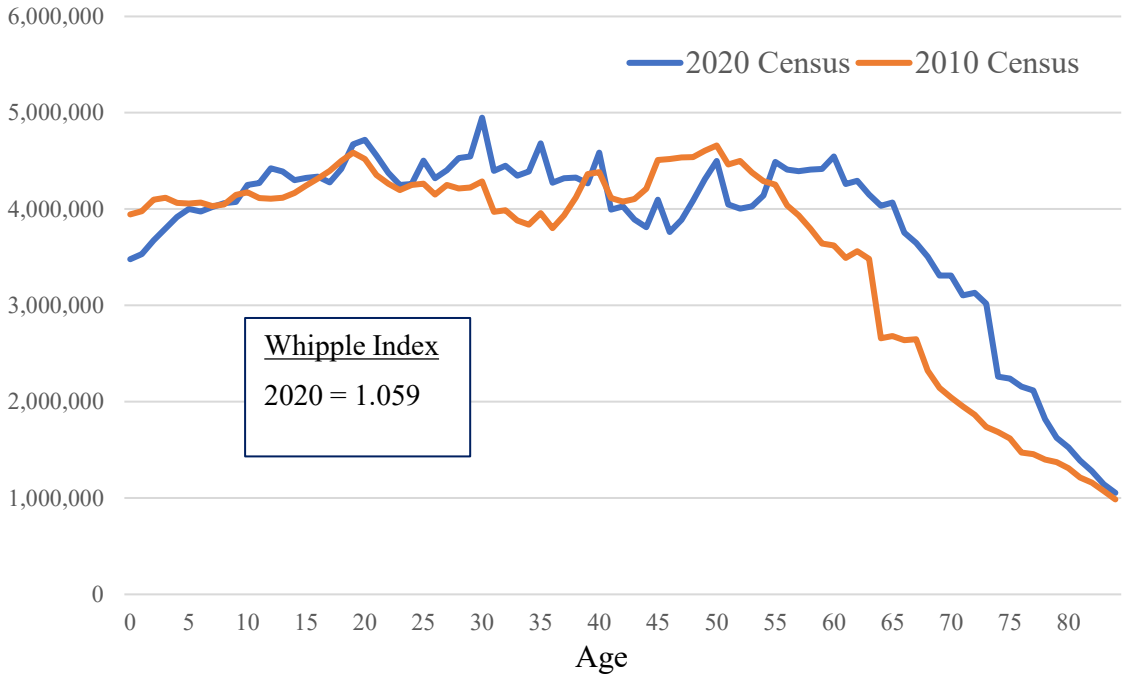
30. The age distribution of the population is a key indicator of the demographic quality of census. Figure V shows the age distribution for the total U.S. population in the 2020 and 2010 Censuses. We also report the Whipple Index which is a measure of heaping, or the tendency for ages to be clustered on values ending in 0 and 5 within the age distribution.

31. From 2010 to 2020, there was a significant decline in the size of the population in the youngest ages. This pattern is consistent with declines in fertility in the United States during that period.[3] In addition, the final 2010 Census data included a sizable number of babies who

[3] Osterman MJK, Hamilton BE, Martin JA, Driscoll AK, Valenzuela CP. Births: Final data for 2020. 2022. National Vital Statistics Reports; vol 70 no 17. Hyattsville, MD: National Center for Health Statistics. DOI: https://dx.doi.org/10.15620/cdc:112078..30

were born after April 1, 2010, which inflated the size of the youngest population.4 The college-aged population (18-24) is larger than other age groups, which may reflect the rise in international students in the United States in recent decades.

Figure V
Age Distribution for Total U.S. Population: 2020 Census and 2010 Census



Source: U.S. Census Bureau, 2020 Census special tabulation (DRB Approval Number: CBDRB-FY22-DSEP-001) and 2010 Census HDF file.

32. One interesting pattern that we see in the age distribution graph is the aging of the baby-boom cohorts over time. In 2010, there is a large increase relative to other ages in the population between the ages 46 and 64. These are the cohorts born from 1946 to 1964, which demographers refer to as the baby boom. The larger population size for these cohorts is evident in the 2020 Census results as well.

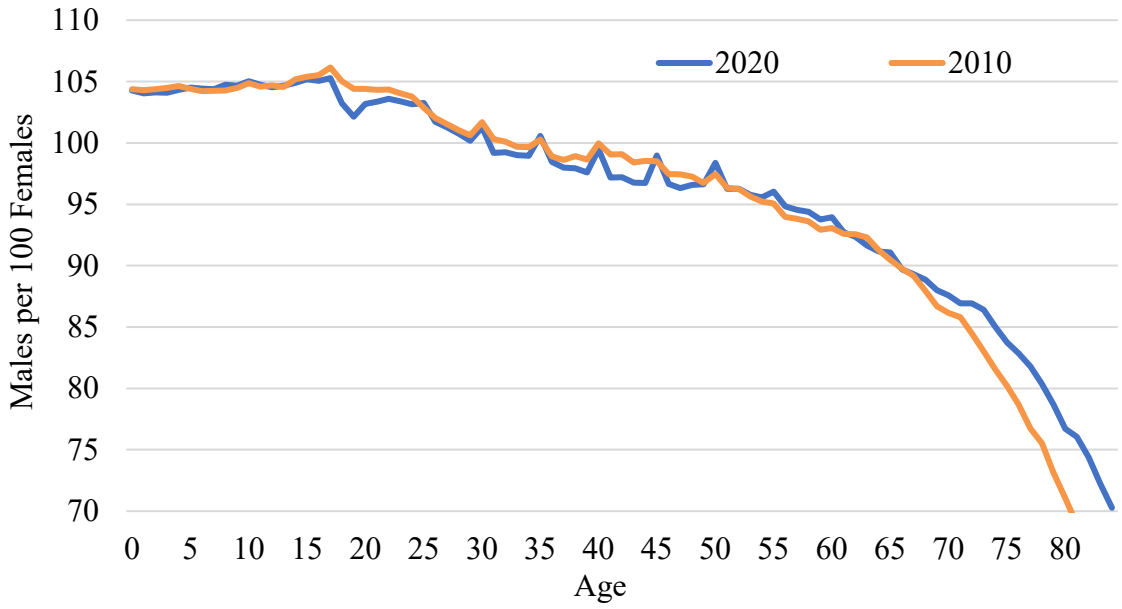
33. A pattern that we see in all census data is age heaping; however, age heaping in the 2020 Census is more pronounced than in 2010. We use the Whipple Index to quantify the amount of age heaping in the census results. The Whipple Index score for the age distribution in the 2010 Census indicates that the data were highly accurate. However, the Whipple Index score for the 2020 Census was higher, indicating that the data were now only fairly accurate.

[4] Howden, Lindsay. M. 2013. Research Note: Babies Born After Census Day: How the Census Bureau Addressed Dates of Birth After Census Day in the 2010 Census. *Population Research and Policy Review*, *32*(5), 791-801.

2. Sex ratios

34. Sex ratios report the number of males per 100 females in the population. At birth, the sex ratio is 105 males per 100 females, but over the life course this ratio can change because of sex differences in mortality, migration, and other factors.[5] Sex ratios could fluctuate in the decennial census data because of differential patterns in coverage as well as in the quality of age reporting.

Figure VI
Sex Ratios by Age: 2020 Census and 2010 Census



Source: U.S. Census Bureau, 2020 Census special tabulation (DRB Approval Number: CBDRB-FY22-DSEP-001) and 2010 and 2000 Census HDF files.

35. Figure VI shows the sex ratios by single year of age for the 2020 and 2010 Censuses. The sex ratios remain close to the 105 males per 100 females that are observed at birth until the late teens. In 2010, we see an increase in the number of males to females starting at age 17, but we do not see the same pattern in the 2020 Census. In fact, there is a sharp decline in the sex ratio at age 19 that increase slightly until age 24. It has been highlighted earlier that these are the typical college ages.

36. The graph also illustrates the impact of age heaping on the sex ratios. We should note that we also see age heaping in the sex ratios in the 2010 Census results, not just the 2020 Census. However, the pattern for 2020 is more distinct than what we see for the 2010 Census. In 2020, the sex ratios between the heaped ages drop lower than they did in 2010. This could

[5] Hesketh,Therese, and Zhu Wei Xing. 2006. Abnormal sex ratios in human populations: causes and consequences. *Proceedings of the National Academy of Sciences*, *103*(36), 13271-13275.

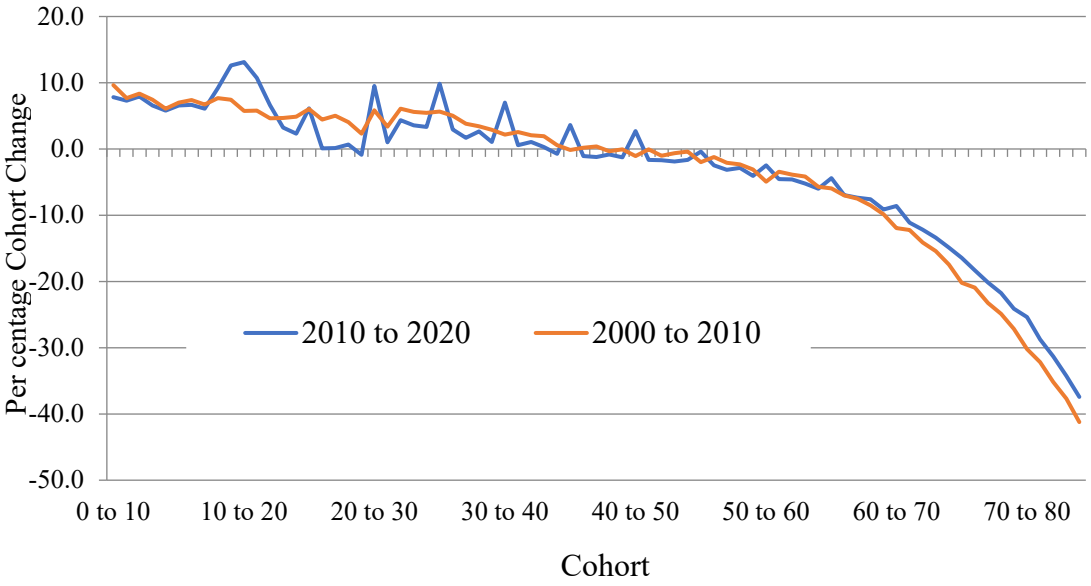
be related to the differential coverage by sex observed in the DA net coverage error estimates for working-age adults.

3. Cohort change

37. Cohort change analysis is a method that compares a specific birth cohort in one census to the same birth cohort in a later census. Cohorts change in predicable ways. Assuming that there is no coverage or measurement error, cohorts at the national level will decline because of mortality and emigration and increase because of immigration. Mortality and migration are both more likely to happen at certain ages; therefore, cohort change analysis can help us to understand the overall demographic quality of the census results.

38. We calculated the per cent change for birth cohorts from ages 10-84 in between the 2020 and 2010 Censuses and the 2010 and 2000 Censuses. For 2020, this measure is the percentage change for a birth cohort in the 2010 Census compared to that same birth cohort in the 2020 Census. Similarly, we calculated the per cent change for birth cohorts in the 2000 Census compared to the 2010 Census, see equation below.

Figure VII
Per cent Cohort Change from April 1, 2010 to April 1, 2020 and April 1, 2000 to April 1, 2010



Source: U.S. Census Bureau, 2020 Census special tabulation (DRB Approval Number: CBDRB-FY22-DSEP-001) and 2010 Census and 2000 Census HDF files.

$$Percent\ Cohort\ Change\ = 100\left(\frac{Census_{T2}\ Age^{x+10}\ -\ Census_{T1}\ Age^{x}}{Census\ _{T1}\ Age^{x}}\right)$$

39. An example using hypothetical data would be that if the number of 30-year-olds in the 2020 Census was 400,000 and the number of 20-year-olds in the 2010 Census was 375,000, then the percentage change for that cohort would be 6.7 per cent. This indicates that this population increased by 6.7 per cent from 2010 to 2020. This increase could have been caused by international migration or improved census coverage.

40. The analysis shows that from the 2000 to 2010 Censuses, cohort change was relatively stable with younger cohorts increasing in size over the decade, most likely from international migration, and older cohorts decreasing because of mortality (Figure VII). Cohort change between the 2010 and 2020 Censuses was much less stable with large spikes and drops. These irregular cohort aging patterns are most likely caused by the pronounced age heaping in the 2020 Census.

IV. Conclusions

41. In the United States, the results of the decennial census have many important uses including the apportionment of congressional seats between states and providing data for the redistricting of congressional districts. Additionally, the decennial census results play a key role in the federal statistical system. The census data are used as the base population for the postcensal estimates. The census results and the population estimates are used as controls for household surveys, denominators for vital rates, and demographic research.

42. Given the many challenges that the 2020 Census faced, there have been some concerns whether the data will be fit for use for its many uses. In this paper, we have focused on the demographic quality of the 2020 Census results. The analysis focused on estimates of coverage error, demographic benchmarks, and internal demographic consistency.

43. Overall, the finding show that there were some differences in the demographic quality of the 2020 Census compared to past decades. The coverage patterns revealed that similar groups who have been undercounted in the past were also undercounted in the 2020 Census, but the size of the undercounts may have been larger. Using demographic benchmarks, we showed that there were regional differences between the population estimates and the 2020 Census and that these differences were larger when we look at more detailed characteristics such as Hispanic origin.

44. Finally, the internal consistency of the age data may be problematic, because of age heaping in the 2020 Census results. Although the Whipple Index indicates that the data are still fairly accurate, when we used them to analyse sex ratios and the percentage of cohort-change, the 2020 Census results become somewhat uncertain. The Census Bureau will continue to examine the quality of the census and will determine whether the 2020 data will be used in the official population estimates over the next decade.