Specific Aims

The decennial census is the most important source of demographic information for studying health disparities across the United States (U.S.). Decennial counts, and population estimates and projections derived from it, are the denominators used to calculate incidence and prevalence rates of health conditions at the national, state, and sub-state level[1,2]. The accuracy of these rates depends on how close the counts of the event of interest are to the real value (numerator) and the population at risk (denominators). Rates could be biased in two ways. First, there could be under coverage issues that results in the undercount of the events of interests (numerator), and lower rates. Second, there could be error in the denominator that overestimates or underestimates the population at risk[3]. If the denominator overestimates the population, the rate will be lower than what it should be, and vice versa. The calculation and evaluation of these rates allows researchers and policymakers to monitor public health issues and allocate resources at the federal, state and local planning level. Ensuring that census tabulations, and products derived from it reflect the populations we are studying is paramount if we are to develop policies and interventions that assist in the improvement of health and well-being.

The advent of modern computational methods has brought with it concerns regarding the risk of reidentification of census respondents. This has prompted the U.S. Census Bureau to propose the adoption of a new DAS to decennial tabulations[5]. The new DAS, based on principles of differential privacy works by infusing noise into data through a top-down algorithm, beginning at the level of the nation then to states, and on down to census blocks. Although prior research has identified differences in the rates calculated using the original census tabulations and those produced under the proposed DAS[6], it has yet to be determined if the implementation of this system will affect our understanding of age-specific differences and whether this effect is homogenous across racial/ethnic groups. At the same time, no research has explored whether the changes in rates, resulting from the implementation of the proposed DAS, will affect our understanding of the factors associated with differences in mortality rates.

For the 2020 Census, the U.S. Census Bureau has announced the adoption of a disclosure avoidance system (DAS) that will sacrifice accuracy to protect the privacy of the population[4]. The primary objective of this proposal is to test the central hypothesis that the implementation of the proposed DAS will affect our understanding of health disparities in the United States. This will be accomplished through the following three specific aims:

Aim 1: To evaluate the differences in county-level age-specific mortality rates for the overall population and by racial/ethnic group by comparing rates. Age-Specific Mortality Rates will be calculated using the original 2010 census counts and those produced using the proposed DAS. County-level mortality rate ratios for each age-group, race/ethnicity combination will be calculated and used to determine if the implementation of the DAS will impact the accuracy of mortality rates differently.

Aim 2: Determine if the implementation of the proposed DAS will impact the analysis of trends and magnitude of differences in mortality. Mortality Rates and Age-Specific Mortality Rates will be calculated for the overall population and racial/ethnic groups for 2000 and for 2010 using original counts and those produced using the proposed DAS. We will compare whether the implementation of the proposed DAS will impact the tracking of mortality trends.

Aim 3: To evaluate if the implementation of the proposed DAS has any effect in the associations derived from empirical models. Mortality Rates and Age-Specific Mortality Rates (i.e., Infant Mortality Rates) for 2010 will be calculated using the population counts derived with the traditional disclosure avoidance techniques and the proposed DAS. Ordinary least square regression models (OLS) will be used to examine whether the associations between population composition and demographic and socioeconomic characteristics are impacted by the changes in mortality rates due to changes in their denominators.

This proposed research is innovative in two ways. It will be the first to investigate the impact of the changes in the DAS on age-specific indicators and analysis of trends by comparing rates for 2000 and 2010, an area that remains unaddressed. Next, it will explore potential changes in the associations derived from regression models due to the changes in the denominators. The knowledge generated from this project will contribute to the ongoing discussion about the adoption of new DAS and the potential consequences of this change. The expectation is that this project will expand our understanding on how health disparities research will be affected by the implementation of the proposed DAS. Finally, this research can inform the ongoing discussions at the U.S. Census Bureau about the implications of the implementation of the DAS for the practical uses of the census tabulation and its proposed expansion to other tabulations.

Research Strategy

A. SIGNIFICANCE

An estimated 17,000 publications per year are generated using either the decennial census counts or the American Community Survey (ACS)[1]. These data are also used in economic analyses, assessing changes in population size and composition, and are a crucial component of public health monitoring systems. In September 2018, the U.S. Census Bureau announced they would implement a new disclosure avoidance system (DAS) in 2020 census tabulations and future releases of other census products. The proposed DAS relies on differential privacy, which injects noise to the data protect respondent's privacy based on a series of invariants (elements that remain constant) and a privacy budget (the variation introduced in the counts). The noise infusion introduces variation in the data to reduce the probability of identifying individuals by combining census data with other publicly available information such as voter registration rolls or property records[6]. The initial run of the proposed DAS revealed that the population counts for small areas were significantly altered by its implementation produced counts that reduced the number of Alaska Natives and Native Americans, which the Census Bureau Chief Scientist categorized as unacceptable[7]. While the research community recognizes the need for improved privacy protections, users should be able to use the public data confident that their results reflect the reality of the place and population of interest.

In standard practices, data users, researchers, and other stakeholders access census tabulations through a platform such as Data Census (formerly American Factfinder) or the Integrated Public Use Microdata Series (IPUMS). Census Bureau officers have stated that if the data produced with the proposed DAS are unusable, research would need to be conducted through the Federal Statistical Research Data Centers (FSRDCs or RDCs)[1]. Thus, implementing the proposed DAS will difficult the study of population processes and assessment of health disparities endeavors usually undertaken by leveraging the publicly available information. An evaluation on this matter indicates that carrying out the totality of this research through the RDCs is not feasible due to these center's limited capacity and because most projects would be ineligible to be carried out through them[8]. Because of the implications of this implementation and the challenges that data users will encounter following the implementation of the proposed DAS it is imperative to assure that the data products achieve both the protection of privacy while still providing usable data that can allow for research to be carried out with confidence in the results. If the rates produce are misguided, so will be the decisions taken based on them.

Emergent evidence indicates that the implementation of the proposed DAS will affect health indicators across the U.S., with more variation observed for the rates produced for racial/ethnic minorities[5,9]. A comparison of mortality rates produced for counties with small population size and a lower degree of urbanization were more variable[5] when the population counts produced with the proposed DAS were used as a denominator. Similarly, a simulation of an event with comparable incidence and fatality as the COVID-19 pandemic concluded that the proposed DAS could distort our understanding of mortality associated with the event and in some cases the differences in rates exceeded 100%[9]. The differences found in this simulation were present for both sex- and age-specific monitoring as well as for racial/ethnic minorities. These differences are the direct result in the changes in denominators produced by the implementation of the DAS.

Although there is increasing evidence indicating the implementation of the proposed DAS will affect our understanding of health disparities across the US[5,9,10], no knowledge exists about how it will affect our understanding of patterns and trends in age-specific mortality and by race/ethnicity. There is also no information about the effect the implementation will have in the evaluation of the determinants of mortality. Because age and racial/ethnic composition varies across the United States, there is differential risk in some groups being identified as "at-risk" of reidentification and thus have noise injected to make the population more homogeneous. Simply said, some areas or population groups may be more affected by the implementation of the proposed DAS than others may. An assessment of changes in mortality for the overall population and mortality rates for the three major racial/ethnic groups indicated that counts for minorities living in less urbanized/populated areas are more likely to have noise infused, resulting in inaccurate mortality rates[5]. Within the United States, focusing on a combination of characteristics such as school-aged Hispanics (age and Ethnicity) or women in reproductive ages who are non-Hispanic black (sex, age and race/ethnicity) would increase the likelihood of having noise injected into the population count. **Thus, the distortion in rates caused by the implementation of the proposed DAS may differ when we consider populations of a particular age-group stratifying by race/ethnicity.**

The scientific premise of the proposed project is that the implementation of the new DAS will affect our understanding of age-specific health differences (i.e., mortality), and the factors associated with mortality across the US. Only three studies, to our knowledge, have been published thus far that examine how the implementation of differential privacy will affect our understanding of health disparities in the US. The first study on this matter used the 2010 decennial counts produced with the proposed differential privacy DAS and traditional techniques, calculated county-level mortality rates for the overall population and the three major racial/ethnic groups. The study concluded that the implementation of proposed DAS produced changes in population counts for racial/ethnic minorities in small areas and less urban settings, significantly altering knowledge about health disparities in mortality[5]. The second study compared census-tract premature mortality - *deaths before age 65* - using three population counts as denominators: 1) the 2010 counts produced under the proposed DAS and 2) traditional system, and the 2008-2012 5 year ACS estimates[10]. The results are consistent with those of the first study where small variation is observed in the mortality rates produced for the overall population. Still, the analysis does not go into any other population subgroups (i.e., race/ethnicity, age-groups, etc.), which was where substantial variation was observed in the first one. The third study was a simulation an event comparable to the COVID-19 pandemic that focused on age and race/ethnicity distortions. This study applied COVID-19 fatality curves to 2010 population counts produced under the proposed and traditional privacy systems to assess the distortion introduced by implementing the proposed DAS in monitoring a similar event. Substantial variation was observed in the fatality rates for racial/ethnic minorities and every age group with differential effects observed for areas with smaller populations. Dr. Santos, the Principal Investigator, has been a coauthor of two of these studies. The proposed project seeks to elucidate the extent to which our understanding of health disparities may be further distorted by focusing on variation in age-specific mortality indicators and race/ethnicity.

The proposed project constitutes a significant advance over prior studies that only examine county-level period-specific indicators and thus do not provide insights into variation in age-specific indicators or analyses of trends in these indicators. The proposed study leverages data from the demonstration product, age group and racial/ethnic counts, to determine if our understanding of mortality is affected when focusing on specific stages of the life course while considering racial/ethnic diversity. It will also help elucidate if the implementation of the proposed DAS will affect our understanding of the determinants of ASMR differences at the national level and inform ongoing discussions regarding the implementation of the proposed DAS to census products.

B. INNOVATION

The study includes several innovations over prior research on this topic.

First, it proposes a comprehensive analysis of how implementing differential privacy will affect our understanding of age-specific and racial/ethnic disparities in health by focusing on mortality (Aim 1). The proposed study has the advantage of focusing on the changes in ASMRs, which are crucial to understanding emerging/ongoing transformation in health of the nation[11–13]. So far, research has only explored the effect of the implementation in county-level counts. Second, it compares conclusions derived from 2000-2010 comparisons in ASMRs (Aim 2). Existing studies only focus on the variation introduced by the changes in 2010 counts to period-specific indicators. The proposed analysis expands this by incorporating 2000 indicators and studying if the analysis of trends would change based on the implementation of differential privacy to decennial counts. Third, mortality rates produced using both sets of denominators are linked with county-level demographic and socioeconomic characteristics. The proposed analysis moves beyond the descriptive approach found in the totality of studies on this subject. It proposes to study if the changes due to the implementation of differential privacy will have any effect in the empirical associations derived from regression-based techniques (Aim 3). **Pursuing these aims will allow an opportunity to determine the extent to which the implementation of the proposed DAS will introduce variation to decennial counts unequally by race/ethnicity and/or age groups possibly hindering our understanding of health disparities in the United States.**

C. APPROACH

Preliminary Studies. Dr. Alexis Santos, the PI on the project, is Assistant Professor of Human Development and Family Studies at the Pennsylvania State University. He is also a research associate of Penn State's Population Research Institute (PRI), an NICHD-funded population center that provides core infrastructure support in grant management, information resources, computer hardware and software, programming, and statistical analysis. Over the last two years, he has presented and published research about the implications of implementing the proposed DAS for the analyses of health disparities in the US. His presentation on the consequences for the calculation of mortality rates was presented at a workshop at the

National Academies of Sciences, Engineering and Medicine[14]. A 2020 *Proceedings of the National Academy of Sciences* piece lead-authored by Santos summarizes the implications of the initially proposed DAS to the analysis of mortality disparities in the United States[5] with emphasis in race/ethnicity and across the Rural/Urban Continuum. A 2021 *Socius* article co-authored by Santos summarizes how the implementation of the proposed DAS will distort the monitoring of a pandemic comparable to the COVID-19 pandemic[9]. These analyses give him a high degree of familiarity with the datasets featured in the proposed study.

Data Sources. The proposed study uses five publicly available datasets. First, 2010 death counts come from the National Vital Statistics System[15]. These will constitute the numerators for the rates being analyzed in each Aim of the proposed project. Second, the 2010 Census demonstration products include the population tabulations produced under the traditional and proposed DAS[16]. On February 3, 2021 the U.S. Census Bureau reported that they will release a final set of demonstration products under a set of invariants that have been already established and a final "privacy budget" that will constitute the amount of allowable noise that will be infused in the population counts. This demonstration product will be used conduct the proposed analyses. These are the denominators that will be used to calculate and analyze changes in ASMR for 2010 (Aim 1). Third, we will use the 2000 decennial tabulations for every county of the US will be used to calculate county-level ASMR for 2000. Death counts for 200 will also come from the National Vital Statistics System. A comparison of the ASMR for 2000 and 2010 will allow us to understand whether implementing the proposed DAS will affect our understanding of mortality trends (Aim 2). Fourth, we will use the 2003 Rural-Urban Continuum Codes (RUCC) to produce a county-level indicator of metropolitan classification[17]. Finally, the ACS provides county-level, demographic and socioeconomic characteristics, industrial structure, employment, and family structure information required to assess whether the changes in mortality rates resulting from the implementation of the proposed DAS will impact the empirical associations derived from regression models (Aim 3). All analyses will be conducted using R and RStudio, and a public repository will contain data and code required to replicate the analyses.

Measures. ***Mortality Rates.*** The main variable of interest is mortality rates. Two sets of mortality rates will be produced for every county of the US. Age-specific death counts by age-groups (*j*) will be calculated using death counts obtained from the CDC Wonder as the numerator. The first set of ASMRs will use the 2010 decennial counts as denominators ($M_{1,i}$). These are the ASMRs that better illustrate the state of mortality in 2010. These counts were produced under the traditional disclosure avoidance methods. The second set of ASMRs will be calculated using the 2010 counts produced under the proposed DAS ($M_{2,i}$). Because the death counts used in these calculations remain constant, any difference in county-level mortality rates are produced by implementing the proposed DAS.

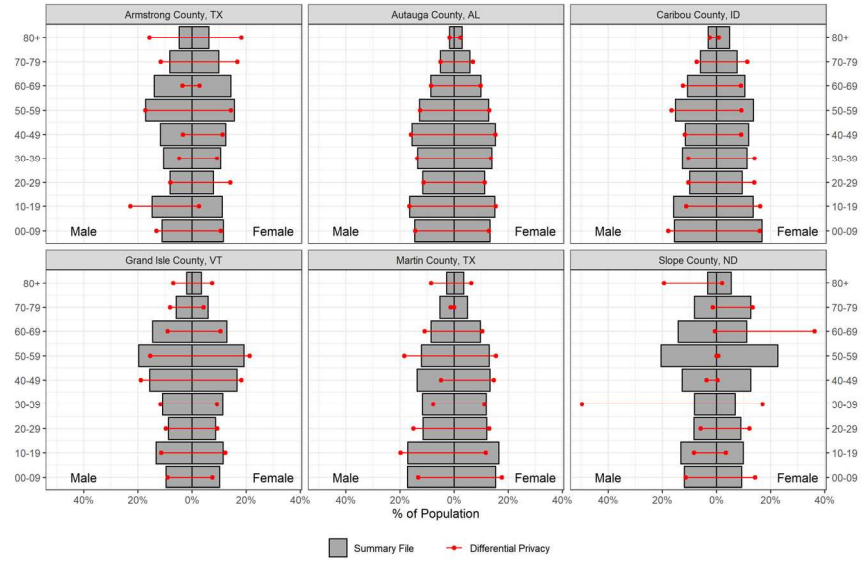

Figure 1. Population Pyramids produced with the 2010 decennial counts (gray) and 2010 counts produced with differential privacy (red). Supplement to Hauer and Santos (2021).

Mortality Rate Ratios. Differences in mortality rates are better captured by the calculation of Mortality Rate Ratios (MRRs). The MRRs are calculated by dividing M_1 by M_2 ($MRR=M_{1,j}/M_{2,j}*100$) and indicate whether M_2 was higher than ($MRR < 100$), the same as ($MRR=100$), or lower than ($MRR > 100$) M_1. The distance from 100 indicates the magnitude in the differences in mortality rates produce by implementing the proposed DAS. Comparisons will be pursued for each county-race/ethnicity-age group (*j*) combination to explore better the implications of the implementation of the proposed DAS in our understanding of mortality disparities.

Age Groups. The demonstration products that implement different iterations of the differential privacy algorithm include population counts using two categorizations. First, Table P12 - Sex by Age of the summary file includes population counts by five-year age-groups (i.e., Under 5 years, 5 to 9 years, 10-14 years, etc.). Second, Table P14 includes county-level counts

for the population under 20 years categorized by single-age (i.e. Under 1 year, 1 year, 2 years, etc.). Table P14 will be used to produce county-level estimates of infant mortality. These tables will be used to calculate ASMRs for each group to complete the analyses proposed in Aims 1-2.

Race/Ethnicity. The demonstration products also include information about age by race/ethnicity using the five-year age-groups categorizations consistent with those contained in Table P12. Population counts by age and race/ethnicity are available for people who are: 1) White alone (Table P12A), 2) Black or African American alone (Table P12B), 3) American Indian and Alaska Native Alone (Table P12C), 4) Asian alone (Table P12D), 4) Native Hawaiian and other Pacific Islander Alone (Table 12E), 5) Some other race alone (Table 12F), 6) Two or More Races (Table 12G), 7) White alone, not Hispanic or Latino (Table 12I) and 8) Hispanic or Latino (Table H9H). The population counts contained in these tables will constitute the denominators employed to calculate the mortality rates that are crucial for accomplishing the specific aims of the proposed project. Similar tables are available in the 2000 Summary File, which allows for the assessment of trends as proposed in Aim 2.

Covariates. We will produce county-level demographic characteristics, industrial structure, poverty, and unemployment rates. *Demographic characteristics* will be calculated as percent: 1) NH-Black, 2) Hispanic, 3) Less than 18 and 3b. aged 65 and older, 4) female-headed households, and 5) adult population with less than a High School diploma. We will measure *Industrial Structure* by calculating the percent of the population that works in 1) manufacturing, 2) extractive activities, 3) services, and the 4) government/public administration. These measures will be constructed using the American Community Survey (2008-2012). These controls are consistent with the well-established approaches to study county-level differences of numerous socioeconomic, health and mortality outcomes[2,18–22]. Differences in mortality rates are observed by metropolitan classification[23–25]. We will also account for these differences within the empirical models using the 2003 USDA Urban/Rural Continuum Codes[17]. The RUCC codes allows for the classification of counties into: metropolitan (RUCC in 1-3) and nonmetropolitan (RUCC in 4-9). These are key components for the analysis proposed in Aim 3.

Analytic Plan

Aim 1. Differences in ASMR due to the implementation of the proposed DAS. Changes in the population counts due to the implementation of the proposed DAS result from changes in the population composition. Changes in population composition (i.e. age, age-sex composition, etc.) are bound to impact the mortality rates produced with them. Figure 2, presents the changes in Infant Mortality Rates for the US in 2010 resulting from the implementation of the proposed DAS. We will first compare the changes in mortality rates by major age-groups (Panel A, Figure 2) and will calculate MRRs to ascertain the magnitude of changes in mortality attributable to the implementation of the proposed DAS. MRRs will enable us to analyze Metro/Non-Metro differences in the magnitude of these changes, and whether these changes are associated with population size (Panel B, Figure 2). Our next comparison will be to determine the proportion of counties in every state, that experience increases above 5% and 10% thresholds to illustrate how the proposed DAS will differently impact states across the nation. We anticipate that the more diverse states will be more likely to experienced more (count) and higher (magnitude) displacement in mortality rates resulting from implementing the proposed DAS.

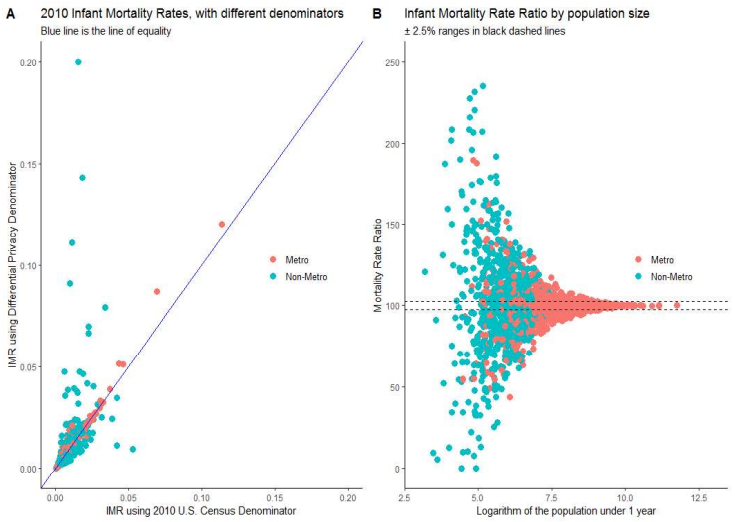

Figure 2: Panel A shows the infant mortality rates and includes a reference line (in blue) where the points would fall if the rates were the same. If the point is above the line of equality the mortality rate produced using the DP denominator is higher than the one produced using the SF denominator. **Panel B** shows the infant mortality rate ratio and ± 2.5% range, equivalent to 5% error.

Aim 2. Impacts in the analysis of trends and magnitude in differences. A key aspect of the calculation of rates is comparability across time. A change in the privacy disclosure algorithm could impact our ability to track the evolution of rates produced with decennial counts and products derived from them, such as population estimates. Until 2020, data products employed a combination of record-swapping, item imputation, whole household imputation, rounding, and top-

and bottom-coding to protect the privacy of respondents[26]. The changes in denominators[27] and in the resulting mortality rates are likely to impact our assessment of ASMR trends and by race/ethnicity. Figure 3 presents the percent population change by race/ethnicity using 2010 counts produced under the traditional (x-axis) and proposed disclosure avoidance system (y-axis) and by county-level metro/non-metro classification (color). Substantial variation is observed in population change for both non-Hispanic Blacks and Hispanics. We will first compare population ASMRs for the overall population and race/ethnicity (see Measures). In the next step we will study whether differences in trends and magnitude vary by population size and metro/non-metro classification. We anticipate that smaller areas and non-metropolitan areas will have higher variation in population counts for racial/ethnic minorities by age group; resulting in directly proportional variations in ASMRs.

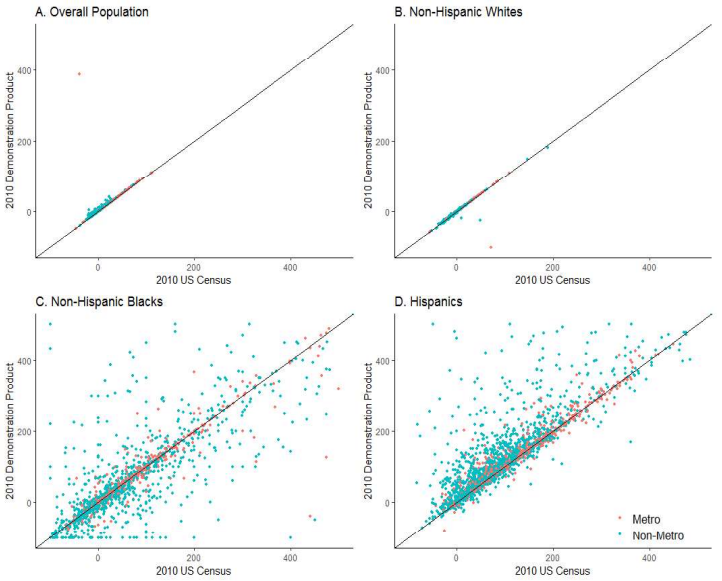

Figure 3. Percent Population Change 2000-2010 comparing 2010 counts produced under the traditional disclosure avoidance systems (x-axis) and the 2010 counts produced under proposed DAS (y-axis) colored by Metropolitan/Non-Metropolitan classification.

Aim 3. Impact in empirical associations. Regression models will be fit to assess the determinants of county-level mortality as established in the extant demographic and epidemiological literature. Beyond documenting differences in the associations derived from empirical models of mortality, we intend to explore whether the variation in these associations is found by race/ethnicity and age-groups via the estimation of linear regression models. We performed a preliminary assessment of differences in associations using denominators from the traditional and initial run of the proposed DAS. The results were limited to mortality rates for the overall population and indicated that the coefficients were comparable[28]. To date this analysis has not been performed for age-specific mortality rates and/or by race/ethnicity. The working hypothesis is that the changes in mortality rates resulting from implementing the proposed DAS will distort the coefficients derived from regression models.

Analysis. We will fit OLS regression models to study is the implementation of the proposed DAS causes differences in the assessment of the determinants of infant, adult, and older adult mortality. Using the mortality rates produced in Aim 1, we will study whether the coefficients derived from OLS models rates calculated using the denominators from 2010 counts and synthetic ones produced using the proposed DAS. Models will also be fit by race/ethnicity for non-Hispanic whites, non-Hispanic blacks, Hispanics, and non-Hispanic others for each outcome (4 race/ethnicity * n age-groups * 2 denominators=8 *n models) to assess whether the implementation of the proposed DAS will differently affect the determinants of mortality by race/ethnicity. In our analysis, n represents the number of age-groups where the maximum number of observations are attained due to the suppression of data in the CDC Wonder and Natality count tabulations. The minimum number of models will be 24 where rates are calculate for: infant mortality (Under 1 year), adults (24-64 years) and older adult (65 years or older). When sufficient data is available, we will perform analysis on other racial/ethnic groups described in the *Measures* section.

Modelling Approach. After determining the number of models to be calculated. We will estimate OLS regression models to assess the association of county-level characteristics and age-specific mortality rates. Coefficients derived from each series of models will be compared to determine in the association, direction, magnitude and significance levels change due to implementing the proposed DAS. For each age-race/ethnicity combination, the first model will have mortality rates calculated using 2010 counts (denominator) as the outcome. The second model will have mortality rates calculated using the synthetic 2010 counts produced using the proposed DAS as the outcome. Each model will include the covariates described in the *Measures* section. We will calculate Chi-Square scores to compare coefficients derived from each pair of the empirical models. We will perform assessments of model fit by examining the following indicators: R-squared and Adjusted R-squared, F-test, and Variance Inflation Fact (VIF) will be calculated for each coefficient to determine if multicollinearity is present within the empirical models.

Potential Problems and Alternative Strategies

Some potential issues that may arise concerning the data analysis. First, there will likely be a certain number of counties for which death counts are not shared due to privacy issues. We will employ two strategies to retain the largest number of counties in the analysis. The first strategy will be requesting death counts from the CDC Wonder using different age-groups categorizations such as a) Younger than 19, b) 20-64 Adults and c) Older Adults 65+. Adjustments will also be done for the denominators. This will allow for less suppression of the numerators, which are one of the two components required for assessing changes in mortality rates and the calculation of ASMRs. The second strategy consists of requesting death counts for three or five years with 2010 as the center point (2009-2011 or 2008-2012) and using the average as the numerator in the calculation of the rates. This method is employed in the estimation of state-level life tables and provides robust estimates of mortality rates and life expectancy[29]. Another issue that may arise is the publication of new demonstration products by the US Census Bureau revising the "*privacy budget*" specifications. While the specification of a new "*privacy budget"* has the potential of shifting some of the population counts, previous revisions have not altered the conclusion derived from the initial analyses in a significant way. As of February 2021, the U.S. Census Bureau has decided on the number of counts that remain invariant (counts that are held constant in the proposed DAS) and is finishing the allocation of the privacy budget in the first semester of 2021. Based in this timeline, the final 2010 demonstration product will be available at the beginning of the proposed timeline.

Timetable. The first half of year 1 will be devoted to data harmonization. During this period, we will also compare the different vintages of the demonstration products to assess differences in age-sex structures for every county in the US and by race/ethnicity (Aim 1). These comparisons and descriptive analyses for all other aims will be conducted during the second half of year 1. In the first half of year 2, we will to explore whether the proposed changes in the DAS affects the analysis of trends by comparing 2000 mortality rates with the corresponding rates for 2010 produced using the original 2010 tabulations and those produced with the proposed DAS (Aim 2). The second half of year 2, will be devoted to Aim 3. We will use the mortality rates calculated and used in Aims 1-2 to study whether the changes in mortality due to implementing the proposed DAS alters the coefficients derived from county-level regression models.

The preparation of manuscripts will begin late in year 1 and continue through the project's end. Drafts of these manuscripts will be submitted to appropriate conferences (e.g. Population Association of America, American Public Health Association, Society of Epidemiological Research, Applied Demography Conference), then revised for journal review and eventual publication.

Tasks and Aims	Months 1-6	Months 7-12	Months 13-18	Months 19-24
Data Preparation				
Descriptive Analyses for Aims 1-3				
Analyses for Aim 2				
Analyses for Aim 3				
Manuscript preparation				
Conference Presentations				