Project Summary
Rural areas in the United States (U.S.) have exhibited higher mortality rates than urban areas since the late 1990s, a pattern known as the rural mortality penalty. Recent research has found that the rural mortality penalty continues growing due to mortality associated with preventable causes (metabolic and cardiovascular causes, alcohol use, and mental health). The expansion of Medicaid adopted by many states in the U.S. had the potential to reduce death due to these and other causes by facilitating access to healthcare to people who were not eligible under previous eligibility thresholds. While some state in the nation adopted this expansion, a process that started in 2014, others rejected it. While the adoption/rejection of this expansion is well-documented, little is known about the role the adoption of this policy at the state level impacted well-established demographic phenomenon such as the rural mortality penalty. This project requests access to restricted data to produce mortality rates for the population aged 19-64, by sex and by race/ethnicity to conduct a novel analysis of the differences observed in the rural mortality penalty employing a difference-in-difference design. The project evaluate whether the Medicaid expansion impacted the rural mortality penalty emphasizing the overall population, and disparities by sex and race/ethnicity. The project will also be the first to explore whether the COVID-19 pandemic impacted rural/urban mortality dynamics based on state-level adoption of the expansion of Medicaid by 2020. The analytic approach will combine formal and mathematical demographic methods with novel statistical models to evaluate the impact of the expansion of Medicaid in rural/urban mortality dynamics. Findings from this project will illustrate the role that state-level policies have in shaping diverging or congruent trajectories in mortality and in the face of the ongoing COVID-19 pandemic.

Project Narrative

The purpose of this project is to (1) estimate age-specific mortality rates for rural and urban areas by state, Medicaid expansion status, sex, and race/ethnicity (2) to study the effect of Medicaid expansion on rural mortality penalty using data from 1999 until 2019, and (3) to determine whether states that expanded Medicaid witnessed differential mortality increases during the first two years of the COVID-19 pandemic (2020 and 2021). This project will use restricted NCHS mortality data, census population estimates, rural-urban continuum codes, standardization techniques, and regression-based research design to examine the effect of Medicaid expansion on rural and urban age-specific mortality rates for the population aged 19-64, by sex, and by race/ethnicity. The project will also evaluate the disparities in mortality observed in the first two years of the COVID-19 pandemic at the intersection of residential context and state policies.

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Specific Aims

This two-year exploratory/developmental project will initiate research on evaluating whether Medicaid expansion impacted rural-urban disparities in mortality in the United States (US). Rural areas in the US have exhibited higher mortality rates than urban areas since the late 1990s[1], a pattern known as the rural mortality penalty[1]. More recent work shows lifespan disparities across more nuanced categories of the rural-urban continuum in the US, underscoring the role that place has in shaping disparities within the nation[2]. Furthermore, there is substantial variation in the rural mortality penalty when evaluated by race/ethnicity[3] and at the intersection of race/ethnicity and region of residence[4]. The rural mortality penalty can be attributed to a lack of health insurance coverage, as well as socioeconomic deprivation and health care supply[5]. Medicaid expansion – an effort to significantly increase access to health insurance among low-income working age adults – has been linked to declining mortality[6] . However, the potential role of Medicaid expansion in shaping the rural mortality penalty remains unaddressed. Given that rural working age adults (i.e. those targeted in expansion) were disproportionately clustered in states that did not initially expand Medicaid[7], expansion may have exacerbated the rural mortality penalty.

Consistent with the goals of the R21 mechanism, the current project represents a crucial first step toward the goal of understanding how state-level policies interact with residential contexts to shape variation in the rural mortality penalty in the US. In line with the National Institute of Aging's objective of considering the role of place in the aging processes—taking into account geography in studies of late-life disability and mortality trends —the current proposal takes an innovative approach by also considering how state-level approaches to expansion of a healthcare policy influence spatial disparities in mortality. A major strength of the proposed analytic plan is the use of restricted death records to examine the intersection of sex and race and ethnicity with a nuanced categorization of rural-urban status. In addition, we use a nuanced measure of Medicaid expansion – the state-level income eligibility thresholds to account for wide variation among those states that have and have not expanded Medicaid. This project requests support to use restricted vital statistics mortality files to estimate age-specific mortality rates for rural and urban areas by state between 1999 and 2021 for the population aged 19-64, by sex, and by race/ethnicity. These rates will be used to evaluate whether the expansion of Medicaid resulted in changes in the rural mortality penalty between 1999 and 2019, and for 2020-2021 (COVID-19 pandemic). This will be accomplished by addressing the following specific aims:

Aim 1. Estimate age-specific mortality rates for rural and urban areas by state and by degree of Medicaid expansion for the population aged 19-64, by sex, and by race/ethnicity, 1999-2021. Public data available through CDC Wonder does not include county-level age-specific mortality rates by sex, race/ethnicity, and rural-urban status for each state in order to protect decedent's privacy. Moreover, the detailed urbanization codes in the publicly available data restricts user's ability to rely on other categorizations. The project will address these limitations by accessing restricted records and producing county-level age-specific mortality rates for rural and urban areas for the total population, by sex, and by race/ethnicity for the 50 states and the District of Columbia for the 1999-2021 period.

Aim 2. Determine if and how states that expanded Medicaid observed changes in their age-adjusted mortality rates, and on their rural mortality penalty (1999-2019). Using a difference-in-difference research design, we will determine how the extent of Medicaid expansion shaped observed changes in rural and urban age-adjusted mortality rates (for the population aged 19-64, by sex, and by race/ethnicity). We will test whether changes occurred in (1) urban areas, (2) rural non-remote areas and rural remote areas, and (3) mortality rate ratios comparing rural areas with urban areas.

Aim 3. Determine if and how the rural mortality penalty changed during the COVID-19 period (2020-2021) based on Medicaid Expansion by 2020. The mortality impact of the COVID-19 pandemic in the US has been greater in rural counties[8,9]. We will analyze data from 2020 and 2021 to describe whether there are differences in the rural mortality penalty based on adoption of the Medicaid expansion by 2020 for the population 19-64, by sex, and by race/ethnicity.

The principal investigator has a background in applied demography and extensive experience using demographic techniques and producing population estimates relying on mortality records and Census population data. The research team is composed of population health scientists with interdisciplinary training and expertise. The project will use official data for state death and population counts to calculate age-specific mortality rates for the 50 states and the District of Columbia for the population aged 19-64, by sex, and by race/ethnicity for the period of interest. This project is <u>innovative</u> in both scope and methodological applications, employing a difference-in-difference research design to an unaddressed area in mortality research. Findings from the project can yield insights into the consequences of unequal adoption of Medicaid expansion across the US, emphasizing the role that state-level health policies have in shaping population-level outcomes. It will also determine if and how this expansion shaped COVID-19 mortality dynamics. The <u>expectation</u> is that this project will expand our understanding on how rural-urban and state-level disparities may be shaped by the adoption of federal policies aimed at mitigating and reducing health disparities across the nation.

Research Strategy

A. SIGNIFICANCE

According to the U.S. Census, approximately 46 million U.S. residents live in rural areas, accounting for 14% of the total population. Research has consistently shown that rural residents exhibit worse health outcomes than their urban counterparts, with higher rates of population decline[10], under employment[11] and declining healthcare access[12] being part of the complex set of structural and systematic factors that shape this disparity[13]. Importantly, higher rates of uninsurance in rural areas is driven by the reduced labor force opportunities, which are more likely to be precarious, part-time, and with small employers who may not provide employer sponsored coverage[14]. Lack of health insurance along with socioeconomic deprivation and physician shortages, largely explain the rural mortality penalty[5]. Medicaid expansion provided an opportunity to address this gap, by increasing access to state-subsidized health insurance for all working age adults (regardless of if they had children) who earned less than 138 percent of the federal poverty line (FPL). However, the 2012 Supreme Court ruling in *National Federation of Independent Business v. Seblius* resulted in Medicaid expansion being left optional for states. Initially, nearly half of states chose not to expand. As a result, insurance coverage rates improved substantially in Medicaid expansion states[14], however, Figure 1 shows that rural working age adults were disproportionately clustered in the states that did not initially expand Medicaid[7]. However, no previous research has examined if and how the rural mortality penalty was affected differently between states that did and did not expand Medicaid. The results have the potential to inform the ongoing discussion around health insurance access in and across the U.S. and efforts to address the persistent overall rural mortality penalty.

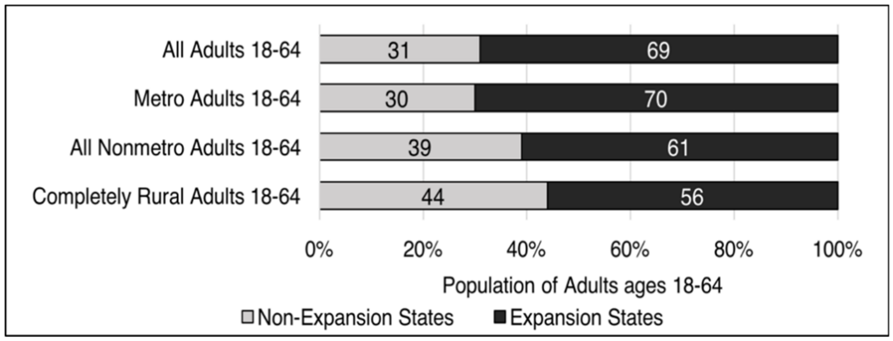

Figure 1. The Distribution of Adults Age 18-64 by Medicaid Expansion Status
Source: Rhubart, Monnat, Jensen and Pendergrast (2021).

In addition, previous research has pointed to important racial/ethnic and sex differences in the rural mortality penalty[15–17]. In fact, a manuscript under review by the PI and a Co-I is one of the first to examine racial and ethnic differences in the rural mortality penalty beyond mere white and black categories[4,15,17,18]. The findings show that the rural mortality penalty varies substantially by race and ethnicity. Understanding how Medicaid expansion has shaped the rural mortality penalty differently for different racial and ethnic groups is critical for describing how state-level policy decisions have the potential to shape rural mortality penalties differently across historically marginalized populations. Moreover, while research on the rural mortality penalty has started to emphasize variation by race/ethnicity; little is known about whether these patterns vary by sex. An article published in 2020 approached this issue using a decomposition approach showing a substantial growth in the rural mortality penalty driven by smaller declines in mortality from cancer and cardiovascular diseases, and large increases in metabolic/respiratory diseases, suicide, alcohol and mental health related deaths[19]. In the US, mortality differences by sex are well-established with men having higher mortality rates than women[20]. This pattern was also observed across the US during the COVID-19 pandemic[21,22]. While evidence continues suggesting that women have lower mortality rates than men, there is a gap in scholarship concerning the trends in the rural mortality penalty by sex, and whether Medicaid expansion has influenced mortality disparities by sex. The proposed research will address this gap in extant scholarship through the (1) careful examination of rural and urban mortality trends by sex, at the intersection of sex and race/ethnicity, and considering the role that the Medicaid expansion had on these patterns; and (2) by exploring patterns by sex during 2020 and 2021 (first two years of the COVID-19 pandemic).

The proposed project constitutes a significant advancement over prior studies that only examine the impact of Medicaid expansion on mortality among selected decedents (i.e. maternal mortality[23]) or for working age adults without accounting for rural-urban residence[6]. The proposed study will expand our understanding of the interaction between state policies and the rural mortality penalty. The proposed study leverages data from the restricted vital records, and publicly available information to determine if well-established place-based mortality dynamics have been altered by the adoption and implementation of Medicaid expansion. It will determine if and how Medicaid expansion affects subpopulations (i.e. sex and race/ethnicity) differently. In addition, it will help elucidate if rural and urban COVID-19 mortality dynamics vary based on the Medicaid expansion and inform growing research on rural-urban disparities in population health and aging[13].

B. INNOVATION

The study includes several innovations over prior research on this topic. First, it is <u>innovative in subject area</u> as it proposes a comprehensive analysis of how the rural mortality penalty has been shaped by the expansion of Medicaid and examining whether these dynamics were present during the COVID-19 period. The proposed study has the advantage of focusing on age-specific mortality rates overall and by sex, race, and ethnicity in urban, rural non-remote, and rural remote areas, which may have been differently impacted by the early adoption of the Medicaid expansion (Aim 1). While research has only explored the effect of Medicaid expansion on access to health insurance[14] as well as mortality rates overall[6] and for specific sub-populations (e.g. maternal mortality[23]), none of this prior work has examined the effect of Medicaid expansion on the rural mortality penalty[16,24]. Thus, it will enhance understanding of rural-urban mortality disparities in the US. Second, there is substantial variation in access to Medicaid in states that did and did not expand Medicaid because of variable income eligibility thresholds used. We improve upon previous studies that have used dichotomous measures, to treat Medicaid expansion not only as a continuous measure, but also as a process of changing income eligibility thresholds rather than a point in time. Third, it is innovative in methods as it employs a difference-in-difference design allowing for the testing of the effect of Medicaid expansion while accounting for past trends (Aim 2). This is possible because the dates in which states implemented Medicaid expansion are well-documented and these dates are publicly available. Fourth, it is innovative in scope as it proposes a careful examination of the rural mortality penalty during the first two years of the COVID-19 pandemic (Aim 3). **Pursuing these aims will determine if and how Medicaid expansion has influenced rural-urban mortality disparities in the United States.** The project will also foster a unique interdisciplinary collaboration within the College of Health and Human Development at Penn State, joining faculty who specialize in mortality and place-based disparities, and time-series analyses. This two-year developmental project has the potential for integrating these different lines of research in additional work to be proposed in a future grant.

C. APPROACH

Preliminary Studies. Dr. Alexis R. Santos, the PI on the project, is Assistant Professor of Human Development and Family Studies at the Pennsylvania State University (Penn State). Over the last five years, he has presented and published research about mortality estimates[25,26], analysis of health, population and mortality trends[27–29], and led discussions of the use of vital statistics records in conjunction to census products[30,31]. In this line of work he has emphasized the utility of newly released census data to study disparities across the rural-urban continuum[32,33]. His research on accurate production of mortality estimates using census data is currently funded by the NICHD (R03-HD107173). In addition, he has been funded by a Diversity Supplement through the NIA-funded Interdisciplinary Network for Rural Population Health and Aging (2021-2023, R24-AG065159) to study rural-urban disparities in stress and mortality. Dr. Danielle C. Rhubart, Co-Investigator on the project, is Assistant Professor of Biobehavioral Health and Demography at the Pennsylvania State University. She has conducted research on the impacts of Medicaid Expansion[14], rural-urban disparities in health[34], and published on the disparate rural-urban impacts of federal and state policies[7]. Santos and Rhubart are Research Associates of Penn State's Population Research Institute, an NICHD-funded population center that provides core infrastructure support in grant management, information and computational resources, programming support and statistical analysis. Figure 2 presents trends in rural/urban age-adjusted mortality rates by race/ethnicity in the US, which are part of previous work conducted by them (currently *Under Review*). Dr. Zachary Fisher, Co-Investigator on the project, is Assistant Professor of Human Development and Family Studies at the Pennsylvania State University. He is a leading scholar in analyzing and modeling time series data[35] and statistical programming having developed R software packages[36,37]. **Research Team**. PI Santos will oversee the work conducted under the three Specific Aims. Co-I Rhubart will advise on the issue of rural-urban disparities, measures of policy changes, and contextualizing the effects derived from the analysis. Co-I Fisher will provide advice on statistical modelling of the data derived from this project. A PRI Programmer will conduct the initial statistical analysis under the supervision of the PI and Co-Is. The project will also incorporate a summer RA who will support data processing, rate calculation and will conduct the robustness analyses. The RA will be mentored on demographic methods including: (1) use of vital records, (2) accurate rate calculation, (3) the use of advanced statistical methods and time-series analyses, and (4) population health and aging research.

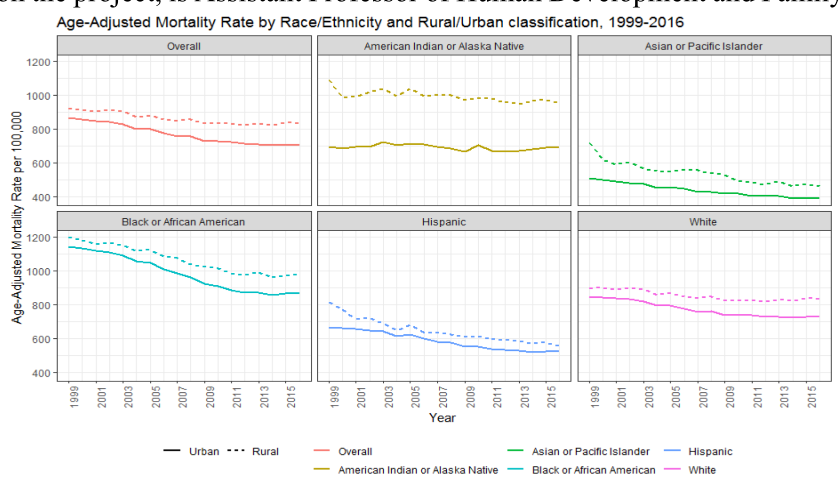

Figure 2. Age-Adjusted Mortality Rates by Rural/Urban classification and race/ethnicity in the United States, 1999-2016 (Rhubart and Santos, Under Review)

Data Sources. The proposed study uses one restricted dataset and four that are available publicly. First, 1999-2021 death counts will come from the National Vital Statistics System[38]. Age specific death counts in each state for the population aged 19-64, for males and females, and by race/ethnicity will be derived from the NCHS-provided Restricted Use Vital Statistics contained in the Detailed Mortality - Limited Geography Files. These files include information about decedent's state and county of residence, sex, race, and Hispanic origin. Detailed information about recodes and aggregation of the data for the proposed analysis is included in the *Measures* section. The second dataset consists of state-level income thresholds (as a percent of the federal poverty level (FPL)) used for determining eligibility for Medicaid. These will be used as a measure of the extent to which each state has expanded Medicaid from 1999 through 2021. We accessed data from the Kaiser Family Foundation Medicaid Expansion dashboard, and validated it with data from both the Department of Health and Human Services (HHS) and the Center for Medicare and Medicaid Services (CCS). These data will be matched with the death rates based on state identifiers (STATE FIPS). The third dataset is the 2003 Rural-Urban Continuum Codes (RUCC) which will be used to produce a county-level indicator of metropolitan classification[39]. These codes will be matched with the death rates based on county identifiers (COUNTY FIPS). Fourth, data from the Population Estimates Program (PEP) produced by the US Census Bureau includes counts for the population aged 19-64, by sex, and by race/ethnicity[40]. These data will be matched with the corresponding Year-County-Age-Group counts to produce the crude death rates, which will be then standardized using the 2000 standard population. Finally, the Center for Diseases Control published the 2000 standard population[41], which will be used to adjust the mortality rates to account for differences due to rural areas having older populations[42].

Measures. ***Medicaid expansion.*** While formal Medicaid expansion occurred in 2014, states have adjusted their eligibility thresholds over many years. Among states that have and have not formally adopted Medicaid expansion, there is substantial variation in the income thresholds used to determine eligibility. For example, in states that have not expanded Medicaid, eligibility ranges from a low of 16% of the FPL in Texas to 100% of the FPL in Wisconsin. And among expansion states, eligibility ranges from 138% of the FPL in most expanding states to 221% of the FPL in the District of Columbia. Figure 3 presents the states that had initiated the expansion by 2016 and those that had not. Using the income eligibility thresholds provides a more nuanced picture of expansion, which varies temporally and spatially. We accessed the annual income thresholds used for all 50 states and the District of Columbia and created a dataset indicating the income eligibility thresholds for each year from 1999 through 2021. This constitutes the main "exposure" of interest for the proposed analyses. The way this variable is incorporated in the analysis is discussed in the following sections: *Analytic Plan*, *Analysis*, and *Modelling Approach*.

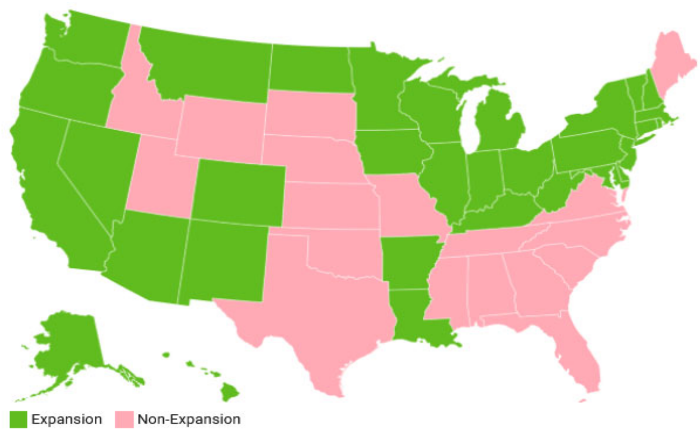

Figure 3. State adoption of the Medicaid expansion by 2016. (**Source**: Status of State Medicaid Expansion Decisions: Interactive Map maintained by the Kaiser Family Foundation)

***Rural-Urban Areas*.** Rural-urban disparities in mortality have been explored in previous scholarship[1,43,44].The proposed project will determine if the rural mortality penalty was impacted by state-level Medicaid expansion. Following the literature that explores the rural mortality penalty we will classify counties as urban or rural[1,45]. We will also account for these differences within the empirical models using the 2003 USDA Urban/Rural Continuum Codes[39], contained within it are the Rural-Urban Continuum county codes (RUCC codes). The RUCC codes indicate whether a county is considered: 1) County in a metropolitan area with 1 million population or more, 2) County in a metropolitan area of 250,000 to 1 million population, 3) County in a metropolitan area of fewer than 250,000 population, 4) Nonmetropolitan county with urban population or 20,000 or more, adjacent to a metropolitan area, 5) Nonmetropolitan county with urban population of 20,000 or more, not adjacent to a metropolitan area, 6) Nonmetropolitan county with urban population of 2,500 to 19,999, adjacent to a metropolitan area, 7) Nonmetropolitan county with urban population of 2,500-19,999, not adjacent to a metropolitan area, 8) Nonmetropolitan county completely rural or less than 2,500 urban population, adjacent to a metropolitan area, and 9) Nonmetropolitan county completely rural or less than 2,500 urban population, not adjacent to a metropolitan area. The RUCC codes allows for the classification of counties into: urban (RUCCs 1-3), rural non-remote (RUCCs 4, 6, 8) and rural remote (RUCCs 5, 7, 9). Under this classification schema we will have: 1,090 urban counties, 1,062 rural non-remote counties, and 990 rural remote counties. Under the traditional dichotomous classification schema the rural categories are collapsed into one, resulting in: 1,090 counties are classified as urban, and 2,052 counties are classified as rural. We will hold urban and rural status constant across the period of analysis to eliminate the possibility of biasing our comparisons due to county reclassification[44].

Age-Specific Mortality Rates. We will produce age-specific mortality rates for the population aged 19-64, by sex, and by race/ethnicity for rural and urban areas aggregating death and population counts for each state. We will use CDC guidelines to standardize these rates. The use of age-adjusted mortality rates is required due to differences in age structures observed based on rural and urban classifications[42]. This will assure that comparisons are not biased due to differences in age structures (see ***Age*** for more details). ***Mortality Rate Ratio.*** The magnitude and direction in differences in mortality rates are better captured by the calculation of Mortality Rate Ratios (MRR). The rate ratios are calculated by dividing the age-specific mortality rates for rural non-remote or rural remote areas by the age-specific mortality rates for urban areas and multiplying the result by 100. We will also calculate the MRR collapsing all rural areas into one group (see Rural-Urban Areas). If the ratio is equal to 100, it indicates equal rates. If the rate ratio exceeds 100, it is indicative of the rural mortality penalty, and vice versa.

Age. Variation in age structures across the rural-urban continuum are bound to result in higher number of deaths with rural areas exhibiting higher crude rates. Because of varying age-structures, these rates are not directly comparable. Key for this comparison is the production of Age-Adjusted Mortality Rates (discussed above). To make mortality rates comparable, the Center for Diseases Control and Prevention has published a series of "standard populations" which can be used to eliminate differences in crude rates resulting from different age distributions[41,46]. Death counts for the population aged 19-64, by sex, and by race/ethnicity will be aggregated in these age groups and matched with corresponding population estimates to produce crude rates to which the standardization will be applied to produce the Age-Adjusted Mortality Rates (discussed above).

Sex. In both the NCHS death records and the population estimates produced by the US Census Bureau, data can be accessed for (1) the population aged 19-64 and (2) by sex (male and female counts). We will conduct three sets of analyses - one for each of these counts. The analysis of male and female mortality dynamics is warranted given well-documented mortality disparities based on sex (i.e. male-female health-survival paradox[47]). By adequately considering both sexes in our analysis, we will be able to evaluate if and how Medicaid expansion affected rural-urban disparities in mortality. This consideration is critical for the interpretation, applicability, and generalizability of the findings that will be derived from the proposed project.

Race/ethnicity. In both the NCHS death records and the population estimates produced by the US Census Bureau, the data can be disaggregated by race/ethnicity. First, we will determine if the decedents' ethnicity was Hispanic or Latino. Among those who a not Hispanic or Latino, we will determine whether they are classified as: White, Black or African American, Asian or Pacific Islander (API) or American Indian or Alaska Native. We will calculate Age-Adjusted Mortality Rates for each racial/ethnic group to evaluate if the Medicaid expansion affected rural-urban disparities in mortality differently for racial/ethnic groups.

***State and Year fixed effects*.** State and year fixed effects have been included in previous research that seeks to evaluate the effects of policies. The inclusion of these effects allows the role that states or periods have on this matter to be accounted for[23,48]. The year fixed effects will allow for the estimation of trends and are crucial for the modelling of the effect we seek to capture with the quasi-experimental design. The inclusion of these effects will allow for a more accurate estimation of the effects we sought to find through the implementation of the quasi-experimental research design. The models will be fit with and without these effects to compare results across specifications (see *Modelling Approach*).

Analytic Plan.

Aim 1. Estimate age-specific mortality rates for rural and urban areas by state and by degree of Medicaid expansion for the population aged 19-64, by sex, and by race/ethnicity, 1999-2021. Using data from the NCHD restricted mortality files 1999-2021, we will calculate age-adjusted mortality rates for the overall population, by sex, and by race/ethnicity. Death records will be matched with the rural-urban classification described using county level identifiers (County FIPS). Second, each death record will be matched with state-level Medicaid income eligibility thresholds (State FIPS). Death counts will be aggregated by state, rural-urban classification and age group, resulting in a Year-State-Rural/Urban-Age Group data file that contains the death counts for the group of interest (i.e. overall, sex, or racial/ethnic group) by Age with observations for the 50 states and the District of Columbia by year. These counts will be divided by the corresponding population estimates which will produce the age-specific mortality rates which will be multiplied by the 2000 standard population. The resulting number of deaths will be aggregated and divided by the total 2000 standard population. The resulting product is the age-adjusted mortality rate for the population of interest. These rates will be used to perform the analyses proposed in Aims 2 and 3.

Aim 2. Determine if and how states that expanded Medicaid observed changes in their age-adjusted mortality rates, and on their rural mortality penalty (1999-2019). Using the age-adjusted mortality rates produced in Aim 1, we will test whether Medicaid expansion affected the trends in rural and urban mortality. This will be accomplished by using a difference-in-differences approach that leverages a continuous treatment indicator, to determine if expansion affected rural and urban mortality rates differently. The models will be fit specifying trend effects (Year), the time-varying Medicaid implementation indicator and their interaction. If the interaction is significant, it means there is a change in the trend based on the extent of Medicaid expansion; which means the expansion of Medicaid impacted urban and/or rural non-remote and rural remote mortality rates. We will also explore the trends in the MRR across the period of analysis to examine changes in the ratio between rural mortality (using the non-remote/remote distinction and the dichotomous measure) and the corresponding urban mortality rates. Robustness checks will be conducted by calculating Annual Percent Change (APC) to evaluate whether there is a different rate of change in the age-adjusted mortality rates based on the rural-urban classification and by the extent of Medicaid expansion. The analysis will be restricted to 1999-2019 to capture the effects before the onset of the COVID-19 pandemic.

Aim 3. Determine if and how the rural mortality penalty changed during the COVID-19 period (2020-2021) based on Medicaid expansion by 2020. The COVID-19 pandemic has claimed more than one million lives in the United States a number that increases every day, with estimates placing excess deaths during the first year around 600,000 deaths[49]. Yet, there is limited understanding of if and how these patterns varied for rural-urban areas and at the intersection with Medicaid expansion. We will focus on the pandemic period by analyzing changes in rural and urban age-adjusted mortality rates for the U.S., emphasizing the patterns observed for states based on their degree of Medicaid expansion. To do this, we will benchmark the analysis in 2019 and will compare the rates observed in 2020 and 2021 emphasizing rural-urban trends, differences based on Medicaid expansion by 2020, and degree and magnitude of these changes which are better captured by analyzing the MRR. The Annual Percent Change (APC) will be used to ascertain the degree to which each population of interest experienced mortality during the COVID-19 pandemic in comparison to 2019. This analysis will be highly descriptive and will emphasize changes in trends in rural and urban age-specific mortality rates, and how different they are based on the implementation of the Medicaid expansion. The analysis will expand our understanding of rural-urban mortality dynamics evaluating heterogeneity in patterns by sex and race/ethnicity.

Analysis. Using the age-adjusted mortality rates for the groups of interest produced in Aim 1, we will fit OLS regression models to study whether the degree of Medicaid expansion affected the rate of increase of the rural and urban mortality rates. These models will be first specified only to evaluate differences due to Medicaid expansion. The fully specified model includes the Year effect (continuous variable) and Medicaid expansion (continuous variable), and their interaction to ascertain whether the trend changes as Medicaid is expanded. Models will be fit for the population aged 19-64 (2 models), for males and females (4 models), and by race/ethnicity (10 models). We will also evaluate the APC for each of these time series to obtain additional evidence for the effects of interest (see comment in the *Potential Problems and Alternative Strategies*). The various groups for which the analysis will be conducted are discussed in the *Measures* section. Results presented in Figure 3 are from the proof of concept using Crude Death Rates for the overall population, which are biased due to older population structures in rural areas (and vice versa). This research proposal seeks to address this limitation by producing age-adjusted mortality rates to allow for the comparisons of interest. **Modelling Approach.** The proposed study will use a quasi-experimental research design. Using difference-in-difference models, we will compare the age-adjusted mortality rates in states that expanded their Medicaid programs with time-varying Medicaid expansion status. This will allow for the rolling expansion of the Medicaid expansion. The models will specify an effect to measure differences due to the expansion. The effect of Medicaid expansion is estimated as the change in rural and urban mortality rates due to Medicaid expansion. These models will be fit using the rates produced for the overall population, by sex and by race/ethnicity. We will test for the parallel trends assumption for the difference-in-difference model to ascertain whether there were differences in trends before the Medicaid expansion. Models will be fit in a nested manner. The first set of models will test for the effect without any additional effects. The second set of models incorporate state and year fixed effects to account for the influence of these factors in the model estimation. Robustness checks will include State fixed to account for state-level differences in the mortality dynamics. Such effects have been documented in previous scholarship[33,50]. **Power Analysis.** Given we will be using restricted records we will have full coverage of US mortality from 1999 to 2021. The use of restricted records will eliminate the suppression of rates due to small populations, something that happens when public data are used[30,42]. The descriptive analysis shows that the crude death rate for rural and urban areas differ based on expansion of Medicaid by 2016 (Figure 3). This data indicates that the average rural mortality penalty for crude mortality rates metropolitan and non-metropolitan from 2016 to 2019 based on the Medicare expansion by 2016 was 0.32 (expansion states) and 0.38 (non-expansion). Using *Statulator*, we estimate we will need between 246 observations based on α = 0.05 and a power of 80% to detect a difference

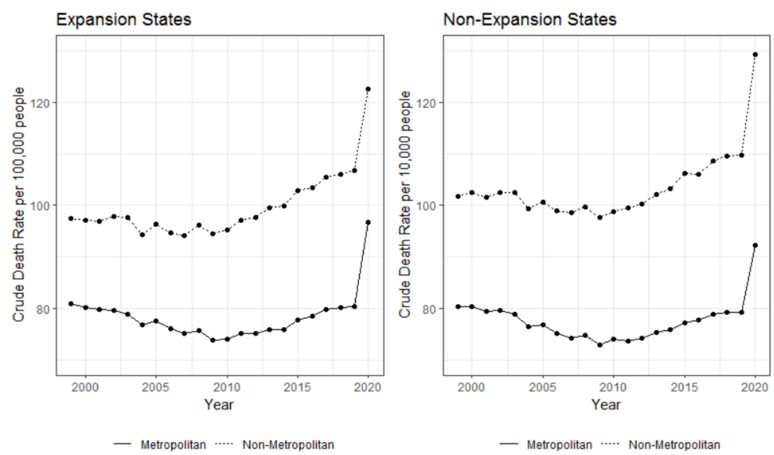

Figure 3. Crude Death Rates for Expansion and Non-Expansion States, 1999-2020. (**Source**: CDC Wonder, 1999-2020)

of this size. The use of restricted records will allow us to have enough observations to estimate the Age-Specific Mortality Rates and conduct the proposed analyses.

Potential Problems and Alternative Strategies. Some potential issues may arise concerning the proposed project. First, there is a possibility that the access to the restricted data will take more than six months. While this would preclude the data analyst or research assistant from conducting the data analysis, PI Santos is in the process of obtaining sworn status due to work on other NIH-funded projects and it is highly likely he will be able to conduct the analysis while the data analyst or research assistant goes through the process. Access to restricted data is warranted, as age-specific mortality rates past 2016 are not publicly available and even if they were, it is possible some could be suppressed due to privacy concerns. Second, the analysis of a time series that spans multiple decades results in the possibility of some areas previously considered rural not being classified as such in recent times. This issue, known as county-reclassification[44], has been shown to introduce substantial bias in mortality comparisons. This will be remediated by establishing a rural-urban classification schema that holds counties in their respective rural-urban category across the period of analysis. As described above, the rural-urban classification will be produced using the 2003 USDA Rural-Urban Continuum Codes. During the last six months of the project, we will conduct two robustness analyses where rural-urban classifications are determined using the 1993 and the 2013 county codes[39]. The resulting information will allow us to determine the extent to which these results vary based on county reclassification. Third, the 2021 restricted file may not be available at the beginning of the research project. Based on the NCHS publication timelines this dataset should be available by mid-2023. Nevertheless, the analyses for the 1999-2019 period and the 2020 can be conducted to successfully address the study's Specific Aims. There is ample time to update the results for Aim 3 in the last six months of the proposed project to include 2021 once it is available (see *Timeline*). In our data proposal, which will be submitted to the Restricted Data Center, we will request access to the 2022 death counts to be able to incorporate these data if they become available before the conclusion of the proposed study. Finally, it may be possible that the parallel trends assumption is not met in some of the models. In such cases, we will turn to the analysis based on APC, which is a reliable method for comparing trends. PI Santos has familiarity with this method as he has employed it in previous publications that analyzed mortality trends and compared groups[28].

Timeline. The first half of year 1 will be devoted to securing access to the restricted death records through Penn State's Restricted Data Center. During this period, we will also build the dataset that contains population estimates for the overall population, by age, age and sex, and by age and race/ethnicity for the 50 states and the District of Columbia between 1999 and 2021, which will be matched with the death counts produced using the restricted death files. For each year-state, we will have three data points corresponding to the three county classifications based on the RUCC codes. A second set of estimates will be produced where we operationalize RUCC codes using a dichotomous measure. Under this measure we will have two data points: one for the urban and the other corresponding to the rural population. The second half of year 1 will be devoted to producing the age-specific mortality rates for urban and rural areas for each state and the calculation of mortality rate-ratios (Aim 1). In the first half of year 2, we will explore the age-adjusted mortality rates for 1999-2019 and 2020-2021. The first part of the analysis will concentrate on the 20 years that precede the COVID-19 pandemic (Aim 2). The second part of the analysis will explore and describe effects for 2020 and 2021 (Aim 3). This is necessary based on the substantial shift in mortality dynamics resulting from the COVID-19 pandemic[8,9,21]. The second half of year 2, will be devoted to conducting robustness checks for the analyses and additional activities required to complete the project. The preparation of manuscripts will begin late in year 1 and will continue through the project's end. Drafts of these manuscript(s) will be submitted to appropriate conferences (e.g. Population Association of America, Association for Public Policy Analysis and Management, etc.), then revised for journal review and eventual publication.

Contributions to Research, Practice and Policy. Results from this project will significantly contribute to our understanding of rural-urban mortality disparities by producing empirical evidence related to U.S. mortality trends, public health practices, and by evaluating how inequalities are shaped by the interaction between state-level policies, residential context, and individual sex and race/ethnicity. The age-specific rates produced will be made available to the public so others can evaluate and replicate our analyses. Results from the project will highlight the role that state-level policies can have in reducing mortality in the US. Results will also highlight the role that Medicaid expansion had in shaping rural-urban disparities in mortality during the COVID-19 pandemic. The results are highly relevant to central topics concerning population health in the US, understanding place based disparities, and the interaction between state-level policies and mortality trends. The results will influence future research on place based health disparities, inform emerging scholarship on the role that policies and politics influence mortality dynamics in the US[50,51], and possibly influence public health policy.

Impact and Future Plans. The current project will lay the groundwork for an R01 application to develop a larger research project on the impact of state-level policies in rural-urban health, aging, and mortality using additional administrative data and survey linkages, including Medicare and Medicaid data, and data from the National Neighborhood Data Archive (NaNDA). Using these data, we can examine the mechanisms through which the expansion of Medicaid impacts population health and mortality in the US, and pursue a more detailed analysis of these dynamics during the COVID-19 pandemic.