County Level Suicide Rates in the United States from 2000 to 2014:

Changes over Time and Associations with Contextual Factors

DISSERTATION

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ABSTRACT

Suicide is a public health problem that takes the lives of more than 40,000 Americans every year. The impact of suicide is far reaching, effecting families and communities while also carrying a large economic burden. Previously, suicide rates have been shown to be higher and increasing more rapidly in rural areas than in urban areas. Reasons suicide rates are higher in rural areas have been attributed to factors such as high socioeconomic deprivation and a lack of availability of mental health services. However, few studies exist that examine how these factors impact rural and urban areas differently. The following study examines patterns and trends in suicide rates over a 15-year period, stratified by gender, age, and geographic location. It then examines the relationship between a variety of contextual factors and suicide rates, and whether the associations vary by geographic location.

All individuals who died by suicide between 2000 and 2014, were between ages 25 and 64, and resided in the US at the time of death were included in the study. Suicide decedents were aggregated in five three-year periods at the county level and combined with population data to calculate suicide rates and standardized mortality ratios (SMRs). Numerous contextual variables were collected at the county level and reduced to measure socioeconomic deprivation, social fragmentation, social capital, provider availability, veteran population, gun availability, and drinking establishments. Suicide rates and trend

tests were calculated over time, smoothed SMRs were calculated and mapped, and negative binomial regression was used to find factors associated with suicide rates.

The results show increasing suicide rates across all groups, regardless of age, gender, or geographic location. Suicide rates increase 23% overall, with the greatest increase in rural areas (40.6%). The youngest age group, 25 to 34, had the greatest difference between rural and urban counties, with the most rural counties having suicide rates 2.2 times higher than large metro counties in the final study period. SMRs show an excess risk for suicide across the western US and throughout portions of Appalachia and the Ozark mountains. Two contextual variables, social capital and psychiatrist ratio, were associated with decreased suicide rates, while four variables, socioeconomic deprivation, social fragmentation, veterans, and gun availability, were associated with increased suicide rates. Deprivation and gun shops varied by geographic location, with deprivation having a greater impact in rural counties compared to large metro counties and gun shops having less impact in rural counties compared to large metro counties.

These findings show that suicide rates are still higher in rural areas than urban areas and multiple factors are associated with increasing suicide rates. Existing suicide prevention programs, such as those used in schools, colleges, and police departments, may be successful if adapted to communities with high suicide rates. Improving the socioeconomic outlook and promoting connectedness within a county may also be useful to reduce suicide rates. Additional research is necessary to understand variations by age, gender, and method of suicide and to evaluate how effective suicide prevention programs are at the county level.

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Study Objectives

Suicide is a global health problem that affects tens of thousands of people in the United States each year ("WISQARS," 2018). While a great deal of research has gone into studying the epidemiology and individual risk and protective factors for suicide, much less is known about the contextual factors that contribute to high suicides. This is evident in rural areas, where suicide rates are consistently higher than suicide rates in urban areas (Fontanella et al., 2015; Hirsch & Cukrowicz, 2014; Nance, Carr, Kallan, Branas, & Wiebe, 2010; Singh & Siahpush, 2002) yet the reasons for high rural rates have not been empirically tested. Factors such as economic deprivation and health service availability within a community have been shown to be related to suicide rates (Kposowa, 2009; Mok et al., 2013; Rehkopf & Buka, 2006; Tondo, Albert, & Baldessarini, 2006), but it is unclear if these and other factors are associated with an increase in rural suicides. How combinations of contextual factors and interactions between contextual factors affect the geographic differences in suicide has not been studied in the literature. Further, suicide and mortality rates have been shown to be increasing among the working age group (ages 25 to 64) in recent years (Case & Deaton, 2015; Kegler, 2017; "WISQARS," 2018) but this age group is not regularly studied separately from suicides across the lifespan. This has limited the available information on the impacts of contextual and geographic factors on this group specifically. The following study will focus on suicides

among those in the working age group to better understand the contextual factors associated with suicide and how the contextual factors vary across geographic location in relation to suicide. The specific objectives and hypotheses for this study are as follows.

Objective 1. To examine the patterns and trends in suicide in the US over a 15-year period (calendar years 2000 through 2014) among those aged 25 to 64 across geographic location, stratified by gender and age.

Hypothesis 1a. Rural areas will have higher suicide rates than urban areas.

Hypothesis 1b. Suicides will be increasing across time, with a faster rate of increase in rural locations.

Objective 2. To determine whether several contextual factors, including deprivation, fragmentation, social capital, health service availability, availability of firearms, alcohol, and veteran population, are associated with suicide across time.

Hypothesis 2a. Fragmentation, access to firearms and rural location will remain significantly positively associated with suicide after controlling for other contextual factors.

Objective 3. To determine if the associations between contextual factors and suicide vary across geographic location.

Hypothesis 3a. The association between suicide and deprivation will vary with geographic location, with highly deprived rural areas having a stronger positive association with suicide than highly deprived urban areas.

Hypothesis 3b. The association between suicide and fragmentation will vary with geographic location, with highly fragmented rural areas having a stronger positive association with suicide than highly fragmented urban areas.

Hypothesis 3c. The association between suicide and social capital will vary across geographic location, with high levels of social capital in rural areas having a stronger negative association with suicide than high levels of social capital in urban areas.

Chapter 1: Introduction

The subject of suicide has been around for a long time and generated a great deal of research and analysis. Emile Durkheim's work on the topic in the late 1800's (Durkheim, 1951) encouraged the examination of suicide at the societal level, using ecological variables to better understand the fluctuations in the overall rates of suicide. Researchers have expanded on his ideas in the more than century since, allowing for the use of more sophisticated data analyses and techniques on the study of suicide. Data on suicide deaths is better tracked allowing for a more detailed exploration of the epidemiology of suicide and suicide rates. Several risk and protective factors have also been identified in relation to suicide and suicidal behavior as will be discussed below. The following will outline information that is known about the epidemiology, trends, and risk and protective factors in relation to suicide. But suicide is far from being completely understood and although individual factors that impact suicide rates are well studied, less is known about the contextual factors that impact suicide.

Epidemiology of Suicide

Current rates and prevalence.

Suicide remains a leading cause of death globally and nationally. According to the World Health Organization, suicide was the second leading cause of death for individuals aged 15-29 and the 17th overall leading cause of death around the world in 2015

("WHO," 2018). An estimated 788,000 people died by suicide in 2015, amounting to one person every 40 seconds and a global rate of 10.7 suicide deaths per 100,000 individuals ("WHO," 2018). In the United States, according to data available from 2016, suicide was the tenth leading cause of death across all age groups ("WISQARS Leading Causes of Death Reports," 2018). A total of 44,965 individuals died by suicide in the US in 2016. The overall age-adjusted suicide rate has been on a steady increase since 2000, from 10.40 suicides per 100,000 persons up to 13.42 suicides per 100,000 individuals in 2016 – the highest the rate has been in two decades ("WISQARS," 2018). Looking at distinct age groups, suicide is the second leading cause of death for individuals in the age groups 10-14, 15-24, and 25-34 (436, 5,723, and 7,366 suicides respectively in 2016), the fourth leading cause of death for those aged 35-44 and 45-54 (7,030 and 8,437 suicides respectively in 2016), and the eighth leading cause of death for those aged 55-64 (7,759 suicides in 2016) ("WISQARS Leading Causes of Death Reports," 2018). Most suicide deaths in the US affect the working age groups, those between ages 25 and 64, accounting for nearly 70% of suicides that occur each year.

Economic costs.

There is also a great economic cost to suicide. A recent study estimated the costs of suicide and suicidal behavior for the United States in 2013 (Shepard, Gurewich, Lwin, Reed, & Silverman, 2016). Based on data provided by the Center for Disease Control (CDC), the researchers calculated the fatal and nonfatal suicide related costs to society at $58.4 billion, with nearly $53.2 billion going to completed suicides. Males contributed to over 82% and indirect costs over 97% of the total economic costs. When the authors

adjusted to account for the underreporting of suicide, the economic costs increased to $93.5 billion, or $298 per capita. The greatest proportions of the costs were associated with suicides and suicide attempts among individuals aged 25 to 44 ($25.9 billion or 44% of costs before adjusting for underreporting; $40.4 billion or 43% of costs after adjusting for underreporting) and 45 to 64 ($16.0 billion or 27% of costs before adjusting for underreporting; $26.8 billion or 29% of costs after adjusting for underreporting). Loss of productivity causes most of the costs, while less than 3% of the costs are related to medical expenses. The authors also estimate that suicides could be reduced by 10% across the board with the introduction of psychotherapy and other interventions, saving $9.4 billion with a cost-benefit ratio of 1 to 2.5 (Shepard et al., 2016). The overall costs of suicide to society are high and the introduction or expansion of treatment and prevention of suicide could help reduce these costs.

Gender.

Males account for the majority of suicide costs due to the high rates of suicide among males compared to females. Suicide rates are tracked by gender to show these differences. Male suicide rates tend to be three to four times higher than female suicide rates in the US (Curtin, Warner, & Hedegaard, 2016; Nock et al., 2008; "WISQARS," 2018). The age-adjusted suicide rate for males in the US was 21.83 per 100,000 males in 2016, nearly 3.5 times greater than the rate for females at 6.24 per 100,000 females ("WISQARS," 2018). Over the last 16 years, suicide rates for both genders have been increasing. The greatest percent increase is among women, with the suicide rate up over 50% since 2000 (3.95 per 100,000 in 2000). Male suicide rates have also increased but

since they started out higher, the overall percentage increase is only 23.5% since 2000 (17.67 per 100,000 in 2000).

Race and ethnicity.

Like gender differences, suicide rates for white and Native American ethnicities are two to three times higher than the suicide rates for Black or Asian ethnicities (Suicide Prevention Resource Center, 2018; "WISQARS," 2018). In 2016, the overall age-adjusted suicide rate for white individuals was 15.89 per 100,000 and for Native American individuals it was 13.58 per 100,000 ("WISQARS," 2018). The suicide rates for Asian/Pacific Islander and black individuals were 6.84 and 6.11 per 100,000 respectively the same year. The differences by race hold up across gender as well, with white and Native American males having the highest rates of all groups (25.8 and 27.4 per 100,000 respectively in 2014) (Curtin et al., 2016). Females, while lower overall rates than males, also have the highest rates of suicide among white and Native American groups (7.5 and 8.7 per 100,000 respectively in 2014) compared to Asian/Pacific Islander, blank, and Hispanic females (3.5, 2.1, 2.5 per 100,000 respectively in 2014) (Curtin et al., 2016). Trends in overall suicide rates by race have remained relatively stable for black individuals over the past 16 years, but not for the other races that are readily identifiable in the online database ("WISQARS," 2018). The suicide rate among white individuals has increased 40%, up to 15.89 per 100,000 in 2016 from 11.29 per 100,000 in 2010. The suicide rates among Asian/Pacific Islanders and Native Americans have fluctuated up and down over the past 16 years, with both races seeing the highest suicide rate in 2016.

Age.

While age-adjusted suicide rates are common, examining suicide rates across specific age groups gives a better description of how suicide impacts individuals across the lifespan. The suicide rates by age in 2016 were bimodal, with peaks among those in their 40s through early 60s, and then those in their late 70s and up ("WISQARS," 2018). Examining five-year age groups for 2016, individuals age 50-54 have the highest suicide rate of 20.92 per 100,000 whereas the youngest age categories of 10-14 and 15-19 have a suicide rate of 2.11 and 10.02 per 100,000 respectively ("WISQARS," 2018). While young adult and adolescent suicide rates tend to be lower in the US than suicide rates in later life, the US tends to have youth suicide rates nearly twice as high as similar Western countries (Miller, Azrael, & Barber, 2012). Gender differences are also evident when suicide rates are examined by age in the US. Men have increasing rates across the lifespan, with the highest rates at ages 75 and over (38.8 per 100,000 in 2014) (Curtin et al., 2016). Female suicide rates tend to peak in the middle of life, with the highest rates in midlife from ages 45 to 64 (9.8 per 100,000 in 2014) (Curtin et al., 2016).

Changes in suicide rates across age groups overtime gives additional insight to suicide in the US. The elderly (those aged 65 and up) had declining rates of suicide in the 90's, which plateaued in the early 2000's, but have started to increase over the past 5 years (14.88 per 100,000 in 2010 up to 16.66 per 100,000 in 2016) ("WISQARS," 2018). Similarly, the adolescent and young adult (those aged 10-24) suicide rates peaked in the 90's and were stable during the early 2000's but have been trending upward over the last decade to 9.60 suicides per 100,000 individuals in 2016, the highest rate since 1995.

However, the greatest, most consistent, upward trend in suicide rates has occurred among the middle, or working, age groups (those aged 25-64). The rates decreased in the 90's but have been increasing since the early 2000's, jumping from 13.4 suicides per 100,000 persons in 2000 up to 18.06 suicides per 100,000 persons in 2016, a 34.8% increase ("WISQARS," 2018). This is the highest the rate has been since at least 1981, which is the earliest data is available via the CDC's online data system ("WISQARS," 2018). This increase is similar for males and females, with the male rate for ages 25 to 64 up from 21.23 per 100,000 in 2000 to 27.58 per 100,000 in 2016 and the female rate for ages 25 to 64 up from 5.75 per 100,000 in 2000 to 8.73 per 100,000 in 2015, 29.9% and 51.8% increases respectively.

Geographic location.

It is becoming increasingly common to examine suicide rates across geographical location in addition to the characteristics described above. Several analyses have shown that rural areas tend to have higher suicide rates both in the US and around the world (Burrows, Auger, Gamache, & Hamel, 2013; Kapusta et al., 2008; Levin & Leyland, 2005; Middleton, Gunnell, Frankel, Whitley, & Dorling, 2003; Nance et al., 2010; Singh & Siahpush, 2002; Wilkinson & Gunnell, 2000). Within the US, there are specific states, that tend to be less densely populated, that routinely have very high suicide rates (e.g. Wyoming, Alaska, Montana, New Mexico, Utah, Nevada), and specific states that have very low suicide rates and are more densely populated (e.g. New York, New Jersey, Maryland, Massachusetts, Connecticut) (Miller et al., 2012; "WISQARS," 2018). The high suicide rate states ranged from 21.41 per 100,000 in Nevada to 26.01 per 100,000 in

Montana in 2016, whereas the low suicide rate states ranged from 7.17 per 100,000 in New Jersey to 10.01 per 100,000 in Connecticut in 2016, a three-fold difference between some states.

Not only are rural suicide rates consistently higher than urban suicide rates, but the differences are increasing with time. Time trend analyses of counties in the US have shown an increasing gap in the difference between rural and urban suicide rates (Fontanella et al., 2015; Kegler, 2017; Singh & Siahpush, 2002). Each analysis found the rural suicide rate was higher than the urban suicide rate, and the difference was increasing with time. Singh and Siahpush (2002) reported on suicides by county across the US from the years 1970 to 1997 for ages 15 and up. Among males, they found higher suicide rates in rural areas than urban areas with the difference increasing with time. In the period 1980 to 1984 male suicide rates in the most rural counties (those with an urban area of no larger than 2,500 individuals) were 21% higher than the most urban counties, but by the period 1995 to 1997, those rural rates were 54% higher than the urban rates. Females showed a different trend, with higher rates of suicide among women in urban areas during the earlier time periods (6.00 per 100,000 in urban vs 4.58 per 100,000 in rural in 1980-1984) and no difference in suicide rates by area in the most recent time-period (4.05 per 100,000 in urban vs 4.01 per 100,000 in rural in 1995-1997).

Another study reported on rates of suicide in the United States among 10- to 24-year-olds from 1996 to 2010 and found increasing suicide rates among males and females in rural areas (Fontanella et al., 2015). The most rural counties (counties with an urban area of no larger than 2,500 individuals) male suicide rate increased from 18.98 per

100,000 in 1996-1998 to 19.93 per 100,000 in 2008-2010; the most rural counties female suicide rate increased from 3.19 per 100,000 persons in 1996-1998 to 4.40 per 100,000 in 2008-2010. While the rural suicide rate for young men was increasing, the urban suicide rate was actually decreasing (11.95 per 100,000 males down to 10.31 per 100,000 males), resulting in a growing differential between rural and urban areas for young men. The differential for young women was also growing due to a quicker rate of increase in rural suicides (rate of increase = 0.021, p = 0.04) as compared to urban suicides (rate of increase= 0.008, p =0.04).

The most recent analysis on data from 1999 to 2015 for all individuals 10 and older who died by suicide found similar geographic trends (Kegler, 2017). Suicide rates for all areas were increasing over time, with the rates in medium metro, small metro, micropolitan and rural areas increasing at the greatest pace especially since 2007. Prior to 2007, the most rural counties had a suicide rate increasing at 0.18 per 100,000 individuals each year, but after 2007, the suicide rate in those same counties was increasing at 0.55 per 100,000 individuals each year. The suicide rate in large central urban areas was only increasing at a rate of 0.09 per 100,000 during the entire study period. Across age groups, gender, and time, suicide rates have been found to be higher in rural areas than urban areas, with an increasing differential largely due to the faster growth of suicide rates in rural areas.

Method of suicide.

Understanding suicide also requires examining the methods that are used for completed suicides. Firearms account for roughly half of all suicide deaths in the US,

with over 22,000 suicides involving firearms in 2016 ("WISQARS," 2018). Males are more likely to die by suicide via a firearm than females, as 56.6% of all male suicides in 2016 involved a firearm but only 32.1% of all female suicides involved firearms the same year. Hanging and suffocation are the second most common method of suicide, accounting for over a quarter (25.9%) of all suicides in 2016. Suicide by poisoning represents a low overall percentage of suicide completions (14.9%), but for women it is the leading method of death by suicide, accounting for 33.0% of all female suicides in 2016.

Trends in method of suicide also speak to the lethality of firearms and hanging/suffocation. The overall firearm suicide rates have not changed much in the past 16 years, from 10.98 per 100,000 in 2000 to 12.35 per 100,000 in 2016 for males and 1.47 per 100,000 in 2000 to 2.01 per 100,000 in 2016 for females ("WISQARS," 2018). But firearm use is particularly high among elderly men (those 65 and older) with a suicide rate of 24.00 per 100,000 in 2016, which is slightly lower than the rate in 2010 (25.76 per 100,000). And males between the ages of 25 and 64 have shown increasing rates in suicides by firearms, with an increase from 12.04 per 100,000 in 2000 to 14.24 per 100,000 in 2016. Rates by firearm among women of the same age have slightly increased from 2.12 per 100,000 to 2.80 per 100,000 during the same time-period. The suicide rates for hanging/suffocation have also been increasing but started much lower than firearm rates. In 2000, the male suicide rate by hanging/suffocation was 3.42 per 100,000 and increased to 5.69 per 100,000 in 2016; similarly, in 2000 the female suicide rate by hanging/suffocation was 0.66 per 100,000 and increased to 1.58 per 100,000 in

2016 (“WISQARS,” 2018). The use of hanging and suffocation among those aged 25 to 64 between 2000 and 2016 increased among males from 4.41 per 100,000 to 7.95 per 100,000 and more than doubled among females from 0.78 per 100,000 to 2.06 per 100,000. Suicide rates for poisoning has fluctuated among males age 25 to 64 but remains relatively low (3.07 per 100,000 in 2016) while poisoning has started to increase among females of the same age, from 2.33 per 100,000 in 2000 to 3.05 per 100,000 in 2016.

Risk and Protective Factors

In addition to understanding the epidemiology of suicide in the US, a great deal of research has been conducted aimed at prevention, especially through identifying and providing treatment for those at greatest risk for suicide. Factors that increase the risk of and protect against suicide and attempted suicide have been identified in the literature. Below is a brief summary of risk and protective factors for suicide within the United States.

Sociodemographic factors.

Several factors that relate to an individual’s sociodemographic and economic situation have been documented to impact suicide risk. Marital status can be a risk or protective factors, as individuals who are divorced, separated, or widowed have been shown to have higher suicide rates, while those who are married have lower suicide rates (Kposowa, 2000; Smith, Mercy, & Conn, 1988). Separation and divorce seem to have a greater impact on men (Kposowa, 2000), as women are often the primary caregivers of children, which is a protective factor (Kposowa, 2000; Nock et al., 2008). A strong family or social support network is also a protective factor and can reduce risk of suicide

even when other risk factors are present (Kleiman & Liu, 2013). Similarly, religious beliefs tend to be a protective factor, although there can be variation in the protectiveness based on the type of religion and commitment to the beliefs (Lawrence, Oquendo, & Stanley, 2016; Nock et al., 2008; Robins & Fiske, 2009; Wu, Wang, & Jia, 2015). Some studies have indicated that specific religions do a better job at protecting against suicide, such as Islam, Judaism, and Catholicism (Spoerri et al., 2010). This may be due to the beliefs taught within the religion, or the strong social support system that is developed through the practice of these and similar religions (Lawrence et al., 2016; Nock et al., 2008). Unemployment has also been identified in the literature as a risk factor for suicide, although there is less agreement about who is at risk from unemployment and how long unemployment affects suicide risk, possibly due to other factors like unemployment benefits that counter the negative risks (Kposowa, 2001; Milner, Page, & LaMontagne, 2013).

Prior attempts.

Many studies have reported that one of the greatest individual-level risk factor for dying by suicide is a prior suicide attempt, especially among adolescents and young adults (Bridge, Goldstein, & Brent, 2006; Gvion & Apter, 2012; Miller et al., 2012; Nock et al., 2008; Sakinofsky, 2000). Individuals who have attempted suicide in the past are at an increased risk for attempting and dying by suicide in the future. One study reported that previous suicide attempts increased risk of dying by suicide by more than ten-fold (Brown, Beck, Steer, & Grisham, 2000).

Lethal means.

The means that are used to attempt suicide can increase the risk of a comleted suicide. Both firearms and hanging/suffocation tend to be more lethal methods of suicide. The case fatality ratio (CFR), or proportion of suicidal acts that prove to be fatal, was shown to be highest for firearms at 85 in the US in 2001, followed by hanging/suffocation at 69 (Miller et al., 2012). The third highest CFR was among suicidal acts involving falls at 31, much lower than firearms and hanging but one of the more lethal means. Other methods of suicide have much lower CFRs; poisoning has a CFR of 2, indicating only 2 out of 100 suicide attempts through poisoning are likely to be fatal.

Beyond the fatality ratios, several studies have been conducted that show availability of firearms increases the risk of suicide. Numerous case-control studies have been analyzed within the US and consistently show firearms within the home are associated with increased risk for suicide (Beautrais, Joyce, & Mulder, 1996; Brent et al., 1993; Cash & Bridge, 2009; Miller et al., 2012; Shah, Hoffman, Wake, & Marine, 2000). Longitudinal studies have also shown associations between gun ownership and suicides in the US (Miller et al., 2012). One study showed a significant relationship between the decrease in the percentage of Americans living in a home with a firearm and both the overall suicide rate and suicide rate by firearms (Miller, Azrael, Hepburn, Hemenway, & Lippmann, 2006). The authors adjusted for multiple factors and examined the rates across different groups and the findings consistently showed a positive relationship between decreasing households with firearms and decreasing suicide rates.

Mental health.

The presence of psychiatric disorders is also a well-documented risk factor for suicide (Gvion & Apter, 2012; Miller et al., 2012; Nock et al., 2008). Specific psychiatric conditions such as depression, bipolar, schizophrenia, substance use, anxiety, and personality disorders have been associated with increased risk for suicide based on numerous reviews of the literature (Allgulander, 2000; Bridge et al., 2006; Cash & Bridge, 2009; Gvion & Apter, 2012; Hert & Peuskens, 2000; Linehan, Rizvi, Welch, & Page, 2000; Lonnqvist, 2000; Murphy, 2000; Nock et al., 2008). Some studies have estimated that 90-95% of all suicides are completed by individuals who have a diagnosable mental health condition (Bridge et al., 2006; Gvion & Apter, 2012; Nock et al., 2008). Multiple psychiatric conditions, or psychiatric conditions in combination with other risk factors, also increases the risk for suicide (Bridge et al., 2006; Nock et al., 2008).

Psychological factors.

Many individuals who have psychiatric diagnoses do not attempt or die by suicide. Additional research has identified specific traits and qualities of individuals that lead to increased risk for suicide beyond psychiatric diagnoses. These traits and qualities include impulsivity, aggression, hopelessness, high emotional reactivity, and alienation (Bridge et al., 2006; Gvion & Apter, 2012; Nock et al., 2008; Williams & Pollock, 2000). These traits may increase the likelihood that an individual will see suicide as an appropriate option for the difficulties in life.

Physical health.

Chronic or terminal health conditions, long-term chronic pain, and physical disabilities and impairments have all been identified as risk factors for suicide (Bridge et al., 2006; Nock et al., 2008; Stenager & Stenager, 2000). Individuals who suffer from these conditions can view suicide as a way to escape the burden and endless pain.

Biological factors.

Suicidal behavior has been shown to impact multiple generations within a family, indicating a potential genetic risk factor for suicide (Bridge et al., 2006; Nock et al., 2008; Roy, Nielsen, Rylander, & Sarchiapone, 2000). History of a family member with suicidal behaviors or completed suicide increases the risk of suicide for an individual. Part of the familial connection could be due to the learned behaviors and responses within a family, but numerous twin and family studies have indicated a hereditary link in suicidal behavior (Nock et al., 2008). Research to identify why certain families may be at increased risk for suicide has led to potential biological factors that relate to suicidal behavior. Studies have shown that disruptions in the neurotransmitter serotonin are associated with an increase of impulsive and aggressive behavior, which increases the risk for suicide (Bridge et al., 2006; Nock et al., 2008; Roy et al., 2000). General consensus is that the serotonin system is involved in some way, if indirectly, with increasing the risk for suicide among individuals.

Current Study

Although a great deal has been learned about suicide and those at risk for suicide, hundreds of thousands of individuals are still impacted by suicide every year. The risk

and protective factors described above may explain some of the epidemiological trends in suicide, such as why men are more likely to die by suicide than women (e.g. due to aggressive and impulsive traits, lethal means), why older individuals are more likely to die by suicide than younger individuals (e.g. due to physical health, feeling burdensome), or why white and Native American individuals are more likely to die by suicide than individuals of other races (e.g. due to social support, substance use). But individual risk and protective factors do little to explain why individuals in rural areas tend to experience a disproportionate amount of the burden of suicide (e.g. in 2016, 18.8% of all suicides occurred in non-metro areas but only 14.4% of the population lived in non-metro areas ("WISQARS," 2018)). More research is still necessary to understand why suicide rates in rural areas tend to be higher than urban suicide rates.

Some of the individual characteristics of rural residents could contribute to differing suicide rates across geographic location. Residents of rural areas have historically been predominately white (Johnson, 2003) and slightly older than metro area residents (Glasgow, 2003). Gun availability is also higher in rural areas, increasing access to lethal means (Branas, Nance, Elliott, Richmond, & Schwab, 2004; Dresang, 2001; Kaplan, McFarland, Huguet, & Valenstein, 2012; McCarthy et al., 2012; Nance et al., 2010). But other risk factors, such as depression and other psychiatric conditions and traits, have not been shown to be higher in rural areas (Probst et al., 2006; Qin, 2005).

Rather than relying on individual risk factors alone, the context in which rural individuals live can also play a rule in increasing suicide risk. Several studies that have shown rural suicide rates are higher than urban rates suggest that community level

factors, such as poverty, unemployment, isolation, and lack of services, are contributing to the high rates of rural suicide (Fontanella et al., 2015; Singh & Siahpush, 2002). However, these contextual factors are rarely studied empirically with consideration of geographical location in relation to suicide rates. Studies examining suicide rates will often control for contextual factors including level of rurality, but do not examine how rurality impacts the connection of contextual factors with suicide.

Studies of suicide rates regularly incorporate measures that account for unemployment, poverty, socio-economic status, or a deprivation index (i.e. a combination of variables on economic status, income, and education attainment) at the area level. Deprivation indices were initially developed and used across Europe (Middleton et al., 2003; Rezaeian, Dunn, St Leger, & Appleby, 2005; Whitley, Gunnell, Dorling, & Smith, 1999) but have been adapted to the United States with available census data (Singh, 2003). Singh's area deprivation index has been used in studies and shown high deprivation is related to high suicide rates (Knighton, Savitz, Belnap, Stephenson, & VanDerslice, 2016; Singh, Azuine, Siahpush, & Kogan, 2013). Similar ecological variables and indices that measure social fragmentation within a society are becoming more common in the suicide literature (Congdon, 1996, 2011b; Whitley et al., 1999). Fragmentation relates to Durkheim's original ideas of the amount of integration or connection within a community. Variables such as percent of people living alone, population turnover in the last year, and percent of divorced individuals are used to measure the concept of fragmentation within a society. Generally, social fragmentation

also tends to be positively associated with suicide, i.e. as fragmentation increases, so does the suicide rate in a society (Congdon, 1996, 2011b; Whitley et al., 1999).

Additional ecological variables that have been examined in association with suicide are social capital and service availability. Levels of social capital have been incorporated into models as explanatory variables (Desai, Dausey, & Rosenheck, 2005; Fontenot, 2015; Recker & Moore, 2016; Yang, Jensen, & Haran, 2011) although there is not a consistent way of measuring social capital and few studies include a social capital component. Studies that exist tend to show social capital is associated with reduced suicide rates (Chauvin, 2013; Fontenot, 2015; Kelly, Davoren, Mhaoláin, Breen, & Casey, 2009; Recker & Moore, 2016; Smith & Kawachi, 2014). Availability of services has been included in models of suicide in the literature, and typically demonstrates an inverse relationship (Fiske, Gatz, & Hannell, 2005; Kapusta et al., 2009, 2010; Kposowa, 2009; Tondo et al., 2006), showing that availability of mental health services is related to a decrease in suicide rates. Again, the measure used for service availability often differs across studies and locations.

Contextual factors are increasingly common in the study of suicide, but they still do not empirically show why rural rates are so much higher than urban rates. Ecological studies might control for geographical location due to high suicide rates in rural areas but do little else to understand the differences in rates. It is still unclear if these contextual factors alone contribute to rural rates being higher than urban rates or if something more specific to rural areas add to the complexities of these contextual factors, increasing the impact these factors have on rural suicide rates.

The following study will expand upon the literature that is already available related to suicide and contextual factors. Three objectives will be explored to increase knowledge of suicide across geographic locations. The first objective is to examine the patterns and trends in suicide in the US over a 15-year period (2000 to 2014) across geographic location, stratified by gender and age. This will give a broad understanding of how suicide rates are changing across time and space within the US, while also confirming whether suicide rates are still higher in rural areas compared to urban areas. Next, the second objective is to determine whether several contextual factors are associated with suicide across time. Finally, the third objective is to determine if interactions between contextual factors and geographic location are associated with suicide rates. The two objectives that examine contextual factors will provide insight into which factors are associated with suicide and how location might impact the level of association between contextual variables and suicide.

Organization of Dissertation

The rest of this project is outlined as follows. Chapter two begins with a review of suicide theory that explains why ecological factors could influence suicide rates and how these factors might influence rural areas differently than urban areas followed by an in-depth review of the literature that relates ecological factors to suicide rates. The third chapter outlines the methodology used for this study, including sources of data, variables, and statistical analyses. The fourth chapter highlights the results of the project and the final chapter discusses the results, drawing conclusions related to suicide prevention efforts.

Chapter 2: Theory and Literature Review

Suicide is a major public health concern with overall rates increasing in recent years. Rural suicide rates are consistently higher than urban suicide rates (Kegler, 2017), but limited evidence is available to fully understand why rural and urban rates differ. Several contextual factors have been suggested to be related to higher rates in rural areas, such as deprivation or lack of services (Fontanella et al., 2015; Singh & Siahpush, 2002), but empirical tests are limited. Evidence that is available shows contextual factors are associated with suicide rates without consideration of geographic location and will be outlined below. It remains unclear if high suicide rates in rural areas are simply related to contextual factors or if these factors interact with other rural features to relate to increased suicide rates.

This chapter will summarize the theory and literature that exists in relation to suicide and contextual factors. The first section of this chapter will address theoretical concepts that help to explain how suicide and contextual factors are connected, followed by an explanation of how rural location can intensify the relationships that exist. The next section summarizes the literature that has examined the relationship between contextual factors and suicide rates. Finally, gaps in the literature will be identified to provide a detailed rationale for the current study with a summary of the objectives and hypotheses for this study.

Theoretical Framework

To fully understand geographical differences in suicide rates, individual level factors alone are insufficient. A recent review of the literature on rural suicide concluded that there are rural specific factors, such as lack of access to care, remoteness, isolation, and worldview, that impact suicide rates (Hirsch & Cukrowicz, 2014). Factors that relate to the community or context in which rural residents live can provide additional insight to understanding rural and urban differences in suicide rates. The theories that guide this study, starting with Durkheim's groundbreaking study of suicide in the late 1800's, and including additional theories related to stress and social stratification, will be discussed below, followed by how they apply to rural communities specifically.

Durkheim.

Durkheim's work on suicide shifted the focus from an individual act to the result of variations within societies. Durkheim (1951) examined individual factors in his book, but repeatedly concluded that there was no evidence to show individual factors (e.g. alcoholism and psychiatric distress) could explain variations in suicide rates. He demonstrated that social causes, and the variations in social causes across different groups of people and time, could better explain suicide rates than the unique qualities of the individuals dying by suicide. Durkheim particularly focused on social integration (i.e. the amount of interconnectedness and comradery within a community) and social regulation (i.e. the amount of structure and order provided within a community) as the two main variants that contributed to overall suicide rates. Moderate amounts of both

would be the best-case scenario, with high or low amounts of either construct leading to high rates of suicide in a community.

To understand social integration and regulation, different types of suicide were described by Durkheim. He categorized suicide into four separate types: altruistic, fatalistic, anomic, and egoistic. According to Durkheim's model of suicide, societies with high levels of integration tend to have more altruistic suicides where individuals choose to die by suicide for the good of others. Similarly, high levels of regulation lead to fatalistic suicides, where individuals feel so restricted and without options, they choose to die by suicide. Durkheim admitted in his work that these two types of suicide are not useful for explaining modern suicides, as present day (in the 1800's or today) deaths are rarely the result of altruistic or fatalistic gestures.

Anomic and egoistic suicides come from low levels of regulation and integration. Low regulation within a society leads to anomic suicides, where individuals are not provided enough structure within the social setting. Johnson (1965) described societies with low regulation as having weak control over individuals, allowing them to become disoriented and overwhelmed by their own passions, leading to suicide. Low levels of integration lead to egoistic suicides, the primary focus of Durkheim's work, where individuals are not connected to their society. Johnson (1965) described societies with these suicides as having a weak common conscience, or few commonalities, that prevents individuals from deriving meaning or purpose from the group. Self-interests take precedence in these societies, which allows individuals to see suicide as a viable option due to the lack of connection to others.

Durkheim's work on suicide was a success for its time and provided a starting point for numerous researchers. As expected, over the past 120 years, many individuals have built upon his work, updating it as data and methodological advancements allow. Johnson (1965) attempted to understand Durkheim's work more fully and simplified the different types of suicide to egoistic suicides alone. Like Durkheim, he claimed altruistic and fatalistic suicides were irrelevant to modern study but went further to describe anomic suicide as an aspect of egoistic suicide, as societies that lack integration are unable to regulate individuals. This led Johnson to summarize Durkheim's work on suicide to one postulate: 'the *more* integrated (regulated) a society, group, or social condition is, the *lower* its suicide rate' or similarly, 'the *higher* the level of egoism (anomie) prevailing in a society, group, or social condition, the *higher* the suicide rate' (Johnson, 1965, pg. 886).

Durkheim analyzed several factors that he saw connected to integration and regulation within his book. He linked religion, family structure, unemployment, and political upheaval to area suicide rates. Similar factors can be used today to understand suicide rates, with better availability of data for analysis. Indices for fragmentation and integration among individuals within a community have been developed that can be considered constructs for measuring regulation and integration within a society. These indices will be discussed in more detail later in this chapter to determine the available literature concurs with Durkheim's understanding of societal impacts on suicide.

Role conflict and stress theory.

Gibbs and Martin (1958) also reviewed Durkheim's work and made modifications to his ideas on suicide. Like Johnson, they considered regulation an aspect of integration, with highly integrated societies also regulating individuals within the society. They simplified Durkheim's primary postulate as "The suicide rate of a population varies inversely with the stability and durability of social relationships within that population" (pg. 141) and then added to it to develop their own theory that states: "the suicide rate of a population varies inversely with the degree of status integration in that population" (pg. 143). Status integration is primarily indicated by whether individuals hold different statuses within society that conflict with one another. If the different roles that each status requires do not conflict, then integration is high; if the roles often conflict, then integration is low, leading to higher rates of suicide. High levels of role conflict within and between the statuses an individual holds are likely to create high amounts of stress. For example, for someone who is a father and an employee, demands from work can conflict with demands of fatherhood, increasing levels of stress. In rural areas, individuals may hold the role of farmer but also family provider which may conflict in times of drought or flood, increasing stress and conflict for the individual.

Understanding how stress and conflict relate to suicide comes from the well-studied stress process (Pearlin, 1999; Wheaton, Young, Montazer, & Stuart-Lahman, 2013). The process can be simplified as stressors, moderators, and outcomes. Stressors can relate to specific, unexpected events that occur during the life course (e.g. divorce, death of child, loss of job) or as chronic life stressors (Pearlin, 1999), such as role strains

that are outlined by Gibbs and Martin (1958). Individuals can respond differently to these stressors, often based on the resources that are available to them. Pearlin (1999) laid out three common resources for stress: coping or the ability one has to minimize and overcome stress alone, social support or the networks an individual is connected to that help alleviate stress, and mastery or the sense of control over one's life in regard to stressful events. These resources react to stress, either being directly impacted by the stressful event or moderating the effects of the stressful events on other aspects of life. This would also support Durkheim's idea of integration, as the availability of social support to overcome stress and negative events would reflect a high level of integration among individuals in a community to support one another, reducing suicide rates.

Individuals who experience high levels of cognitive vulnerability, a term used in the hopelessness literature (Abramson et al., 2002; Liu, Kleiman, Nestor, & Cheek, 2015), may also be highly susceptible to stressful events. Cognitive vulnerability is theorized to develop based on how individuals perceive negative events and the inferences they draw related to causes, consequences, and characteristics about the self (Abramson et al., 2002). Individuals who tend to see negative events as stable (i.e. persistent or enduring as opposed to temporary), global (i.e. applying to many or all aspects of life as opposed to specific circumstances), leading to additional negative consequences, and a reflection of the flawed self will be more prone to hopelessness and suicidality (Abramson et al., 2002; Cornette, Abramson, & Bardone, 2002; Liu et al., 2015). Individuals who live in poor communities are likely to see negative events as

stable and global due to the limited economic opportunities, potentially making them more prone to suicide.

Social stratification theory.

Another line of theory that has become increasingly common in the study of suicide relates to social stratification. Social stratification can be described as different groups within a society having unequal access to available resources within a community (Eaton, Muntaner, & Sapag, 1999). Social stratification often accounts for three general areas that work collectively to improve or reduce social status: education, income, and occupation (Muntaner, Ng, Vanroelen, Christ, & Eaton, 2013). Education is a tool that can empower individuals by increasing knowledge and resources while also increasing access to better jobs through increased skills. Income can be understood more broadly as economic resources and often includes measures of poverty thresholds for family size. Occupational classifications provide levels of prestige and are often used as a proxy for status, with more control and autonomy provided for those in higher level positions such as professionals and managers. Groups with lower statuses tend to have less access to things like wealth, power, and resources within a community, often resulting from a lack of education, income, and/or occupational prestige. Deprivation indices have been used as a proxy for social stratification within communities, as they generally account for different measures of income, education, and occupation (Carstairs & Morris, 1989b; Townsend, Phillimore, & Beattie, 1988).

Like integration and stress, social stratification can also affect community level suicide rates. Measures of social class and status have been documented to be related to

poor health and mental health outcomes (Adler & Ostrove, 1999; Barr, 2014; Case & Deaton, 2015; Chetty et al., 2016). Thus, communities that have high rates of deprivation with many individuals holding low social status are likely to have high suicide rates as well.

Neighborhood resource model.

Finally, theory that relates to community level resources also applies here although it has not been connected to suicide research regularly. The neighborhood institutional resource model was identified as one of five models in neighborhood research by Jencks and Mayer (1990). The model focuses on how resources within a community can impact children by providing educational and social experiences for learning and development. The availability of public parks, school and childcare centers, libraries, community centers, medical services, and service opportunities can promote learning, connection within the social environment, and healthy behaviors and development (Jencks & Mayer, 1990; Leventhal & Brooks-Gunn, 2000). The focus of this literature has been on how these resources relate to youth outcomes, but adults can also be impacted by the availability of community resources. Integration within a community can increase with the use of community resources by individuals and families. Interactions at these places, whether libraries, parks, or community centers, can increase the ability to manage stress by providing additional social support and coping mechanisms or improve status through educational opportunities and network building. The organizations that exist as resources within the communities (e.g. libraries, schools, etc.) can provide additional linkages for individuals living in the community, further

bonding and integrating society (Small, Jacobs, & Massengill, 2008). The availability of medical services within the community can improve health outcomes and promote wellness for those living in the areas (Starfield, Shi, & Macinko, 2005). Neighborhood resources can be connected to suicide rates in an area due to the impact these resources can have on the stressors faced by those living in the area.

Rural context.

The theories outlined above can be applied to rural areas to understand why suicide rates tend to be higher in rural areas as compared to urban areas. Rural America still consists of 46.2 million people as of July 2015, representing 14% of US residents (United States Department of Agriculture, 2016). Poverty is slightly higher in rural counties than urban areas, with over 17% of rural residents in poverty compared to about 14% of metro residents (United States Department of Agriculture, 2016). Persistent poverty, an indicator for counties that have 20% or more of the population in poverty at each of the last four censuses, also affects rural areas more so than urban areas ("Geography of Poverty," 2017; Miller, Crandall, & Weber, 2002). After the 2010 census, 301 of the 353 (85.3%) persistently poor counties were rural ("Geography of Poverty," 2017), which is actually down from the 2000 census, where 363 of 382 (96%) of persistently poor counties were rural (Miller, Crandall, & Weber, 2002). Of all counties in the US, 62.9% were considered rural in 2010 and 65.3% in 2000, which shows persistently poor counties are disproportionately rural. To further show the disparity, in 2010, 15.2% of all rural counties were considered to have persistent poverty whereas only 3.6% of metro counties were considered to have persistent poverty.

Understanding high poverty in rural areas generally takes a structural approach, focusing on the characteristics of the community or area, such as labor markets, infrastructure, and available job training opportunities over the individual approach (Jensen, McLaughlin, & Slack, 2003). The structural approach automatically brings in contextual factors that can relate to Durkheim's concepts of integration and fragmentation, while the lack of opportunity and changing labor markets that contribute to high poverty can also provide evidence of high role conflict, stress, hopelessness, and social stratification.

One of the contributing factors to poverty in rural areas is the type of industries that drive rural economies. Johnson (2012) classified rural counties as 27.2% manufacturing dominated economies, 19.9% retirement destinations, 18.7% farming economies, and 5.3% mining economies. These economy types provide the majority of earnings in rural areas but are often based on low, uncompetitive wages. Rural areas have higher earnings in agriculture and mining than urban areas, but lower earnings in the producer services, which are business-oriented services such as information; finance and insurance; professional, scientific, and technical; and business management (United States Department of Agriculture, 2016). While almost 20% of jobs in rural areas are within this domain, only about 12% of earnings come from this market. But in urban areas, 25% of jobs and almost 30% of earnings come from producer services. Rural employees hold fewer managerial and professional positions than their urban counterparts in these labor markets (39% in rural areas vs 52% in urban areas). Wage discrepancies between rural and urban areas have also been noted with overall earnings 15% lower in

rural areas, with the highest pay gaps in the producer service sectors. Manufacturing and recreation industries also have lower wages in rural than urban areas (United States Department of Agriculture, 2016). With many rural areas dominated by a single industry (Jensen et al., 2003) or a few low wage industries, workers have limited power to change jobs or demand better pay.

As a result of low wages and limited job availability, rural areas have a large proportion of the working poor or underemployed, families that have one or two incomes from work but are unable to rise above the poverty line (Jensen et al., 2003; Johnson, 2006). Low wage jobs and underemployment contribute to poverty in rural areas, as does the lack of job availability. Rural areas suffer from outsourcing manufacturing jobs and technological advances in the farming and mining industries that reduce the demand for manual labor (Hamilton, Hamilton, Duncan, & Colocousis, 2008). Service sector jobs may be available, but often involve low wages with little opportunity for advancement without moving to larger cities. Former farmers and miners may not have the skills for professional work, nor the ability to develop these skills. All these factors contribute to low wage work and unemployment in rural communities, which adds to stress, income inequality, powerlessness, and hopelessness.

Further, education in rural areas is often limited, with poor quality public education available and limited job education and training accessibility. Poor communities are unable to put money into the education system, which can lead to low human capital among graduates, sustaining a cycle of poverty that prevents industries from moving into areas to establish better wages and training (Johnson, 2006).

Recruitment and retention of teachers in rural areas has also proven difficult (Barley, 2009; Beesley, Atwill, Blair, & Barley, 2010). Rural areas generally do not have institutes of higher education, so youth who pursue post-secondary degrees often leave rural communities and may never return due to the lack of job opportunities in the area. This has resulted in a loss of human capital, job potential and entrepreneur options, and continues a cycle of decline within some communities (Johnson, 2006).

The lack of economic opportunity in rural areas as traditional rural industries have declined has brought about changes to the traditional rural lifestyle (Jeng, 2016; Jensen et al., 2003; Johnson, 2006, 2012; Tickamyer & Duncan, 1990). Rural communities that were initially isolated have continued to lose population and change demographics, which can be associated with increased role strain and stress. Social stratification can also be exacerbated as former employed individuals lose jobs while the managers and professionals maintain jobs and improve their standing. Groups of workers who were once prominent in the community may suddenly be out of work and unable to maintain the roles they once enjoyed in a small town, increasing risk for suicide.

Fewer health services also tend to be available in rural areas (Bird, Dempsey, & Hartley, 2001; Fontanella et al., 2015; Heflinger & Christens, 2006; Jameson & Blank, 2007; Larson, Corrigan, & Cothran, 2012; Smalley & Warren, 2012). The Health Resources and Services Administration keeps track of counties that are considered health professional shortage areas (HPSA), and nearly one third of all rural residents live in an HPSA (Rabinowitz, Diamond, Markham, & Wortman, 2008). These areas are tracked for primary healthcare, mental healthcare, and dental care. Data from 2016 shows that over

64% of all medical HPSAs are rural or partially rural and nearly 62% of mental health HPSAs are rural or partially rural. Over 106 million people live in a designated mental health HPSA, with over 75% of these individuals living in a rural or partially rural area compared to 14% of the entire population (Bureau of Health Workforce, Health Resources and Services Administration (HRSA), US Department of Health & Human Services, 2017). Physician supply has been documented to be especially low in rural areas for specialists, which includes psychiatry (Meit et al., 2014). There were 263 specialists per 100,000 individuals in large metro areas as of 2010 compared to 30 specialists per 100,000 in the most rural areas (Meit et al., 2014). Rural areas tend to have difficulty recruiting and retaining healthcare professionals even though special incentives have been offered for rural healthcare practice (Monk, 2007; Weinhold & Gurtner, 2014; Wheat, Leeper, Murphy, Brandon, & Jackson, 2017).

Health insurance can also be lacking among individuals in rural areas, as several studies have identified higher rates of uninsured individuals living outside of metro areas (Bowers & Holmes, 2013; Coburn, McBride, & Ziller, 2002; Glover, Moore, Probst, & Samuels, 2004; Meit et al., 2014; Ziller, Coburn, Anderson, & Loux, 2008). Lack of insurance can limit the use of services and increase the economic impact if a health concern were to arise for the individual without insurance.

The lack of mental health and specialty services results in rural residents needing to travel longer distances for care, especially emergency and specialty care. Local health services often have long wait times due to higher demand than supply of health services. This can increase stress and role conflict among those suffering from or caring for others

with chronic mental or medical illnesses as they must spend a great deal of time accessing services which can impact income and employment. Areas that lack services could be at increased risk for high suicide rates due to the stress, conflict, and financial burden that comes from seeking care.

Rural communities do have some positive aspects that are likely to protect against suicide. Many rural areas have been shown to be highly integrated communities, where everyone knows everyone else and people rely on one another for support (Cantrell, Valley-Gray, & Cash, 2012; Hirsch & Cukrowicz, 2014). Strong bonds exist within families, churches, and communities that can be used to provide support during times of high stress and conflict to protect against feelings of isolation, hopelessness, and distress. As rural communities continue to change, these bonds may begin to deteriorate as population loss erodes the networks that are in place, reducing the social capital within the community and increasing the impact of negative events.

Review of the Literature

Several contextual factors within a community can be used to measure different constructs that come from the theories described above. Measures of socioeconomic deprivation are becoming increasingly common in the suicide literature to understand how stress and social stratification can impact groups of individuals. Fragmentation and social capital have been used to account for levels of integration within a community. Social capital and availability of providers can be considered neighborhood resources that are protective factors against increased stress within a community, both providing opportunities to develop coping skills and appropriately deal with stress. Each of these

topics, along with others that regularly appear in the suicide literature, will be discussed below. Studies that examine contextual factors often do not include a discussion of variance by rural and urban space, but these differences are highlighted below when they are available.

Methodologies.

***Selection of Studies*.** An extensive search of the literature was conducted to better understand the evidence of contextual factors influencing suicide rates. Several medical databases were searched, and snowballing techniques were used to gather the articles summarized below. The focus of the literature review was published, peer-reviewed work since 2000, that included key words related to suicide, ecological or contextual factors, and the specific areas to be outlined below of socioeconomic deprivation, social fragmentation, social capital, health services/providers, veterans, gun availability, or alcohol. All studies needed to have an outcome of suicide, although how the outcome was measured could vary, as some used rates and other use counts depending on the statistical methodology.

***Samples*.** The studies that were examined for this literature review had a great deal of variation in the sample. Most of the studies examined suicides for all ages, frequently with sub analyses to further delineate different age groups. Some articles restricted suicides to only those who were 15, or 25 and older to exclude very young suicides as these are less common and may have different contributing factors (Blakely et al., 2006; Collings, Ivory, Blakely, & Atkinson, 2009; Cylus, Glymour, & Avendano, 2014; Mok et al., 2013; Pearce, Barnett, Collings, & Jones, 2007; Ross, Yakovlev, &

Carson, 2012; Taylor, Page, Morrell, Harrison, & Carter, 2005). Often studies would also exclude anyone 65 and older (or a similar upper age limit), again likely due to differences in contributing factors among the elderly population (Cylus et al., 2014; Kreitman, Carstairs, & Duffy, 1991; O'Farrell, Corcoran, & Perry, 2016; O'Reilly, Rosato, Connolly, & Cardwell, 2008; Ross et al., 2012). Some studies only looked at male suicides (Crawford & Prince, 1999; Fontenot, 2015; Kreitman et al., 1991; Pearce et al., 2007; Trgovac, Kedron, & Bagchi-Sen, 2015), but the majority included all genders while controlling for gender or stratifying by gender for analyses.

Several countries are also included in this review of the literature. While the majority of suicide work comes from Australia and New Zealand, Western Europe and North America, a few studies from other locations (e.g. Brazil, Iran) are also included due to the limited availability of research on suicide and specific contextual factors. The level of analysis often varies based on the location of the research and the access of data. Several studies include large country level analyses (Andres, 2005; Barth et al., 2011; Fountoulakis et al., 2014; Inoue et al., 2016; Lorant et al., 2005; Noh, 2009; Nordt, Warnke, Seifritz, & Kawohl, 2015; Pritchard, 1988), others include states or provinces (Burrows, Auger, Gamache, St-Laurent, & Hamel, 2011; Cylus et al., 2014; DeFina & Hannon, 2015; Kiadaliri, Saadat, Shahnavazi, & Haghparast-Bidgoli, 2014; Rezaeian et al., 2005; Ross et al., 2012; Smith & Kawachi, 2014; Tondo et al., 2006), and others include smaller level analyses such as counties, municipalities, or districts (Congdon, 2011b, 2011a; Hong & Knapp, 2013; Kposowa, 2009; Pearce et al., 2007; Recker & Moore, 2016; Singh et al., 2013; Whitley et al., 1999; Zammit et al., 2014).

Lastly, the samples vary drastically by year of data as well. Most of the studies use 3 to 15 years of data (Browning, 2005; Fiske et al., 2005; Fontenot, 2015; Hooghe & Vanhoutte, 2011; Middleton et al., 2003; Nordt et al., 2015; Recker & Moore, 2016; Singh et al., 2013; Taylor et al., 2005), with a few looking at only 1 or 2 years (Bando, Lester, Bando, & Lester, 2014; Kawaguchi & Koike, 2016; O'Reilly et al., 2008; Tondo et al., 2006), and a few looking at decades of data (Andres, 2005; Barth et al., 2011; Berk, Dodd, & Henry, 2006; Cylus et al., 2014; Denney, Wadsworth, Rogers, & Pampel, 2015; Noh, 2009). Most studies examine data from the 1990's and 2000's, although availability of data varies based on the level of analysis and country the data is from.

Design. Like the samples described above, the designs also vary drastically across studies of suicide. The primary outcome of the suicide studies was either the overall rate of suicide in a community (generally per 100,000 individuals in the population) or the count of suicides in a community. Studies that used the rate of suicide tended to use linear regression analyses often with a log transformation on suicide rates to account for a non-normal distribution (Andres, 2005; Gibson, 2016; Morrell, Taylor, Quine, & Kerr, 1993; Stark, Hopkins, Gibbs, Belbin, & Hay, 2007; Whitley et al., 1999). Poisson and negative binomial regression techniques were regularly used with count suicide data, as suicide counts tend to exhibit these distribution types (Browning, 2005; Johannessen, Dieserud, Claussen, & Zahl, 2011; Kiadaliri et al., 2014; Kposowa, 2009; Middleton et al., 2003; O'Farrell et al., 2016; Rezaeian et al., 2005; Singh et al., 2013; Taylor et al., 2005). Some studies used principal components analysis to reduce a large number of predictor variables that are highly correlated (Bando et al., 2014; Browning, 2005;

Chauvin, 2013; Fontenot, 2015; Kapusta et al., 2010; Pirkola, Sund, Sailas, & Wahlbeck, 2009).

For statistical analyses, older studies identified in this review tended to be correlational studies (Bagley, 1991; Pritchard, 1988; Young, 1990), while more recent studies use advanced techniques of spatial analyses (Chauvin, 2013; DeFina & Hannon, 2015; Fontenot, 2015; Hong & Knapp, 2013; Hooghe & Vanhoutte, 2011; Hsu, Chang, Lee, & Yip, 2015; Yoon, Noh, Han, Jung-Choi, & Khang, 2015) and multilevel models (Collings et al., 2009; Lee, Lee, Noh, & Khang, 2014; Mok et al., 2013; Zammit et al., 2014). Among the studies using spatial analyses, some tested for spatial autocorrelation but did not find any (Rezaeian, Dunn, St Leger, & Appleby, 2006, 2007), others found spatial autocorrelation and controlled for it by using spatial lag or spatial error models (Hong & Knapp, 2013; Hooghe & Vanhoutte, 2011). A few used more specialized spatial analyses such as conditional autoregressive (CAR) models (Kapusta et al., 2010; Yoon et al., 2015) or geographically weighted regression (GWR) analyses (Trgovac et al., 2015). Other studies that had both individual and community level factors conducted Cox proportional hazard models and adjusted for area level factors (Burrows et al., 2011; O'Reilly et al., 2008).

Several studies used longitudinal data as well, although they tended to be international studies analyzing suicide rates by country (Andres, 2005; Fountoulakis et al., 2014; Nordt et al., 2015) or US studies that examined state level suicide rates (Cylus et al., 2014; DeFina & Hannon, 2015). Only one study was found that looked at county level suicide rates in a longitudinal model and it only included counties from 16 states

(Kerr et al., 2017). In addition, the Kerr study examined suicide rates for individuals who had a blood alcohol level over the legal limit at the time of death and focused on poverty, job loss, and housing foreclosure as explanatory factors. No studies have looked at county suicide rates across the entire nation in a longitudinal study.

***Predictor variables*.** A variety of predictor variables have been used in suicide studies that relate to suicide rates at the community level. The variables described below were the focus for this study because they relate to the theories described at the beginning of this chapter. There was a great deal of variation in how these variables were measured and which variables were included in the different studies.

*Socioeconomic deprivation***.** Variables that represent some type of socioeconomic deprivation are becoming increasingly common in studies examining suicide rates. There are several variables that have been developed to understand health and mental health outcomes that also apply to suicide outcomes. Three indices that represent economic deprivation are often used in suicide studies. Two indices were developed in European countries to classify levels of deprivation. The Townsend deprivation index (Townsend et al., 1988) was developed on data from northern England and includes four community level variables: unemployment rate, car ownership, overcrowded housing, and housing tenure (percent of housing not owner occupied). The Carstairs deprivation index (Carstairs & Morris, 1989b, 1989a) was developed using data from England, Wales, and Scotland and also contains four variables that are similar to the Townsend index: percent living in a house with more than one person per room, percent in household with the head of household in social class IV or V (based on occupation), unemployment rate, and

households without a car. Both indices have been used in suicide studies and adapted to data available in other countries. At least one study has compared the two indices and shown that they both work well in understanding differences in deprivation among areas (Morris & Carstairs, 1991).

While these two deprivation indices could potentially be adapted to fit United States data, another researcher has created a more exhaustive deprivation index for use among US data. Singh (2003) first developed the Area Deprivation Index from 1990 census data and used factor analysis on 21 indicators to develop a final index that included 17 variables. These variables include two measures of educational distribution (i.e. percent of individuals with less than 9 years of education and percent of individuals with 12 or more years of education), median family income, income disparity (i.e. Gini coefficient), occupational composition, unemployment rate, family poverty rate, percent of individuals below 150% of the poverty line, rate of single parent households, home ownership rate, median home value, median gross rent, median monthly mortgage, household crowding, percent of households without a telephone, percent of households without indoor plumbing, and percent of households without access to a motor vehicle. Singh later updated his index based on new data available in the 2000 census and added the following five variables: median annual real estate taxes, percent of households receiving supplemental security income, percent of households receiving public assistance, median rooms per housing unit, and the percent of housing units with four or more bedrooms (Singh et al., 2013). This variable has been used in several studies within

the United States to understand area level deprivation in a more complete way than what either the Townsend or Carstairs variables represent.

Some of the articles that were reviewed include other indexes that measure socioeconomic deprivation, but they tend to be country specific, such as the New Zealand deprivation index (Collings et al., 2009; Pearce et al., 2007) and the index of deprivation developed specifically for England (Rezaeian et al., 2005, 2006, 2007). In addition, when variables are not available to create one of the above-mentioned indices, individual variables that represent economic deprivation are used to understand relationships with suicide. Several studies that are included in this review use only one or two variables, such as unemployment (Chen, Yip, Lee, Fan, & Fu, 2010; Morrell et al., 1993; Nordt et al., 2015; Walsh & Charnigo, 2012), poverty rate (Kerr et al., 2017; Young, 1990), or female labor participation (Andres, 2005; Phillips & Nugent, 2014; B. Yang, Lester, & Yang, 1992) to understand how economic factors contribute to community level suicide rates.

Social fragmentation. Almost directly out of Durkheim's initial study on community level suicide rates, an index for the level of social fragmentation has been developed to operationalize how integrated and fragmented a society is. Congdon is credited with developing an anomie variable in the mid 1990's, which was modified to become a fragmentation index by Whitley and colleagues (Congdon, 1996; Whitley et al., 1999). The index includes the four variables for divorce rate, percent living alone, renter occupied housing units, and the percentage of people who have moved within the last year. When an index is used for fragmentation in the suicide literature, it is almost always

Congdon's fragmentation variable (Collings et al., 2009; Congdon, 2011b; Evans, Middleton, & Gunnell, 2004; Middleton et al., 2003; O'Farrell et al., 2016; O'Reilly et al., 2008). When an index is not used, individual variables have been used such as divorce rate (Barth et al., 2011; Hong & Knapp, 2013; Law, Kõlves, & De Leo, 2016; Trgovac et al., 2015), migration (Trgovac et al., 2015), and the percentage of renter occupied housing (Law et al., 2016). Divorce rate or another measure of marital status is the most common individual variable used in the literature for fragmentation, whereas the other single variables are much less common.

Social capital. Unlike fragmentation, measures of social capital can vary drastically across studies of suicide. Religious and/or social organizations per capita were used to summarize social capital in several studies (Chauvin, 2013; Fontenot, 2015; Recker & Moore, 2016; Smith & Kawachi, 2014). Studies with access to individual data have summarized percentages of individuals in a community involved in organizations, simply through participation (Kim & Jung, 2011), those who volunteer (Blakely et al., 2006), or those who claim a specific religious affiliation (Walker, 2008). Other studies using survey data have summarized questions that related to social trust within an area (Desai et al., 2005; Kelly et al., 2009). At least one index of social capital exists using United States data and was developed at the University of Pennsylvania (Rupasingha, Goetz, & Freshwater, 2006). The index has been created for at least three different years and uses data from the Community Business Patterns (CBP) survey along with a few other factors to determine county level social capital. The variables included in the index are the number of bowling centers, the number of civic and social associations, the

number of physical fitness facilities, the number of public golf courses, the number of religious organizations, the number of business associations, the number of political organizations, the number of professional organizations, the number of labor organizations, the number of sport clubs, managers, and promoters, voter turnout, the most recent census response rate, and the number of registered non-profit organizations (without an international approach). While this index has been used infrequently to examine the relationship between social capital and suicide, it has more often been used to examine the relationship between social capital and other factors.

Health service availability. Similar to the social capital measures, there is little consistency among the studies that examine health and mental health services available in a community in relation to suicide. It is becoming increasingly common to see the number of providers per capita, whether primary care or psychiatrist, included in studies analyzing mental health outcomes (Fiske et al., 2005; Kposowa, 2009; Tondo et al., 2006; Walsh & Charnigo, 2012), but this information is not always readily available so other variables may be used. General service availability in a community, such as outpatient services, 24-hour crisis emergency service, inpatient beds, safety net services, and psychiatric consultations (Cooper, Lezotte, Jacobellis, & DiGuiseppi, 2006; Johannessen et al., 2011; Pirkola et al., 2009) have all been used to understand availability of services and how it relates to suicide. Several studies have examined the amount of spending on mental health at the state or hospital level (Ross et al., 2012; Zimmerman, 1990). A few of the studies reviewed were even able to measure the availability of medications in a community to see if the rate of prescriptions of certain medications reduced the overall

risk of suicide (Johannessen et al., 2011; Kapusta et al., 2009). Some studies have started to examine how health insurance impacts suicide rates (Klick & Markowitz, 2006; Lang, 2013) with the expectation that insurance will increase access and utilization of services. Overall, the type of predictor variable used for services seems to depend on what data is available at the level of analysis specified in the study. Different countries provide and track different data to monitor the availability and accessibility of health and mental health services.

Other variables. Most of the studies mentioned above control for one or two of the predictors already described along with several other variables. Study designs that allow for both individual and community level variables will regularly control for individual factors such age, sex, race, and income (Collings et al., 2009; Lee et al., 2014; O'Reilly et al., 2008; Zammit et al., 2014). Other common variables that are controlled for but do not fit well within one of the areas described above include firearm access, alcohol consumption, and veteran populations.

Firearm availability is a variable primarily studied within the United States, with few other countries looking at firearm availability or regulation. There are multiple ways to study firearm access within the US. Many studies summarize survey data, such as the Behavioral Risk Factor Surveillance System Survey (BRFSS), to estimate the percentage of households with firearms available in them (Kposowa, Hamilton, & Wang, 2016; Miller, Lippmann, Azrael, & Hemenway, 2007; Opoliner, Azrael, Barber, Fitzmaurice, & Miller, 2014). Other studies look at how laws and regulations that relate to firearms affect suicide rates within an area (Andrés & Hempstead, 2011; Crifasi, Meyers, Vernick, &

Webster, 2015; Siegel & Rothman, 2016). Data are neither readily available nor accessible to measure access to firearms within an area smaller than the state, so firearm availability tends to be a state level variable.

Similarly, alcohol consumption has often been studied in the literature through state or country level variables (Innamorati et al., 2009; Kerr, Subbaraman, & Ye, 2011; Landberg, 2009; Ramstedt, 2001, 2005). The per capita consumption of alcohol can be measured by state or the country as a whole through the Alcohol Epidemiologic Data System (AEDS), but county level rates are far less common. The percentage of veterans in a community has recently been added as a census variable and has started to be included in suicide studies within the United States also (Blow et al., 2012; Fontenot, 2015; Kaplan, McFarland, & Huguet, 2009).

Another variable that is often included in suicide studies is a measure of rurality or urbanicity in an area. Sometimes rural and urban location might be the sole focus of a study, as described in the geographical trends section in the introduction. But often a simple measure for rurality is included as a control variable since rural rates are well documented as higher than urban rates. Some researchers include a measure for population density to account for more rural location (O'Farrell et al., 2016; Stark et al., 2007). Other studies use classification schemes that have been developed and used for other areas of research or governmental purposes (Gartner, Farewell, Roach, & Dunstan, 2011; Middleton et al., 2003; Singh, 2003). In the United States, there are multiple systems that classify rural and urban areas including the rural-urban continuum codes (RUCC), the urban influence codes (UIC), the rural-urban commuting areas (RUCA), and

metropolitan statistical areas (MSA). The RUCC codes, or some collapsed variation of the codes, are often used in the suicide literature when more than three categories are used (Fontanella et al., 2015; Singh & Siahpush, 2002). They were developed by the Office of Management and Budget (US Department of Agriculture, 2016) and consist of nine categories that classify counties based on the degree of urbanization and adjacency to a metro area. The RUCC codes are updated after each decennial census and were most recently updated in 2013. Suicide studies often simplify these measures into a dichotomous variable of rural and urban or collapse similar categories into fewer groups.

Findings.

Although a great deal of variation exists across the design and samples used in the analysis of contextual factors and area level suicide, the results often show the same patterns. Factors that are regularly used in the suicide literature have consistently shown similar results, with few exceptions. The contextual topics that have less empirical research available show more variability and inconsistency in the results. Using the same predictor variables identified from the suicide studies above, the findings are discussed below.

***Socioeconomic deprivation*.** Several factors can contribute to the economic deprivation of an area, and as described above, indices are often used to simplify multiple variables into a general concept that can demonstrate the relationship between deprivation and suicide. Multiple indices have been used but largely come to the same conclusion. Rezaeian and colleagues (2005, 2006, 2007) published several studies that looked at how the index of deprivation in England related to suicide across different

areas. While the level of analysis used impacted significance (e.g. large geographical areas, i.e. the local authority, were not significant) (Rezaeian et al., 2005), high deprivation was consistently found to be associated with high suicide rates in small areas, particularly among males (Rezaeian et al., 2006, 2007). Likewise, studies that looked at other areas within England, Wales, and Scotland all found high rates of deprivation to be associated with high suicide rates (Congdon, 1996; Gartner et al., 2011; Middleton et al., 2003; Mok et al., 2013; Stark et al., 2007; Whitley et al., 1999). The majority of these studies used the Townsend index (Congdon, 1996; Gartner et al., 2011; Middleton et al., 2003; Whitley et al., 1999) but the Carstairs index showed similar results (Mok et al., 2013; Stark et al., 2007). In Gartner's analysis (2011), multiple deprivation variables were used to understand suicide rates in England and Wales and no substantial differences were found based on the index used. Additional studies in Europe have shown similar results in regards to deprivation, with high suicide rates and high deprivation positively associated (Hooghe & Vanhoutte, 2011; O'Farrell et al., 2016).

Similar findings linking high deprivation to high suicide rates or increased risk for suicide have also been identified in Australia (Taylor et al., 2005), New Zealand (Collings et al., 2009; Pearce et al., 2007), South Korea (Hong & Knapp, 2013; Lee et al., 2014; Yoon et al., 2015), China (Li, Xu, Zhang, & Liu, 2016), Hong Kong (Hsu et al., 2015), and even Iran, where deprivation was measured as the human development index (Kiadaliri et al., 2014). Measures for material deprivation, which are similar to economic deprivation measures, have been linked to high suicide rates across Canada (Burrows, Auger, Roy, & Alix, 2010; Burrows et al., 2011). Several studies that included both

individual and contextual level measures found that while deprivation was associated with suicide prior to any individual adjustment, deprivation was no longer significant after accounting for individual factors such as age, ethnicity, marital status, and household size (Burrows et al., 2011; O'Reilly et al., 2008; Zammit et al., 2014). At least one study found that area deprivation remained a significant predictor for suicide even after individual factors were added to the model (Martikainen, Mäki, & Blomgren, 2004). Area deprivation may not compensate for individual risk factors, but it may add to suicide risk.

A review of the literature on how contextual factors relate to suicide found that of 21 analyses with a significant relationship between a poverty measure or deprivation index such as Townsend or Carstairs and suicide, all but one showed that as deprivation/poverty increased, so did suicide rates (Rehkopf & Buka, 2006). The same review noted an additional 16 analyses that found no relationship between deprivation/poverty and suicide, although little information is provided to understand this lack of significance. The area of analysis may contribute to a nonsignificant finding, as many studies are based on large geographic areas such as the country which can mask the relationship between deprivation and suicide. The additional variables used in the statistical models could also lead to a nonsignificant finding for deprivation. For example, at least two of the nonsignificant findings were due to fragmentation being related to suicide and eliminating deprivation from the final model (Evans et al., 2004; Whitley et al., 1999).

The use of deprivation indices in the United States is less common, as indices like the Townsend and Carstairs were developed specifically for England. An adaptation of these indices was developed by Singh (Singh, 2003) to begin comparing deprivation within the United States with health and mortality ratings at the county level. Singh and colleagues (Singh et al., 2013) looked specifically at youth mortality and the relationship with area deprivation and found that deprivation was associated with youth mortality, and more specifically, youth suicide. Additional studies have modified deprivation to include fewer variables for the United States (e.g. poverty rate, managerial professionals, unemployment, college graduates/high school dropouts, and female headed households) and found similar results between deprivation and suicide rates (Congdon, 2011b, 2011a; Denney et al., 2015; Gibson, 2016).

At least two studies in England looked at how deprivation impacted rural and urban differences in suicide rates. No significant interaction between rural location and area deprivation was found in England and Wales between 2002 and 2004 (Gartner et al., 2011)**.** An earlier study found that controlling for area deprivation through the Townsend index did not explain the changes in suicide rates in rural areas (Middleton et al., 2003). At least one US study also examined the relationship between rural, area deprivation, and suicide in youth (Singh et al., 2013). The authors found that while suicide rates tended to be higher in rural areas and in areas with higher deprivation separately, the relationship between deprivation and suicide was only significant for young men when a rural variable was added to the same model. Rural location was associated with suicide rates for both young men and young women even after deprivation was included in the model.

While indices are becoming more common for understanding area level deprivation, numerous studies include single variables to represent the economic condition of an area. Unemployment rate is often used as a proxy for the level of economic disadvantage in an area and was one of the factors Durkheim (1951) considered in his initial work on suicide, claiming that high unemployment rates were associated with high suicide rates. Multiple literature reviews have concluded that unemployment rates are positively associated with suicide rates (Chen, Choi, Mori, Sawada, & Sugano, 2012; Milner, Page, & Lamontagne, 2014; Platt, 1984; Rehkopf & Buka, 2006), although some individual studies have found different results (Andres, 2005; Crawford & Prince, 1999; DeFina & Hannon, 2015). One study used a geographical weighted regression to find that while overall suicide and unemployment were positively associated in the US, when spatial location was accounted for, the relationship varied by region with low unemployment associated with increased suicide in the eastern US and high unemployment with increased suicide elsewhere (Trgovac et al., 2015). The authors suggest that social support in eastern states, whether through social or governmental programs, may counter the negative impact of unemployment.

Unemployment and suicide has also been examined over time. Two studies examining United States state level data across several decades found that high unemployment rates were associated with high suicide rates (Cylus et al., 2014; Wasserman, 1984) and one found no relationship early on in the study period, but in more recent decades (i.e. 1990-2010), unemployment was positively associated with the suicide rate (DeFina & Hannon, 2015). Additional studies have examined only a few

years of more recent US data and found unemployment rate and suicide rate positively associated at both the county level (Walsh & Charnigo, 2012) and the state level (Phillips & Nugent, 2014). One study even showed that while unemployment was associated with high suicide rates, the availability of unemployment benefits protected against high suicide rates (Cylus et al., 2014).

International studies have also examined the relationship between unemployment and suicide, with an overwhelming majority finding a positive relationship between the two. Multiple articles examined data from 15 or more countries and concluded that suicide and unemployment were positively associated, even while controlling for other social and economic factors (Barth et al., 2011; Fountoulakis et al., 2014; Noh, 2009; Nordt et al., 2015). Other studies that examined smaller areas within individual countries have also found a positive relationship (Berk et al., 2006; Chen et al., 2010; Morrell et al., 1993; Pritchard, 1988; Yang et al., 1992). One study analyzing 15 European countries between 1970 and 1998 found no association between the suicide rate and unemployment, but did find a negative association between suicide rates and economic growth which may have masked the relationship with unemployment (Andres, 2005).

There are only a few studies that show a negative correlation between suicide and unemployment (Bando et al., 2014; Crawford & Prince, 1999). The review by Rehkopf and Buka (2006) found a total of 63 analyses that looked at how unemployment and suicide rates were related and found that while most of the analyses were not significant (59%), unemployment was associated with increased suicide rates in 73% of the significant analyses. A more recent review examined 30 studies that looked at the

relationship between unemployment and suicide and concluded there was a positive relationship, although it tended to be stronger among males than females (Milner, Page, et al., 2013).

Other measures of socioeconomic status are also included in the literature. Positive associations between suicide and area poverty rates are well documented (Bagley, 1991; Inoue et al., 2016; Kerr et al., 2017; Young, 1990). The review by Milner and colleagues (2013) reviewed 39 studies that examined low income and suicide, with an overwhelming majority finding low income increased the risk of suicide. Similarly, median household income has been studied and shows an inverse relationship with suicide (Chang et al., 2011; Machado, Rasella, & Santos, 2015). Economic growth (Barth et al., 2011; Noh, 2009) and education (Lorant et al., 2005; Machado et al., 2015) have also been shown to have an inverse relationship with suicide rates. One study examining county level data in Florida between 2001 and 2003 did not find a significant relationship between suicide and education, income, or poverty (Browning, 2005) although they were all inverse in direction. The study may not have had enough power to determine significant relationships since there are only 67 counties in Florida.

Additional studies have examined income inequality within a community rather than the other economic variables proposed thus far. Findings tend to indicate that higher levels of income inequality in a community are associated with higher suicide rates (Chen et al., 2012; Chen, Choi, Sawada, & others, 2008; Milner, Hjelmeland, Arensman, & De Leo, 2013). The Gini index has been used to measure income inequality and is positively

associated with high suicide rates in multiple studies (Chen et al., 2008; Machado et al., 2015; Minoiu & Andres, 2008).

Social fragmentation. Like deprivation, the study of fragmentation is often through an index. The primary index used to study fragmentation was developed for suicide research and comes out of Durkheim's concept of anomic suicides as the index was initially called an anomic index (Congdon, 1996). The index is more commonly referred to as fragmentation, or Congdon's fragmentation, ever since it was adopted for use in Whitley's research (Whitley et al., 1999). This variable has consistently shown a positive relationship with suicide across several countries and levels of analysis (Congdon, 1996, 2011b, 2011a; Evans et al., 2004; Middleton et al., 2003; Mok et al., 2013; Whitley et al., 1999). Of the few exceptions, one study found no significant linear association with suicide rates but a potential u-shaped relationship (Collings et al., 2009), another study found a significant relationship that was eliminated once individual level variables (e.g. sex, ethnicity, education) were introduced into the model (O'Reilly et al., 2008), and a third study found that fragmentation was only associated with suicides among those aged 40 to 64 (O'Farrell et al., 2016).

Several studies did not include an index that represents fragmentation but used some of the variables that make up the fragmentation index. Numerous studies used the divorce rate of a community as a contextual factor, and the majority demonstrated that divorce rate and suicide rate were positively associated (Barth et al., 2011; Browning, 2005; Chang et al., 2011; Hempstead, 2006; Trgovac et al., 2015; Wasserman, 1984; Yang et al., 1992). Literature reviews have drawn the same conclusions, although it has

been suggested that male suicide rates are more strongly correlated with divorce rates (Chen et al., 2012; Milner, Hjelmeland, et al., 2013). Measures for population turnover, whether change in population (Hempstead, 2006), out migration (Li et al., 2016), or in migration (Law et al., 2016), have shown positive associations with suicide rates, although literature reviews are inconclusive as other factors included in statistical models can eliminate the relationship between population turnover and suicide (Chen et al., 2012; Milner, Hjelmeland, et al., 2013). At least one study looked at renter occupied homes and found higher suicide rates associated with high tenant housing (Law et al., 2016). Fertility rates have also been studied and generally found to be associated with decreased suicide rates (Andres, 2005; Barth et al., 2011; Chen et al., 2012; Hong & Knapp, 2013; Milner, Hjelmeland, et al., 2013; Noh, 2009). Studies that measure female labor participation rates and rates of people living alone in relation to suicide rates have had mixed findings (Chen et al., 2012; Hempstead, 2006; Milner, Hjelmeland, et al., 2013), possibly due to other contextual factors at play within an area.

Several studies actually examined area deprivation and fragmentation in the same study (Collings et al., 2009; Congdon, 1996, 2011b, 2011a; Evans et al., 2004; Middleton et al., 2003; Mok et al., 2013; O'Farrell et al., 2016; O'Reilly et al., 2008; Whitley et al., 1999), with many concluding both concepts are positively associated with suicide (Congdon, 1996, 2011b, 2011a; Middleton et al., 2003; Mok et al., 2013; Whitley et al., 1999). A couple of the studies found that fragmentation had a greater impact on suicide rates than deprivation (Evans et al., 2004; Whitley et al., 1999), while others found that deprivation had more of an impact than fragmentation (Collings et al., 2009; O'Farrell et

al., 2016). At least one study found that neither variable was significant in a final model that included individual factors (O'Reilly et al., 2008).

Few studies have looked at how fragmentation relates to rural suicides. The studies that include a variable for rurality have found that neither fragmentation nor deprivation account for the entire difference in suicide rates between rural and urban areas (Congdon, 2011b, 2011a; Middleton et al., 2003; O'Farrell et al., 2016). Additional contextual factors could contribute to the rural and urban differences, or interactions between geographic location and fragmentation (or deprivation) may exist. Rural areas may be more strongly impacted by fragmentation and/or deprivation due to the history of poverty in rural areas, the lack of support systems, or the general culture of the area. Testing of interactions between geographic location and deprivation or fragmentation may explain some of the differences that persist, as rural areas may respond differently to deprivation and fragmentation than urban areas.

Social capital. Less research is available for social capital and suicide, but the findings tend to show a negative relationship although the way social capital is measured can vary drastically across studies. A literature review in 2005 looked at studies that examined individual and/or area social capital factors as they related to mental health or suicide in the United States (De Silva, McKenzie, Harpham, & Huttly, 2005). The authors found only two studies that examined how area level social capital influences suicide and the results were mixed. One study found that male suicide rates increased as social capital increased but female suicide rates were unrelated, although the study was never actually published (Harper, 2005 cited in De Silva et al., 2005). The other study

showed that state-level social capital and suicide were inversely associated among individuals who had been released from a Department of Veteran Affairs inpatient psychiatric hospital (Desai et al., 2005).

Another study used county level data across the US to look at the association of the social capital variable that was developed by Rupasingha and colleagues (2006) and suicide rates from 2005 to 2007. There was no significant relationship between social capital and suicide, but social capital was thought to have influence on the other factors included in the model, particularly deprivation, fragmentation and rurality (Congdon, 2011a). Several other studies have examined the relationship between suicide and social capital in the United States and found inverse relationships, indicating social capital in a community could be protective against high suicide rates (Chauvin, 2013; Fontenot, 2015; Kelly et al., 2009; Recker & Moore, 2016; Smith & Kawachi, 2014). The way social capital is captured varies in these studies but generally includes organizations and religious congregations. Studies that look at specific groups in the US have shown that the number of religious groups is inversely related to suicide (Fontenot, 2015; Walker, 2008), but the number of civic organizations is not necessarily related, particularly in larger cities (Fontenot, 2015) or in the south (Chauvin, 2013). Smith and Kawachi (2014) found that the availability of community organizations was associated with lower white female suicide rates and group membership was inversely related to white male suicide rates.

Studies from other countries have similar findings of inverse relationships, although the measure of social capital tends to vary more, using summaries of social trust

from individual surveys (Kelly et al., 2009), volunteering rates (Blakely et al., 2006), group participation (Kim & Jung, 2011), or community integration (Yamamura, 2010). A few studies include religious participation as a measure of social capital and find it is also related to lower suicide rates (Balint, Dome, Daroczi, Gonda, & Rihmer, 2014; Panczak et al., 2013), which agrees with Durkheim's conclusions from a century ago (1951). A few literature reviews have also summarized the impact of religion on suicide rates and found inverse relationships (Chen et al., 2012; Milner, Hjelmeland, et al., 2013), although culture, age, and denomination tended to play a rule in the findings.

Social capital has not been well studied across geographical location. Rural locations have historically been more religious, especially across the south and Midwest (Glenna, 2003; Stark, Riordan, & O'Connor, 2011). The availability of social capital can provide social support and resources against stress that may arise with negative life events. Rural communities have been noted as having strong ties within the community (Duncan, 2000), but this may be eroding as rural areas have been experiencing population loss and changing demographics (Johnson, 2003).

Health service availability. Few analyses have been conducted on the relationship of access to and availability of mental health services to suicide rates. Studies that have been conducted in the United States look at several different aspects of availability of care. At least three studies have looked at state spending related to mental health services or hospital services (Ross et al., 2012; Tondo et al., 2006; Zimmerman, 1990), with only one finding a significant inverse relationship (Tondo et al., 2006). Several studies have looked at the availability or density of mental health and/or primary care providers within

a community with mixed results. Two studies found availability of psychiatrists to be related to lower suicide rates (Kposowa, 2009; Tondo et al., 2006), one found availability of mental health providers not significantly related to suicide (Fiske et al., 2005), and one found that the availability of a mental health safety-net within the community was associated with decreases in suicidal behavior (Cooper et al., 2006). Findings related to primary care providers have been mixed with nonsignificant (Fiske et al., 2005; Kposowa, 2009), negative (Tondo et al., 2006), and positive relationships to suicide (Walsh & Charnigo, 2012) being demonstrated within different studies conducted around the US. Health insurance mandates have also shown mixed results; one study found no impact of mental health insurance mandates on suicide rates (Klick & Markowitz, 2006) while another study found up to a 5% decrease in suicide rates where health insurance laws included physical and mental health components (Lang, 2013). Access to newer antidepressant medications (i.e. SSRIs and SNRIs) has been shown to be related to lower suicide rates in studies that are able to use medication availability measures (Gibbons, Hur, Bhaumik, & Mann, 2005; Grunebaum, Ellis, Li, Oquendo, & Mann, 2004; Olfson, Shaffer, Marcus, & Greenberg, 2003).

Similar international studies have shown mixed results related to primary care providers, with most studies showing no significant relationship (Kapusta et al., 2010; Korošec Jagodič, Rokavec, Agius, & Pregelj, 2013) and one showing physician density related to high suicide rates (Kawaguchi & Koike, 2016). Those that look at density of psychiatrists or psychotherapists found availability was associated with lower suicide rates (Kapusta et al., 2009, 2010; Kawaguchi & Koike, 2016; Korošec Jagodič et al.,

2013). The sale of antidepressant medications was monitored in a few European countries and showed higher availability was related to lower suicide rates (Johannessen et al., 2011; Kapusta et al., 2009; Korošec Jagodič et al., 2013), which agrees with several studies from the US. One study in Norway looked at how the number of psychiatric discharges, psychiatric consults, inpatient days, and hospital beds were related to suicide rates but found no significant relationship beyond the antidepressant sales mentioned previously (Johannessen et al., 2011). A similar study in Finland found that availability of outpatient services, 24 hour emergency services, psychiatric admissions, psychiatric inpatient days, and involuntary psychiatric admissions did not have a significant relationship to suicide but the ratio of outpatient services to inpatient services was associated with lower suicide rates (Pirkola et al., 2009).

As mentioned previously, there is a shortage of mental health care professionals and services in rural areas (Bird et al., 2001; Fontanella et al., 2015). Lack of services is likely to affect a larger proportion of rural residents than urban residents, but some urban areas also have very limited access to services (Rabinowitz et al., 2008). Rural residents tend to have additional issues with accessing care beyond the lack of availability. Wait times and travel times to care are often greater since services, especially specialty services, tend to be in located in urban settings (DeLeon, Kenkel, & Shaw, 2012; Smalley & Warren, 2012). Transportation is also a major concern in rural areas since most do not have a public transportation system as compared to urban areas where some public transportation likely exists (DeLeon et al., 2012; Smalley & Warren, 2012). Rural

location could potentially interact with the lack of services available to increase the rates of suicide.

Firearms. Availability of firearms is well studied relating to suicide rates, however there is no single variable that is regularly used at the contextual level. Several case-control studies have been conducted that show those who die by suicide, and more specifically firearm suicide, are more likely to have had firearms in the home (Beautrais et al., 1996; Brent et al., 1993; Shah et al., 2000). Numerous studies, regardless of the measure of firearm availability, have shown a positive correlation between firearm ownership and suicide rates (Anestis & Houtsma, 2018; Kposowa et al., 2016; Miller et al., 2012, 2007; Miller & Hemenway, 2013; Opoliner et al., 2014; Price, Mrdjenovich, & Dake, 2009; Siegel & Rothman, 2016). One study examined county level firearm accessibility for 219 counties (all those with data available) across the US and found similar results to the state level variables (Opoliner et al., 2014). A recent review of over 70 studies around the world from 1980 to 2015 found that availability is consistently associated with high firearm suicide rates (Mann & Michel, 2016).

The international review of firearms and suicide also found that legislation is associated with reduced firearm suicide rates (Mann & Michel, 2016). There have been several studies in the US that look at how firearm policy impacts suicide rates. The majority of the studies show that strict gun regulation laws are related to reduced suicide rates (Andrés & Hempstead, 2011; Conner & Zhong, 2003; Crifasi et al., 2015; Gius, 2015; Kposowa et al., 2016; Miller et al., 2006). These studies compare state level regulations (Conner & Zhong, 2003; Siegel & Rothman, 2016) or changes in legislation

overtime (Crifasi et al., 2015) to understand the impact of legislation on suicide rates. Several of them have pointed out that suicide by other means does not increase as firearm suicides decrease (Conner & Zhong, 2003; Miller et al., 2007) although some note that other types of suicide are not impacted by the restriction of firearms (Miller et al., 2012; Milner, Hjelmeland, et al., 2013). When comparing age-adjusted suicide rates by state, the five states with the highest rates are New Mexico, Wyoming, Montana, Nevada, and Alaska, all of which are classified as moderate or unrestrictive firearm law states (Conner & Zhong, 2003; Miller et al., 2007). The rates of these states are nearly three times as high as the states with the fewest suicide deaths, New York, New Jersey and Massachusetts, all of which are classified as restrictive gun law states (Conner & Zhong, 2003).

Firearm ownership, while not directly a rural issue, plays a much greater role among rural residents due to the familiarity and availability of firearms in most rural areas of the country. Firearm availability is particularly of interest to this study because several studies have shown that firearm suicide deaths in the US are higher in rural areas than urban areas (Branas et al., 2004; Cantrell et al., 2012; Dresang, 2001; Fontanella et al., 2015; Hirsch & Cukrowicz, 2014; McCarthy et al., 2012; Nance et al., 2010). This pattern also holds up outside the United States, with studies in England, Wales, and Australia finding higher rates of firearm suicides in rural areas (Burnley, 1995; Dudley, Kelk, Florio, Howard, & Waters, 1998; Malmberg, Hawton, & Simkin, 1997; Snowdon & Harris, 1992; Wilkinson & Gunnell, 2000). The culture around firearms in rural areas may cause firearms to be of greater concern in rural areas compared to urban areas.

Alcohol. Alcohol has been noted as a risk factor in individual suicides, with studies reporting a range of 33% to 69% of all suicide deaths involving intoxication (Sher, 2006). At the aggregate level, alcohol consumption is often studied in relation to suicide rates, occasionally while controlling for other factors associated with suicide. Data that is available in the United States tracks alcohol consumption overall, or by specific beverage, i.e. spirits, wine, and beer (Caces & Harford, 1998; Gruenewald, Ponicki, & Mitchell, 1995; Kerr et al., 2011; Landberg, 2009). Studies have found positive associations between alcohol consumption and suicide rates (Fernquist, 2007; Gruenewald et al., 1995; Ramstedt, 2005), with women seeming to have the more consistent positive relationship (Innamorati et al., 2010; Kerr et al., 2011; Landberg, 2009; Ramstedt, 2001). Multiple reviews of the literature have drawn the same conclusions, that alcohol consumption within an area is positively related to suicide rates (Norström & Rossow, 2016; Xuan et al., 2016), although the local customs make have an impact on the relationship (Norström & Rossow, 2016). Alcohol consumption may not impact rural areas differently than more urban areas, as recent studies have shown similar rates of use across geographical areas (Borders & Booth, 2007; Dixon & Chartier, 2016).

Veterans. Concern over veteran suicide rates has become increasingly common in the literature, although the focus tends to be on veterans alone rather than alongside other contextual factors that contribute to suicide. Several studies of recent veterans have shown higher suicide rates among veterans than the general population (Blow et al., 2012; Kang et al., 2015; Kaplan, Huguet, McFarland, & Newsom, 2007; Kaplan et al., 2012; McCarthy et al., 2009), particularly among young veterans (Gibbons, Brown, &

Hur, 2012; Kaplan et al., 2009). However, this has not always been the case, as studies examining older generations of veterans have not shown a positive correlation with suicide (Allen, Cross, & Swanner, 2005; Helmkamp, 1995; Kang & Bullman, 2009; Kaplan et al., 2009; Miller et al., 2009).

Again, rural areas might be at particular risk for higher suicide rates because of the high percentage of veterans who reside in rural communities (Hamilton et al., 2008). It is estimated that 28% of veterans live in rural areas with 3.4 million of them being enrolled in the Veterans Affairs system, whereas it is estimated that only 14% of the general population resides in rural areas. Of patients seen in the VA system, 43% (2.27 million) are from rural areas, 15% of which have a service-connected disability. Nearly one-third (31.9%) of VA enrolled service members who served in recent conflicts (i.e. Operation Iraqi Freedom or Operation Enduring Freedom) live in rural areas (VHA Office of Rural Health, 2011). McCarthy and colleagues (2012) examined suicide rates among Veteran Affairs patients from 2003 to 2004 and again from 2006 to 2007 and found that suicide rates were higher among veterans living in rural areas than urban areas. There was a 20% and 22% greater risk for suicide in rural areas compared to urban areas during the two time-periods analyzed in the study. This could indicate compounding risk for rural areas, with high availability and access to firearms and large percentages of veterans. Further, reports have shown that more rural states such as Montana, Alaska, Maine, New Mexico, and Wyoming have high rates of recruitment into military service (Kane, 2005), which likely increases the percent of veterans and adds to stress and conflict within these communities among service members and their families.

Gaps in the Literature/Rationale

Trends showing higher rates of suicide in rural areas have been documented for the US and around the globe. Studies in Australia, New Zealand, and across Europe have found suicide rates in rural areas to be higher and increasing faster than suicide rates in urban areas (Dudley et al., 1998; Kapusta et al., 2008; Levin & Leyland, 2005; Middleton et al., 2003; Page, Morrell, Taylor, Dudley, & Carter, 2007; Pearce et al., 2007; Razvodovsky & Stickley, 2009; Wilkinson & Gunnell, 2000). These international trends also align with trends in the United States that show suicide rates are higher in rural areas and increasing more rapidly than urban areas (Fontanella et al., 2015; Kegler, 2017; Singh & Siahpush, 2002). Yet the empirical evidence for why rural rates tend to be higher than urban rates and why the differentials are growing remains limited. Contextual factors that are proposed by researchers to increase suicide rates in rural areas have been studied in reference to suicide rates but not in combination with location. For example, deprivation has been documented as associated with high suicide rates, but it is unclear if rural suicide rates are higher because deprivation is high, deprivation interacts with rural location, or some other quality of rural that is not captured by deprivation. The same issue applies to other contextual variables as few studies have included a geographic component while examining any contextual factors and suicide.

In addition to lacking a geographic component, many of the studies described above examine only one or two contextual factors in relation to suicide, leaving out several other variables that could also be associated with suicide rates. Suicide is a multifaceted problem that can only be understood by considering several factors and their

interactions. Including only one or two factors that are expected to be associated with suicide provides an incomplete picture.

Another limiting issue with the available contextual research is the sample that is typically used. Specific age groups such as adolescents and young adults and the elderly have a fair amount of research devoted solely to those groups (Bridge et al., 2006; Cash & Bridge, 2009; Conwell, 2001; Gould, Greenberg, Velting, & Shaffer, 2003; Minayo & Cavalcante, 2010; Robinson, Hetrick, & Martin, 2011), but rarely does research focus only on the working age group (ages 25 to 64). This age group tends to get grouped in with studies across the lifespan and is only occasionally studied separately. While those of working age are a diverse group consisting of a large proportion of the overall population, suicide rates have always been high among this group and have been steadily increasing over the last decade. Recent studies examining overall mortality within the United States show increasing mortality rates for the working age group, especially among the non-Hispanic white population aged 45 to 54 (Case & Deaton, 2015; Shiels et al., 2017; Snyder, 2016). Suicide, along with drug and alcohol poisoning, is much to blame for the increase in mortality among those of working age (Case & Deaton, 2015, 2017). Since the suicide rate is increasing among this group, those aged 25 to 64, it is important to understand what factors are associated with the increase so that appropriate interventions can be used to save lives.

Lastly, several limitations exist among the designs used in the studies described above. The majority of the studies use cross-sectional designs that only examine a few years of suicide data. These studies do not look at how suicide rates change over time or

how contextual factors contribute to fluctuations in suicide rates. Cross-sectional designs, unlike longitudinal designs, cannot provide information on why the differentials in suicide rates are growing between rural and urban areas. The studies that do examine trends across time are routinely at the country or state level. Studies that use such large areas are not useful at determining rural and urban variations because of the drastic differences within such a large unit. A state within the US can have large cities as well as remote rural locations so studying suicide rates across an entire state compared to other states does not provide detailed geographic information. Smaller units, such as counties, census tracts, or zip codes are much better at distinguishing differences based on location that could lead to local changes to decrease suicides.

Not only do the study designs tend to be cross-sectional, but many do not account for the spatial autocorrelation of suicide rates. Only recently have studies started to include a spatial component to account for dependency across suicide rates based on closeness to other areas. Analyses that assume independence in the outcome variable are not always appropriate for suicide data, as maps of suicide rates appear to show geographic patterns in the data. While some spatial studies have shown no spatial autocorrelation in suicide rates (Rezaeian et al., 2006, 2007), most have found a spatial pattern and adjusted analyses accordingly (Chauvin, 2013; DeFina & Hannon, 2015; Fontenot, 2015; Hong & Knapp, 2013; Hooghe & Vanhoutte, 2011; Hsu et al., 2015; Yoon et al., 2015). Since the statistical techniques are available to test and account for spatial autocorrelation, it is important that it be addressed for suicide studies.

Study rationale.

The following study begins to fill in many of the research gaps that were identified above. First, 15 years of data was used at the county level to allow for variation over time and geographic location. Longitudinal data analyses were performed on the 15 years of data divided into three-year periods to better understand factors associated with suicide over time. No other suicide studies have looked at national county level data in a longitudinal analysis. This study also includes numerous contextual factors to capture multiple components of the local county that can be related to suicides. These factors are examined in association with suicide rates individually and in combination to show if any factors reduce the impact of other factors. Interactions among contextual factors were also examined to determine if there are differences in relation to suicide rates across geographic location. This helps indicated if rural adds to the impact of deprivation, fragmentation, or other contextual factors. Again, this is something no other studies have done to such detail. Generally, only one or two contextual variables from different constructs are included in a single model without any interaction terms. The current study focuses on the suicide rates of those aged 25 to 64 as this population has seen an increasing suicide rate over the past decade and growing mortality across the country.

Summary

A great amount of research has been done relating suicide and contextual factors, grounded on theoretical concepts relating certain factors to suicide. However, gaps remain in the literature that allow for further exploration of suicide data. This study adds to the knowledge related to suicide by exploring three objectives with hypotheses related

to each. Each objective and hypothesis is laid out below with a summary of the evidence leading to the hypothesis.

Objective 1. To examine the patterns and trends in suicide in the US over a 15-year period (calendar years 2000 through 2014) among those aged 25 to 64 across geographic location, stratified by gender and age.

Hypothesis 1a. Rural areas will have higher suicide rates than urban areas.

Hypothesis 1b. Suicides will be increasing across time, with a faster rate of increase in rural locations.

Numerous studies have identified higher suicide rates in rural areas compared to urban areas (Fontanella et al., 2015; Hirsch & Cukrowicz, 2014; Nance et al., 2010; Singh & Siahpush, 2002) and the data in this study is expected to support these previous findings. Similarly, recent trends have shown suicide rates for those age 25 to 64 are increasing over time ("WISQARS," 2018) with the highest rates of increase in small towns and rural areas (Kegler, 2017). Again, the data is this study is expected to show those same trends.

Objective 2. To determine whether several contextual factors, including deprivation, fragmentation, social capital, health service availability, availability of firearms, alcohol, and veteran population, are associated with suicide across time.

Hypothesis 2a. Fragmentation, access to firearms, and rural location will remain significantly positively associated with suicide after controlling for other contextual factors.

The contextual variables that were chosen to be included in this study have shown at least partial evidence that they are related to suicide rates. When individual contextual variables are examined for this study, it is expected that they will continue to have an impact on suicide rates. Based on the limited research that is available containing multiple contextual factors, it is expected that fragmentation, availability of firearms, and rural location will all remain significant factors in association with suicide after all the contextual factors are added to the longitudinal model. Of the few studies examining multiple contextual factors in a single model, this pattern has already been demonstrated for fragmentation (Evans et al., 2004; Whitley et al., 1999) and rural location (Congdon, 2011b, 2011a; Middleton et al., 2003; O'Farrell et al., 2016). This is expected for firearms due to the high proportion of suicide deaths that occur from firearms ("WISQARS," 2018) and the research that has shown a strong connection between suicide rates and firearm availability (Miller et al., 2012).

Objective 3. To determine if the associations between contextual factors and suicide vary across geographic location.

Hypothesis 3a. The association between suicide and deprivation will vary with geographic location, with highly deprived rural areas having a stronger positive association with suicide than highly deprived urban areas.

Hypothesis 3b. The association between suicide and fragmentation will vary with geographic location, with highly fragmented rural areas having a stronger positive association with suicide than highly fragmented urban areas.

Hypothesis 3c. The association between suicide and social capital will vary across geographic location, with high levels of social capital in rural areas having a stronger negative association with suicide than high levels of social capital in urban areas.

Although no empirical evidence is available regarding interaction terms, these hypotheses were developed out of the theory as it pertains to rural locations. All three hypotheses draw from the rural context. Highly deprived and fragmented rural areas are likely to experience multiple negative effects the build upon one another more so than in more urban areas. For example, economic disadvantage or lack of integration within the community can add to stress and role conflict that exists to create a permanent negative outlook on life due to the limited opportunity and mobility within rural areas. Individuals in these rural areas may not see a way to overcome the structural poverty and deprivation or mobilize resources the way individuals in more urban areas might be able to. It is also expected that interactions between rural location and social capital will be associated with suicide such that rural counties with high social capital will have lower suicide rates than urban counties with high social capital. Again, this is due to the rural context, as rural areas are often close-knit communities that unite to help those within that are struggling (Duncan, 2000). The support of a healthy interconnected community is thought to promote healthy responses to stressors and negative events in life and thus be associated with lower suicide rates.

Chapter 3: Methods

This chapter will outline the methodology used for this project. The study design, participants, data sources, and variables used in the model are specified, followed by an explanation of the statistical analysis used to examine the three objectives and test hypotheses outlined elsewhere.

Study Design

This was a retrospective study that used spatial, time trend, and longitudinal data analysis to examine the patterns of and factors associated with suicide rates across the United States over time.

Study Participants

Participants in this study included all individuals who were residents of the United States and died by suicide between the years 2000 and 2014. Death by suicide was determined by the reason for death listed in the compressed mortality file (CMF) obtained from the National Center for Health Statistics (NCHS) National Vital Statistics System (NVSS) (National Center for Health Statistics, 2016). All *International Classification of Disease, Tenth Revision* (ICD-10) cause-of-death codes U03*, X60-X84, and Y87.0 were classified as suicides with recorded death dates from January 1st, 2000 to December 31st, 2014. Age at death was limited to between 25 and 64 years for inclusion in the study. This group contains working age adults and excludes both

adolescents/young adults (those under 25 years-old) and the elderly (those 65 years-old and older) as the factors influencing suicide for these groups can vary. This is also comparable to other research that focuses on similar age groups, as the suicide rates tend to be the highest for this age group (Cylus et al., 2014; Fontenot, 2015; Ivey-Stephenson, Crosby, Jack, Haileyesus, & Kresnow-Sedacca, 2017; Kegler, 2017).

In addition to cause of death, the date of death, gender, age, and county of residence for each participant was collected from the death certification in the CMF. This information allowed for the calculation of county level, age- and sex-adjusted suicide rates and standardized mortality ratios (SMRs) over the 15-year study period. To stabilize rates over time, three-year periods were used to calculate county level rates and SMRs, resulting in five time-periods (i.e. 2000-2002, 2003-2005, 2006-2008, 2009-2011, and 2012-2014). The 2000 national population was used for the age- and sex-adjustments for suicide rates and the 2000 national suicide rates for specific age- and sex-groups were used to calculate SMRs. The year 2000 was used for standardization as this common practice in the literature. Age- and sex-adjustment allowed for comparisons across different populations; if this standardization did not occur, high or low suicide rates could be due to the age and sex make-up of the county rather than the contextual factors that are of interest in this study. Further, suicide rates and SMRs were calculated overall, as well as for men and women separately. Examining separate rates and SMRs for men and women allowed for exploration into variations over time and across geographic location by sex.

Data Source

Several data sources were used to compile the data for this study. As mentioned above, the CMF was used to identify individuals who died by suicide during the study period, January 1st, 2000 to December 31st, 2014 (National Center for Health Statistics, 2016). Information on cause of death, date of death, age in years at death, gender, and county of residence was collected from this data source to allow for the calculation of age- and sex-adjusted county suicide rates and SMRs. In order to calculate rates with the suicide data, population data by year, county, age and sex was pulled from the US Census Bureau's website (US Census Bureau, 2017c).

Information on socioeconomic demographics of each county (e.g. poverty rates, unemployment rates, and education attainment) was collected from the US Census Bureau's 5-year American Community Survey (ACS) releases which began in 2005 and replaced the long form of the decennial census (US Census Bureau, 2017a). The ACS is also released in 1- and 3-year summaries, but only areas with populations larger than 65,000 individuals and 20,000 individuals are included in those surveys respectively. While the 3-year survey would fit better with the timeframes of the current study, any county with a population fewer than 20,000 persons would be excluded from the data. The 5-year ACS with the same middle year as the three-year study sample timeframe was used for contextual data. This resulted in three 5-year ACS releases used in this study: the ACS from 2005-2009 for the 2006-2008 study period, the ACS from 2008-2012 for the 2009-2011 study period, and the ACS from 2011-2015 for the 2012-2014 study period.

The first two time-periods in the study, 2000-2002 and 2003-2005, did not have a corresponding ACS to account for the socioeconomic demographics. Instead, decennial census data was used since these censuses captured the same ACS data prior to the ACS. Data for the 2000-2002 time-period was collected through the *Summary File 3 (SF3)* for the 2000 Decennial Census (US Census Bureau, 2011). As for the 2003-2005 period, some variables, such as unemployment and poverty rates, were estimated yearly through the *Regional Economic Information System (REIS)* while others do not have any estimate for the period (e.g. housing without complete plumbing, houses without a telephone). The yearly REIS data was collected from the Area Health Resource File (AHRF) and averaged across the three years in the study period (US Department of Health and Human Services, 2016). The AHRF is a collection of data from multiple sources that relates to health status and health care in the United States. Variables without an estimate available for the 2003-2005 period were given the value from the Census 2000 data. If Census 2000 data was not available, values from the 2006-2008 period were used instead. The precise variables collected through each data source (i.e. ACS, SF3 and AHRF) are identified in the measures section below.

Information was also collected on service providers within a county. This information was retrieved from the AHRF, which contains information on health professionals and health services. Yearly data from the *American Medical Association Physician Masterfile* is provided in the AHRF for the number of health care providers in a county. Hospital information comes to the AHRF through the *AHA Annual Survey of Hospitals*. Since 3-year time periods are used to calculate suicide rates, yearly data was

collected from several versions of the AHRF (2004 to 2014) and then averaged across the same 3-year time periods to produce the county level factors of interest. All variables identified through the AHRF will be identified in the measures section below. The AHRF was also the source for additional variables used in this study such as the number and percentage of veterans living in each county provided through the Department of Veterans Affairs and the rural classification of each county provided through the Department of Agriculture.

Additional data sources were used to collect social capital related data. The US Census Bureau collects information on business patterns across the nation on a yearly basis through the County Business Patterns (CBP) survey (US Census Bureau, 2017b). The CBP includes the number of establishments across different industries as well as employment and payroll information. This data was available online for each year in the study and was averaged across the same three-year periods as the suicide rates. In addition, information on the number of registered nonprofit organizations in a county was included in the study from the National Center for Charitable Statistics (NCCS) (National Center for Charitable Statistics, 2017), which was also available online for each year included in the study period. The NCCS data archive provides information that is derived from forms nonprofit organizations file with the IRS for tax exemption status.

Finally, data on firearm availability and alcohol use was estimated with proxy variables developed from the U.S. Historical Business database (Infogroup, 2018). This database contains names and addresses for all businesses in the United States from 1996 to 2016. Data on businesses between 2000 and 2014 was collected and averaged across

the 3-year time-periods for the study for gun related businesses and alcohol related businesses separately. More detail is provided below on the types of businesses included in the counts.

Measures

Outcome variable.

The outcome measure for this study varied slightly based on the type of analysis being conducted, but overall related to the number of suicides among individuals aged 25 to 64 for all counties in the 50 United States. Suicides were summed across three-year increments for five separate time periods, 2000-2002, 2003-2005, 2006-2008, 2009-2011, and 2012-2014. For geographical analyses, age- and sex- adjusted standardized mortality ratios (SMRs) for suicide were calculated; for trend analyses, age- and sex-adjusted suicide rates per 100,000 individuals were calculated; and for longitudinal analyses, counts of suicide were used as the outcome.

County level suicides were used as they are currently the lowest level of geographical classification available in the CMF or through the NVSS. While other research has used smaller geographical levels, such as census tracts (e.g. Fontanella et al., 2018; Johnson, Woodside, Johnson, & Pollack, 2017), these studies are single state studies. Census tract level mortality data is not readily available at the national level and would leave numerous census tracts with zero suicides across three-year periods. Other studies have used state level analyses, but state level analyses do not allow for rural and urban trends to be analyzed in a useful manner. While individual counties can vary drastically in size and contain a wide variety of urban and rural locations, county analyses

are still useful to show general national patterns and identify areas or trends that may need further exploration.

Primary independent variable.

The primary independent variable of interest in this study was the rurality of each county. The Rural Urban Continuum Codes (RUCC) are used in this study and were developed by the Economic Research Service of the United States Department of Agriculture (US Department of Agriculture, 2016) from the existing Office of Management and Budget classification of metro/non-metro status. The RUCC contain nine classifications, three that are considered metro and six that are non-metro; classification codes 4 through 7 are also often referred to as micropolitan counties since they have a sizeable small urban population. The distinction between the different classifications is based on the size of the metro or urban area within a given county and whether a metro area is adjacent to the given county. Table 1 outlines the nine distinct categories as well as the number of counties that fall into each category. County classifications are updated a few years after every decennial census, so both the 2003 and the 2013 RUCC were used in this study and Table 1 reflects how counties have shifted across the decade. For longitudinal analyses, these categories were collapsed into six distinct categories without regard to adjacency to a metro area. The three metro classifications remained and are identified as large metro, medium metro, and small metro, but classifications 4 and 5 were collapsed into an overall large micropolitan area with an urban population of 20,000 or more, 6 and 7 were collapsed into an overall small micropolitan area, and 8 and 9 were collapsed into an overall most rural classification.

Table 1. Rural Urban Continuum Codes (RUCC) Description and County Count for 2003 and 2013

Code	Description	2003 Number of Counties	2013 Number of Counties
Metro			
1	Counties in metro areas of 1 million population or more	413	432
2	Counties in metro areas of 250,000 to 1 million population	325	379
3	Counties in metro areas of fewer than 250,000 population	351	356
Non-metro			
4	Urban population of 20,000 or more, adjacent to a metro area	218	214
5	Urban population of 20,000 or more, not adjacent to a metro area	105	92
6	Urban population of 2,500 to 19,999, adjacent to a metro area	609	593
7	Urban population of 2,500 to 19,999, not adjacent to a metro area	450	433
8	Completely rural or less than 2,500 urban population, adjacent to a metro area	235	220
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area	435	424

Contextual variables.

To further explore variation in suicide rates, several contextual, or county level, variables were included in this study. Since a wide variety of contextual variables were included, indices were created for many of these variables modeled after indices described in the literature review above. This process will be explained in more detail in the data analysis section.

Socioeconomic variables. A socioeconomic deprivation index was created based on Singh's deprivation index (Singh, 2003; Singh et al., 2013). The original index was developed to understand the multidimensional aspects of area level deprivation. Rather than include individual variables for each aspect of deprivation, the index was developed to improve "validity, robustness, and explanatory power" (Singh, 2003). The 1990 census version of this index examined 20 variables using factor and principal component analysis and included 17 of them in the final index (Singh, 2003). Each variable was selected based on prior research and theory relating it to area deprivation. Two factors were produced from the 20 variables, but based on meaningfulness, only the first factor was kept, and 17 variables were used to produce the index (Singh, 2003). The index was shown to have good reliability, internal validity, and predictive validity (Singh, 2003). The index was updated in 2000 with the addition of five variables for a total of 22 variables, all routinely collected by the US Census Bureau and falling into five general domains: education, occupation and employment, income, poverty and welfare assistance, and housing tenure and quality (Singh et al., 2013). Factor analysis was also conducted on these 22 variables, with factor loadings ranging from 0.39 to 0.92, so all variables were kept for the index. High scores on the index represent higher levels of area deprivation, while low scores indicate low area deprivation. The index has been used in a few studies for health outcomes (Kind et al., 2014; Singh, 2003) including suicide (Singh et al., 2013).

The current study used the same 22 variables from the 2000 version of the area deprivation index to examine county levels of deprivation. The top panel of Table 2 lists

Table 2. Description, Years Available and Source of Variable Used for Socioeconomic Deprivation and Fragmentation Indices

Category	Variable	Year	Source
Socioeconomic Deprivation			
Education			
	Population aged 25+ with < 9 years of education, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Population aged 25+ with at least a high school diploma, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
Occupation and employment			
	Employed persons aged 16+ in white collar occupations, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Civilian labor force population aged 16+ unemployed, %	2000, 2005-2009, 2008-2012, 2011-2015, 2003-2005	Census, 5-year ACS, AHRF
Income			
	Median family income, $	2000, 2005-2009, 2008-2012, 2011-2015, 2003-2005	Census, 5-year ACS, AHRF
	Gini coefficient	2000, 2005-2009, 2008-2012, 2011-2015	5-year ACS
	Median home value, $	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Median gross rent, $	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Median monthly mortgage, $	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Median annual real estate taxes, $	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
Poverty and welfare assistance			

Continued

Category	Variable	Year	Source
	Families below poverty level, %	2000, 2005-2009, 2008-2012, 2011-2015, 2003-2005	Census, 5-year ACS, AHRF
	Population below 150% of poverty threshold, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Single-parent households with children aged < 18, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Households receiving supplemental security income, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Households receiving public assistance income, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
Housing tenure and quality			
	Owner-occupied housing units, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Households without a motor vehicle, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Households without a telephone, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Occupied housing units without complete plumbing, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Households with more than 1 person per room, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Median number of rooms per housing unit	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Housing units with 4 or more bedrooms, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
Social Fragmentation			
	Residents not in the same house 1 year ago, %	2000, 2005-2009, 2008-2012, 2011-	Census, 5-year ACS

Continued

Category	Variable	Year	Source
		2015	
	Single person households, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Divorced residents, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS
	Renter-occupied housing units, %	2000, 2005-2009, 2008-2012, 2011-2015	Census, 5-year ACS

Note. ACS = American Community Survey.

the individual variables used to develop the standardized socioeconomic deprivation index in the current study along with the years of data available and data source for the variable. A description of the principal components analysis to create the index is provided in the data analysis section below.

Social fragmentation variable. A fragmentation index was calculated across the study period based on Congdon's work on fragmentation (Congdon, 1996). This index was created to measure the level of anomie within a society as described by Durkheim. The original index was created by standardizing four variables and summing them with equal weighting using data in England (Congdon, 1996). This measure of fragmentation has become a standard in the suicide literature, with numerous studies using this index and finding a significant relationship with suicide (Congdon, 2011b; Evans et al., 2004; Whitley et al., 1999). A similar index was included in the current study, and principal component analysis was used to standardize the four variables which are listed in the second panel of Table 2.

Social capital variable. The social capital index created for this study was based on a social capital index developed by Rupasingha and colleagues (2006). The existing index is available at the county level for the years 1997, 2005, and 2009 but does not include the states of Alaska or Hawaii. It was created by doing a principal components analysis on four variables, the percentage of voters who voted in presidential elections, the response rate to decennial census, the number of non-profit organizations, and the density of associations in a community. For the current study, adaptations to this index were made to fit the study time-period and geographical span. Rather than collapsing all associations within a county into a single index, specific types of organizations were grouped into different density variables for the PCA. The densities of eight distinct types of organizations were used with the specific organization types listed in the top panel of Table 3.

While voter turnout and the census response rate were included in the Rupasingha index to expand the view of social capital beyond participation in groups, those variables were not included for this study. Using the density of associations within a community models social capital after Putnam's view, where social capital consists of interactions between people and the trust that develops from these connections (Putnam, 1995). While the density of associations does not show how many people participate in these groups, it does indicate the opportunity for building and establishing these connections. This measure of social capital is similar to what has been used in other studies related to suicide (Chauvin, 2013; Congdon, 2011b; Fontenot, 2015; Recker & Moore, 2016).

Table 3. Description, Years Available and Source of Variable Used for Social Capital and Health Service Provider Indices

Category	Variable	Years	Source
Social Capital			
	Charities (foundations and public charities) per 10,000 persons	2000-2014	NCCS
	Arts and nature facilities (libraries, museums, historical sites, zoos and botanical gardens, nature parks) per 10,000 persons	2000-2014	CBP
	Beauty facilities (barbers, beauty salon, nail salon) per 10,000 persons	2000-2014	CBP
	Agents (promotors, agents, managers) per 10,000 persons	2000-2014	CBP
	Recreation sites (public golf courses, physical fitness facilities, bowling centers, skiing, marinas) per 10,000 persons	2000-2014	CBP
	Business and political organizations (business associations, professional, labor, and political organizations) per 10,000 persons	2000-2014	CBP
	Civic and social associations per 10,000 persons	2000-2014	CBP
	Religious organizations per 10,000 persons	2000-2014	CBP
Health Providers/Services			
	Number of psychiatrists per 100,000 persons	2000-2014	AHRF
	Number of psychiatric hospital beds per 100,000 persons	2000-2014	AHRF
	Number of total hospital beds per 100,000 persons	2000-2014	AHRF
	Number of primary care providers/general and family doctors per 100,000 persons	2000-2014	AHRF
	Individuals without health insurance between ages 18 and 64, %	2000-2014	AHRF
	Any community mental health centers	2000-2014	AHRF
	Any federally qualified health centers	2000-2014	AHRF
	Any psychiatric hospitals	2000-2014	AHRF

Note. CBP = County Business Patterns, AHRF = Area Health Resource File.

Health services variables. The literature has shown less consistency on how to measure health services within a county than deprivation or fragmentation. Several variables related to health services were examined in this study. First, an index was developed based on a principal component analysis of the multiple variables listed in Table 3 (PCA description below). While indices are less common for service availability in the literature, a combination of these variables can determine a broader scope of the health service network available within a county. In addition to using an index, individual variables for psychiatrists per 100,000 residents, primary care physicians per 100,000 residents, and the uninsured population (%) were also analyzed in the longitudinal models described below. Other studies tend to use one or two variables rather than a composite index, so individual variables were examined to align with previous research (Fiske et al., 2005; Kapusta et al., 2009, 2010; Kposowa, 2009; Tondo et al., 2006).

While the availability of health providers and services in an area is not an indication of use of these services, it can improve accessibility and visibility within a community. Further, those who are insured are more likely to have access to these services since they have a method for paying, at least partially, for these services. Availability via providers and accessibility via insurance will theoretically provide an indication of use, since these services would not remain available within a community if they were not being used.

Firearms variable. As discussed in the literature review, availability of firearms is linked to the prevalence of suicide. For this study, the number of businesses classified as gun related shops within a county was used as a proxy to measure access to firearms

(see Table 4). All businesses classified as gun-related shops (e.g. guns and gunsmiths, black powder guns and supplies, ammunition) under the North American Industry Classification System (NAICS) were collected and linked to the county they were located in. The number of gun shops was calculated per 10,000 individuals living in the county. While this measure is not used in the literature, no single measure is common at the county level. State level variables exist that look at access to firearms through a survey sample or through the gun regulations within the state (Andrés & Hempstead, 2011; Gius, 2015; Kposowa et al., 2016; Opoliner et al., 2014; Siegel & Rothman, 2016), but this does little to distinguish between rural and urban areas that may have different attitudes toward firearms. The few studies that look at county firearm availability often use suicide deaths by firearm as a proxy which is not suitable here due to the outcome (Hemenway & Miller, 2000; Kleck, 2004), or they are limited to only analyzing counties where survey data is available (Opoliner et al., 2014).

***Alcohol use/consumption*.** Alcohol consumption has been shown to be related to suicide rates (Caces & Harford, 1998; Gruenewald et al., 1995; Kerr et al., 2011) and was included in the current study via a proxy variable. The total number of drinking establishments per 10,000 individuals was used to measure this variable. Drinking establishments were identified based the NAICS codes such as bars, cocktail lounges, pubs, and night clubs. Table 4 provides more detail on the businesses included for this measure. Like the firearm proxy, this variable is not common in the literature; however county level consumption rates are not readily available over the multiple years included in this study.

Table 4. Description, Years Available and Source of Variable Used for Firearms, Drinking Establishments, and Veteran Percent

Category	Variable	Years	Source
Firearms			
	NAICS code 45111001: Ammunition	2000-2014	US Historical Business
	NAICS code 45111002: Ammunition reloading equipment and supplies	2000-2014	US Historical Business
	NAICS code 45111023: Guns and gunsmiths	2000-2014	US Historical Business
	NAICS code 45111024: Gunsights, scopes, and mounts	2000-2014	US Historical Business
	NAICS code 45111076: Black powder guns and supplies	2000-2014	US Historical Business
Alcohol			
	NAICS code 72241001: Bars	2000-2014	US Historical Business
	NAICS code 72241002: Cabarets	2000-2014	US Historical Business
	NAICS code 72241003: Cocktail lounges	2000-2014	US Historical Business
	NAICS code 72241004: Comedy Clubs	2000-2014	US Historical Business
	NAICS code 72241005: Discotheques	2000-2014	US Historical Business
	NAICS code 72241006: Nightclubs	2000-2014	US Historical Business
	NAICS code 72241007: Nightclubs Information Service	2000-2014	US Historical Business
	NAICS code 72241008: Pubs	2000-2014	US Historical Business
	NAICS code 72241009: Karaoke Clubs	2000-2014	US Historical Business
Veterans			
	Percent of veterans	2000-2014	AHRF

Note. NAICS = North American Industry Classification System; AHRF = Area Health Resource File.

Veterans variable. Veterans are at high risk for suicide, particularly the younger generations returning from Afghanistan and Iraq (Gibbons et al., 2012; Kaplan et al., 2009). Veterans also tend to live in rural areas which can have an impact on rural suicide rates (Hamilton et al., 2008; VHA Office of Rural Health, 2011). Due to this, the percentage of the population classified as veteran was used as a contextual variable in this study, as is becoming more common in the suicide literature (Blow et al., 2012; Fontenot, 2015; Kaplan et al., 2009). Additional information on the veteran variable can be found in Table 4.

Data Analysis

Patterns and trends over time.

Standardized mortality ratios and maps. To examine the geographic distribution of suicides, the standardized mortality ratios (SMRs) were calculated for each county during each time-period in the study. County SMRs are based on the ratio of the observed number of suicides within a county to the expected number of suicides. Expected suicides are calculated by multiplying the age and sex population counts within a county by the national age- and sex-specific suicide mortality rates for the year 2000. The year 2000 is used throughout the study as the standardization year. Since SMRs can have a large amount of variability based on the size of the population within an area, a Bayesian hierarchical conditional autoregressive model (CAR) with spatial random effects was used to create spatially smoothed estimates of relative risk in each county for each study period (Lawson, 2013). The smoothing process for a given county accounts for the observed SMR within the county, the national average (global mean) SMR, and the

neighboring counties' (local mean) SMRs with varying weighted averages. The smaller the population within a given county, the greater the weight given to the global and local means when calculating the smoothed SMR. Smoothed SMRs were calculated overall as well as by gender for each time-period of the study. Spatial smoothing was done using the *diseasemapping* package in the R software. Cartographic displays of the smoothed SMRs were made using ArcGIS 10.3 (ERSI, 2011).

***Suicide rates over time*.** While smoothed SMR maps provide some indication of how suicides change over time, rates were also calculated to examine changes across the study period. Age- and sex-adjusted suicide rates were calculated via the direct method, by generating the specific rate of suicide for each sex and ten-year age group within the county, weighting the rate by the 2000 national population of that sex and age group, then summing across all groups. Suicide rates were calculated in a similar manner separately by gender, 10-year age group, and geographic location for each year in the study to examine how suicide rates vary across the different groups. Rates were calculated based on the grouped three-year periods used throughout this study, but the trends in suicide rates over time (i.e. slopes) were calculated based on yearly suicide rates. These analyses were done using SAS 9.4 (SAS Institute, Inc, 2014).

Contextual factors associated with suicide.

Principal component analysis. Prior to examining how contextual factors impact county level suicide, individual variables were reduced to indices through principal component analysis (PCA). Several of the predictors described above include multiple variables that correlate strongly with one another. PCA allows for the reduction of

variables while retaining much of the overall variation in the data. PCA produces new variables, or principal components, that are linear combinations of the original variables (Abdi & Williams, 2010; Jolliffe, 2002). PCA was conducted separately for the socioeconomic, social fragmentation, social capital, and health services/provider variables described above. Correlations were examined between the variables for each area prior to the PCA and variables that had a strong correlation (greater than .80) with another variable were removed since they are likely measuring the same underlying construct. Similarly, variables that did not correlate with any other variables were removed from the analysis since they are likely measuring a very different underlying construct. After the PCA analysis, factor loadings were examined to determine if individual variables were statistically and practically significant to be included in the final PCA (Stevens, 2002). Variables were removed from the analysis if they had a factor loading of less than .2, as this indicates there is less than 4% shared variance between the individual variable and the final component created via the PCA (Stevens, 2002). After variables were eliminated, components were examined for meaning and interpretability which resulted in only a single component from each PCA being kept for the final analyses. Factor scores for the components were computed for each county and time-period of the study with a mean of 0 and standard deviation of 1. All PCA analyses were done using SAS 9.4 (SAS Institute, Inc, 2014).

***Longitudinal data analysis*.** To find associations between suicide rates overtime and contextual variables, a series of hierarchical longitudinal models using maximum likelihood estimation were used. All models used negative binomial regression with

counts of suicides as the outcome due to the over dispersion of suicides. As recommended by Osgood (2000), the log of the population at risk was also included in each model as an offset variable to allow for interpretation as changes in suicide rates. First, an unconditional means and an unconditional growth model were applied to the data to measure the variation across counties and the variation across counties and time. These models are typically examined prior to building more complicated longitudinal models to understand the type of changes that occur with time (Singer & Willett, 2003).

Multivariable negative binomial regression models were developed by first examining models with the individual contextual variables, then by adding all variables that were significant at the .05 level into a combined model. Initially, only interactions between the contextual variables and time were included in the combined model. Once combined, variables that were no longer significant at the .05 level were removed from the model. Model fit statistics (i.e. deviance, the Akaike information criterion [AIC], and the Bayesian information criterion [BIC]) were also monitored as changes were made to the combined model to ensure the model fit improved as variables within the model were adjusted. Random effects were included in the model for both the intercept and the slope to allow for suicide rates to vary across counties at the start of the study and how they change overtime.

Once a final model was fit with only time interaction terms, additional interactions between contextual variables and the RUCC variable were included in the model to see if they improved the overall fit of the model. Only interactions between contextual variables and RUCC were examined since RUCC was the primary

independent variable of interest. Only variables that were included in the model without RUCC interaction terms were tested to interact with geographic location. All longitudinal data analyses were done using SAS 9.4 (SAS Institute, Inc, 2014).

Chapter 4: Results

Over the course of the study period, from 2000 to 2014, 373,030 individuals died by suicide in the United States. Most suicides were among males (n=287,773, 77.1%) and individuals aged 45 to 54 (n=114,061, 31.6%). The age group 35 to 44 accounted for the second highest percent of suicides (n=99,716, 26.7%) followed by the age group 25 to 34 (n=81,888, 22.0%) and lastly those aged 55 to 65 (n=77,365, 20.7%). The large metro counties accounted for the most suicides (n=179,024, 48.0%), followed by medium metro counties (n=81,027, 21.7%), small metro (n=40,567, 10.9%), small micro (n=35,631, 9.6%), large micro (n=28,727, 7.7%), then most rural counties (n=8,054, 2.2%). The highest number of suicides occurred during the final year of the study (n=29,569 in 2014) and the fewest occurred in 2000 (n=19,736). Similarly, when examining the five three-year periods calculated for this study, the final period, 2012-2014 had the greatest number of suicides (n=86,989) with 76.2% occurring among males (n=66,268) and 30.2% occurring among those aged 45 to 54 (n=26,250), 24.8% among those aged 55 to 64 (n=21,591), 23.0% among those aged 35 to 44 (n=20,015), and 22.0% among those aged 25 to 34 (n=19,133). The first time-period was slightly different (n=62,523). A similar percent was among males, (78.3%, n=48,985), but the largest age group was those aged 35 to 44 with 32.1% (n=20,048), followed by 28.3% among ages 45 to 54

(n=17,687), then 23.8% among ages 25 to 34 (n=14,908), and only 15.8% among ages 55 to 64 (n=9,880).

The total number of counties in each data period varied slightly from the overall number of counties in the United States. Modifications had to be made due to county boundary changes during the study timeframe. In Virginia, two counties existed initially that were collapsed into other counties by the end of the study timeframe. One county was created in Colorado after the study began, modifying the boundaries of counties around the newly created county. In Alaska, multiple counties were divided and merged during the study timeframe. While suicide and population data were available for each county as it was created or modified, other variables were not necessarily available and time trends were difficult due to changes within single counties. Rather than exclude these areas from analyses, they were collapsed into larger areas. For example, while Bedford City, VA was a separate entity from Bedford County, VA until 2013, these two separate counties were collapsed throughout the study to form one county. More regions were collapsed in Alaska due to several changes that occurred in county boundaries. A total of six boroughs in Alaska were collapsed into one large area since they started out as three separate areas that were adjusted and recreated to form four distinct boroughs, with only one of the initial boroughs remaining. Appendix A shows more information about which counties were collapsed during the study. These county modifications only impacted the longitudinal analyses as they were the only analyses that required specific counties be tracked over time. Thus, the longitudinal models included 3,137 counties for the 2000-2002 timeframe and 3,138 counties for each subsequent timeframe, whereas the

maps and trends included 3,141 counties for 2000-2002 and 3,143 counties for each subsequent timeframe.

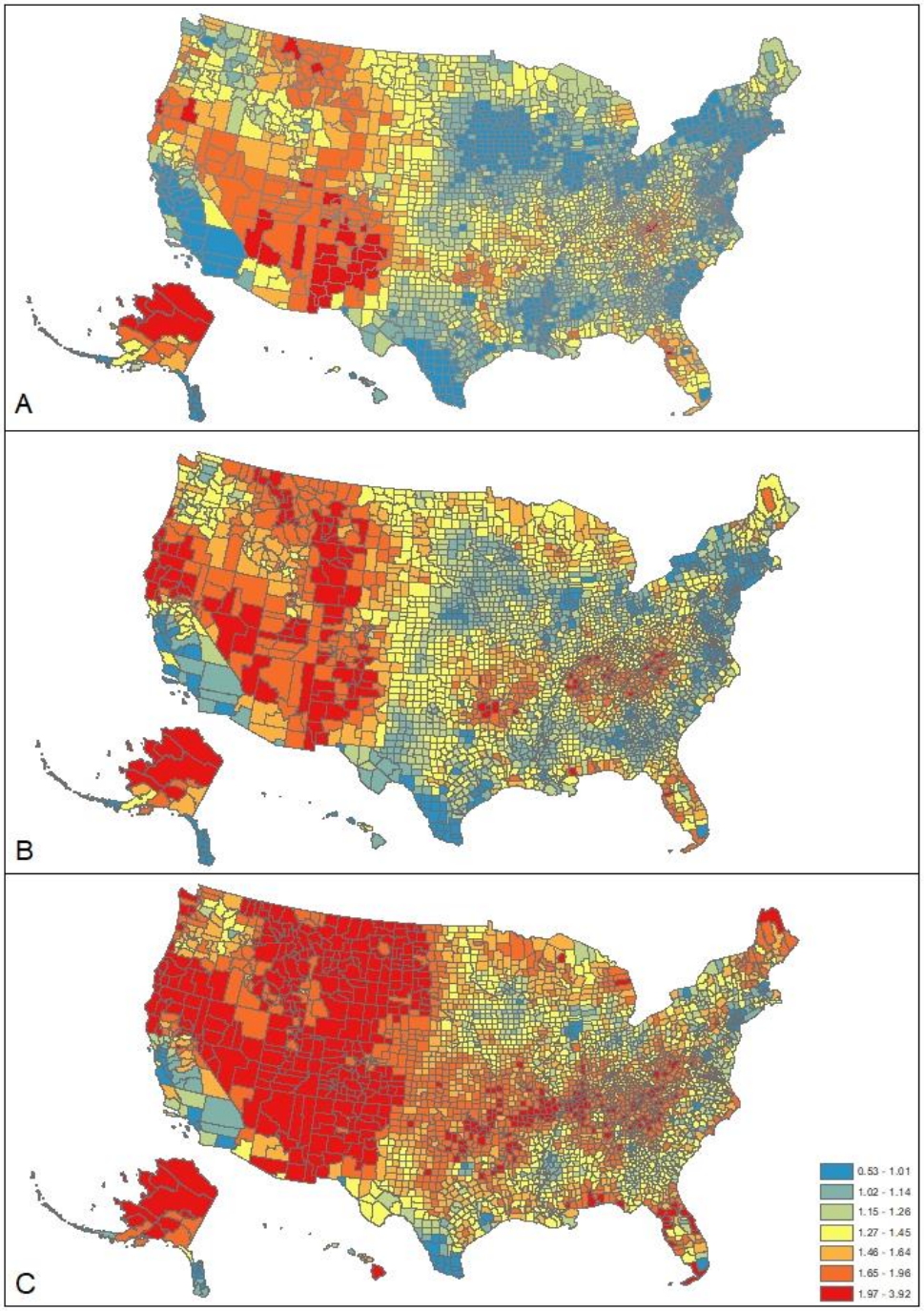
Patterns and Trends in Suicide

Standardized mortality ratios.

Smoothed SMRs were calculated for each study period and are presented in Figure 1 for three time-periods. Overall, SMRs ranged from 0.40 to 3.92 with a mean of 1.38 and a median of 1.33. A ratio of less than one indicates low suicide risk with fewer suicides than expected occurring, based on the age and sex make-up of the county population. Ratios greater than one indicate an excess risk of suicides within the county. Counties with the darkest red color in the maps had the greatest excess risk while the lightest blue counties had the lowest risk. A total of 17 counties had an SMR of 3.00 or higher, with the majority occurring in the final time-period (n=12). Alaska had the most counties with an SMR over 3.00 (n=7), followed by Utah (n=4), Arizona (n=2), and Colorado, Montana, New Mexico, and Oregon (n=1). When comparing time-periods, the final time-period of the study had the most counties with an excess risk of suicide. Changes across Figure 1a, 1b and 1c show an increase in excess risk as the time-periods in the study advance, particularly across western states, in the Ozark region, and throughout Appalachia. In the first time-period, SMRs ranged from 0.43 to 2.85 with a mean of 1.22 and median of 1.19; by the last time-period, SMRs ranged from 0.53 to 3.92 with a mean of 1.60 and median of 1.55.

Closer examination was given to the highest SMRs in each time-period and overall. The majority of the excess risk counties were location in western states such as

Figure 1. Age- and Sex-Adjusted Smoothed SMRs for (a)2000-2002, (b) 2006-2008, and (c) 2012-2014



Montana, Colorado, New Mexico, and Utah. The top 5% of SMRs ranged from 1.68 to 2.85 for the 2000-2002 time-period but increased to 2.30 to 3.92 by the 2012-2014 time-period. When looking across all time-periods, the top 5% of SMRs ranged from 2.013 to 3.92, with more than half (50.8%) of the counties in the top 5% of excess risk falling in the latest time-period. While most states with the highest SMRs were western states (e.g. CO, MO, NM, UT, and ID), several states that contain regions of Appalachia (e.g. TN, KY, VA, and WV) and the Ozarks (e.g. MO and AR) also had numerous counties with high excess risk.

While smoothed SMRs reduce the ability to have an SMR of 0, there were numerous counties that had no suicides in a given year. In the 2000-2002 period, 243 counties had no suicides, in 2003-2005, 245 counties had no suicides, in 2006-2008, 237 counties had no suicide, in 2009-2011, 193 counties had no suicides, and in 2012-2014, 188 counties had no suicides. A total of 21 counties had no suicides during the entire study period, with almost half in Nebraska (n=10), three in both Texas and North Dakota, two in Montana, and one in South Dakota, Hawaii, and Kansas. The maps in Figure 1 demonstrate this, as lighter colors tend to be in these states except for Montana, where high counts of suicides in neighboring counties inflates the smoothed SMR.

SMRs were calculated separately for males and females to examine differences in geographic patterns by gender (Figures 2 and 3 respectively). The overall results are similar, with risk increasing across the time periods for both males and females. For males, the SMRs ranged from a low of 0.43 to 4.05; females had an SMR ranging from 0.42 to 4.07. The female maps demonstrate a greater number of counties with an SMR of

Figure 2. Age-Adjusted Smoothed SMRs for Males (a) 2000-2002 and (b) 2012-2014

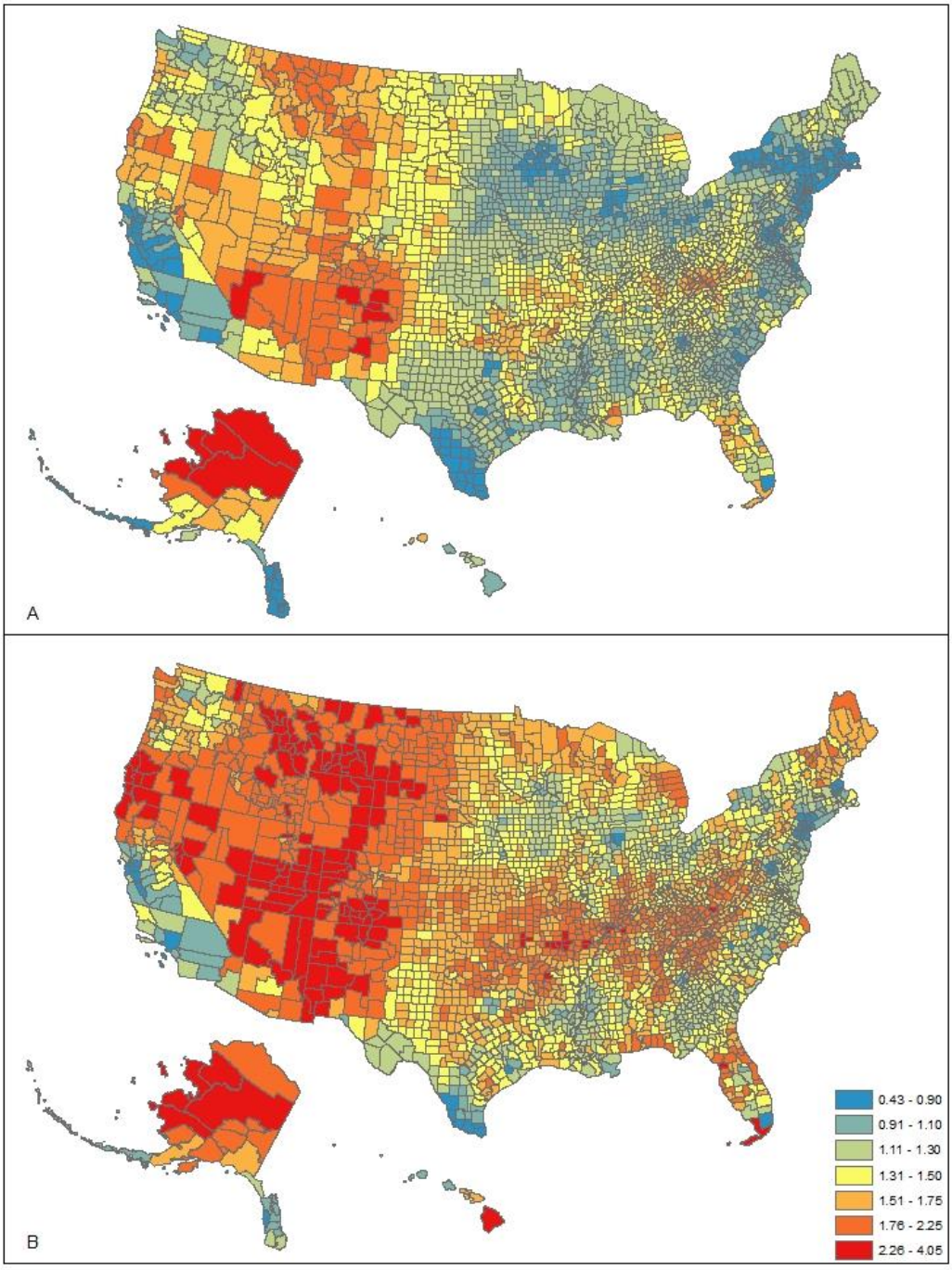
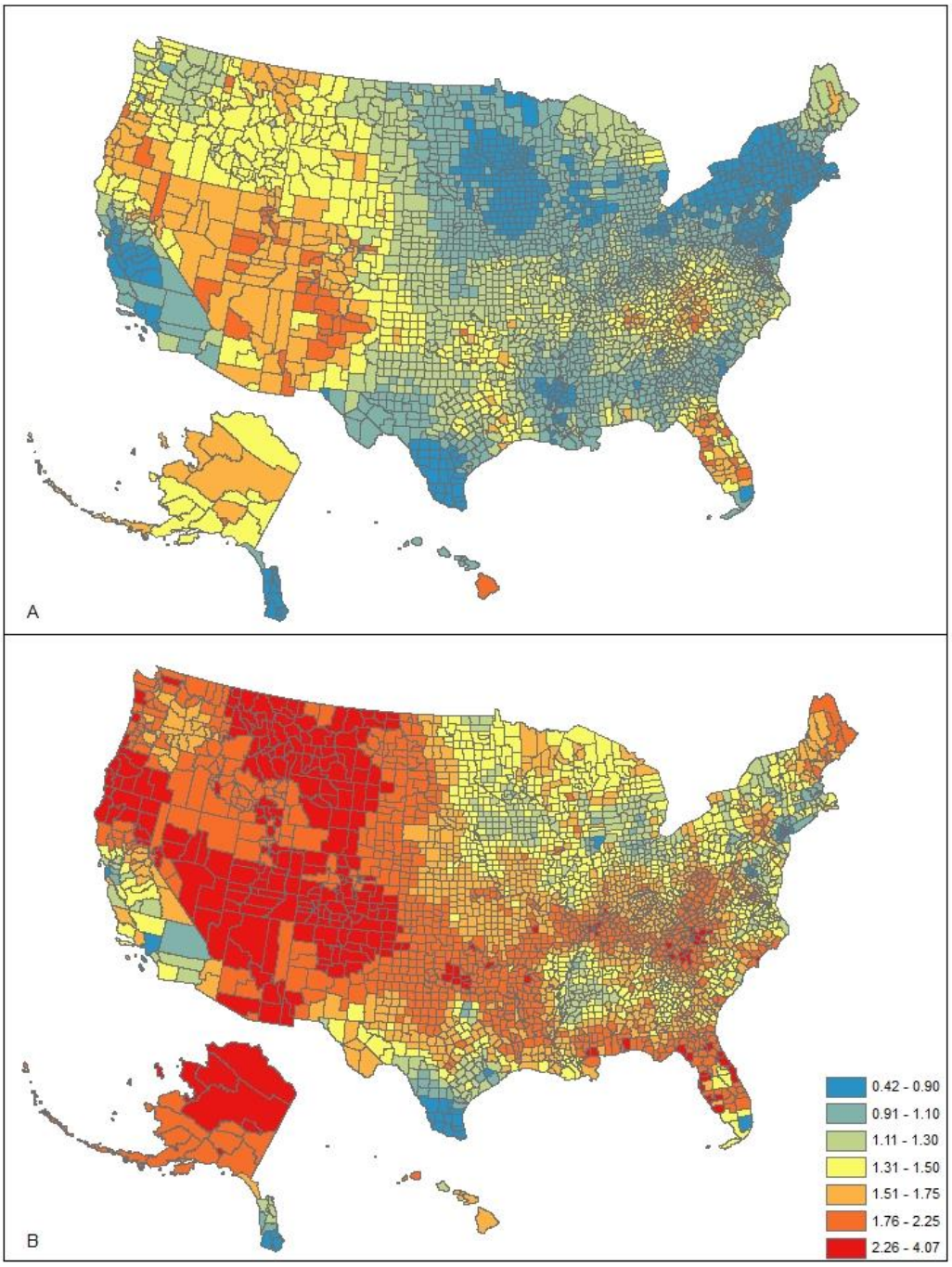


Figure 3. Age-Adjusted Smoothed SMRs for Females (a) 2000-2002 and (b) 2012-2014



greater than 2.25 (the dark red category), 258 counties fall into this category for women but only 149 do for men. The number of female suicides was more than double the expected number for 564 counties while the number of male suicides was more than double the expected number for 350 counties in the 2012 to 2014 period.

Suicide rates over time.

Table 5 shows the overall age- and sex-adjusted rates, followed by age-adjusted male and female rates, sex-adjusted age rates, and the age-and sex-adjusted RUCC category rates grouped in 3-year periods. The two columns on the far right show the slope for annual changes in suicide rates and the corresponding p-value. Regardless of how the rates are broken down, the slopes increased across the study period for all groups at a significance level of less than .001. The overall rates increased 23.0% from the 2000-2002 time-period to the 2012-2014 time-period; male rates increased 19.5% and female rates increased 35.6% between the first and last period. The smallest increase in age occurred among those 35 to 44 (10.6% increase) while the largest increase occurred among those aged 55 to 64 (40.6% increase). In 2000-2002, the overall suicide rate for those aged 55 to 64 was 12.94 per 100,000 but this increased to 18.19 per 100,000 in 2012-2014.

Differences between male and female suicide rates was also noted across the study period (see Figure 4). In the 2000-2002 period, male suicide rates were nearly 3.7 times higher than female rates, and by the 2012-2014, male rates were still approximately 3.2 times higher than female rates. In the large metro counties, male suicide rates were 3.5 times higher than females in the first time-period but only 3.1 times higher by the last

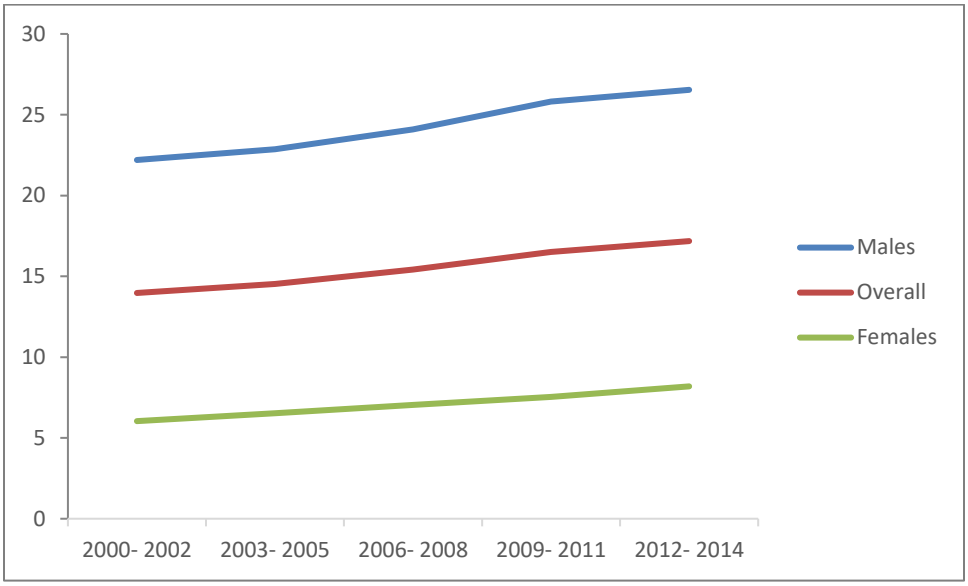
Table 5. United States Suicide Rates Overall, by Gender, Age, and RUCC for Three-Year Time-Periods

	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	Slope[a]	p-value
Overall	13.97	14.53	15.41	16.50	17.18	.28	<.001
Gender							
Males	22.20	22.86	24.09	25.81	26.54	.39	<.001
Females	6.04	6.52	7.05	7.54	8.19	.18	<.001
Age							
25-34	12.46	12.77	12.98	13.80	14.75	.19	<.001
35-44	14.86	15.04	15.59	16.09	16.44	.14	<.001
45-54	15.07	16.27	17.78	19.43	19.86	.43	<.001
55-64	12.94	13.64	15.15	16.92	18.19	.46	<.001
RUCC							
1 (large metro)	12.34	12.69	13.50	14.43	14.67	.22	<.001
2	14.86	15.59	16.62	17.88	19.01	.35	<.001
3	15.87	16.99	18.13	19.77	21.33	.45	<.001
4	16.82	17.33	18.39	19.78	21.39	.38	<.001
5	17.05	17.56	18.91	21.47	22.57	.48	<.001
6	17.12	18.56	18.52	20.38	21.54	.38	<.001
7	17.97	19.26	19.33	21.79	23.66	.47	<.001
8	17.80	18.76	20.00	21.99	22.89	.44	<.001
9 (most rural)	18.28	19.83	21.14	21.83	25.00	.51	<.001

Note. RUCC = Rural Urban Continuum Code.

[a] slope was calculated based on all 15 years of data.

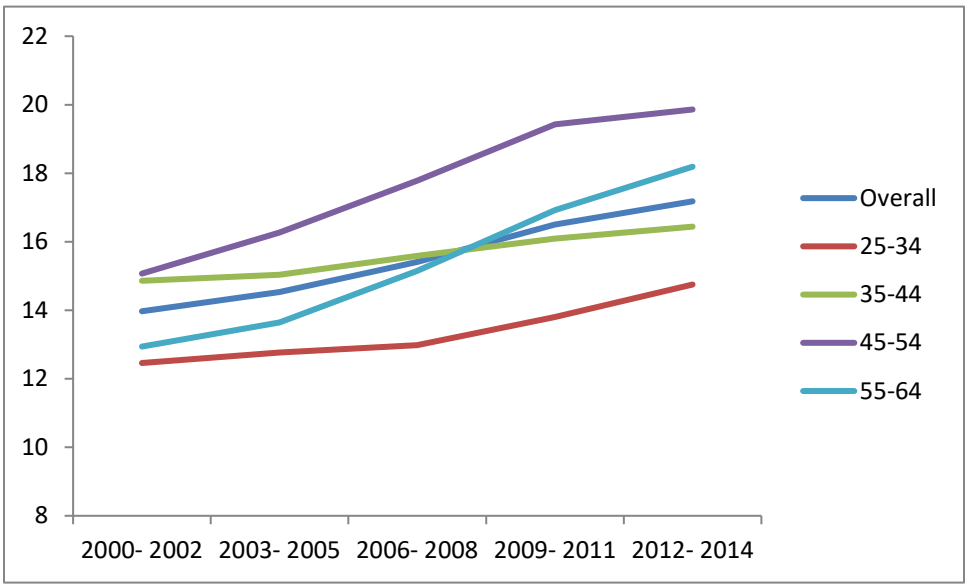
Figure 4. Suicide Rates by Gender, over Time



time-period (see Appendix B). The difference between males and females in rural areas was also reducing, but the gap was larger at the start of this study. In 2000-2002 male rates were 4.9 times higher than female rates in the most rural counties, but this reduced to 3.7 times higher in the 2012-2014 time-period.

Changes were also seen across age groups (see Figure 5). Initially, the 34-45 and 44-55 age groups had the highest suicide rates, with a spread of 12.46 to 15.07 per 100,000 across all age groups. By 2012-2014, the 45 to 54 still had the highest suicide rate at 19.86 per 100,000. But the largest increase occurred in the 55 to 64 group with a slope of .46 and an overall percent change of 40.6% from the first period to the last period, increasing from 12.94 to 18.19 suicides per 100,000 individuals. While both male and female suicide rates increased faster for the 45-54 and 55-64 age groups compared

Figure 5. Suicide Rates by Age Group, over Time

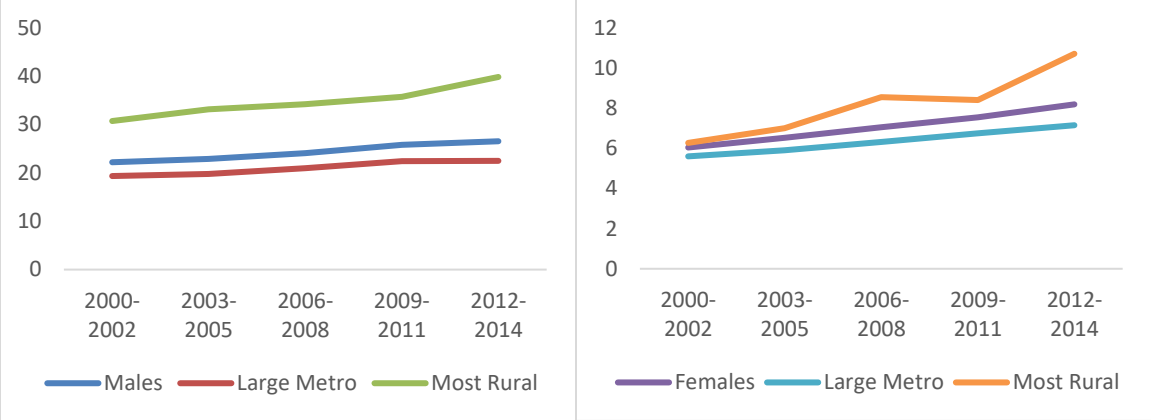


to the 25-34 and 35-44 groups, male rates increased more rapidly than female rates (male slopes .60 for 45-54 and .69 for 55-64 vs female slopes .25 for 45-54 and .25 for 55-64; see Appendix B), but females had an overall greater percent change (females 44.4% for 45-54 and 52.1% for 55-64 vs males 27.8% for 45-54 and 37.3% for 55-64; see Appendix B) since female rates tend to be much lower than male rates.

All RUCC categories showed similar increasing trends over time, with the highest overall percent increase in the most rural category (36.8%) and the lowest percent increase in the large metro category (18.9%). In the earliest time-period, suicide rates gradually increased across county type from 12.34 per 100,000 in large metro counties to 18.28 per 100,000 in most rural counties. Rural suicide rates were 48.1% higher than the most urban rates in large metro areas. By the 2012-2014 period, while the most rural rates

remained the highest (25.00 per 100,000) and the large metro areas the lowest (14.67 per 100,000), the categories in between varied in order but generally ranged between 21 and 23 suicides per 100,000. The percent difference between suicide rates in large metro areas and the most rural areas was up to 70.4% in 2012-2014, due to a rate of increase of .51 in rural areas compared to a rate of increase of only .22 in large metro areas. RUCC categories of 3 (small metro), 5 (large micro, non-adjacent), 7 (small micro, non-adjacent), and 8 (rural, adjacent) all had rates of increase greater than .44 during the study period.

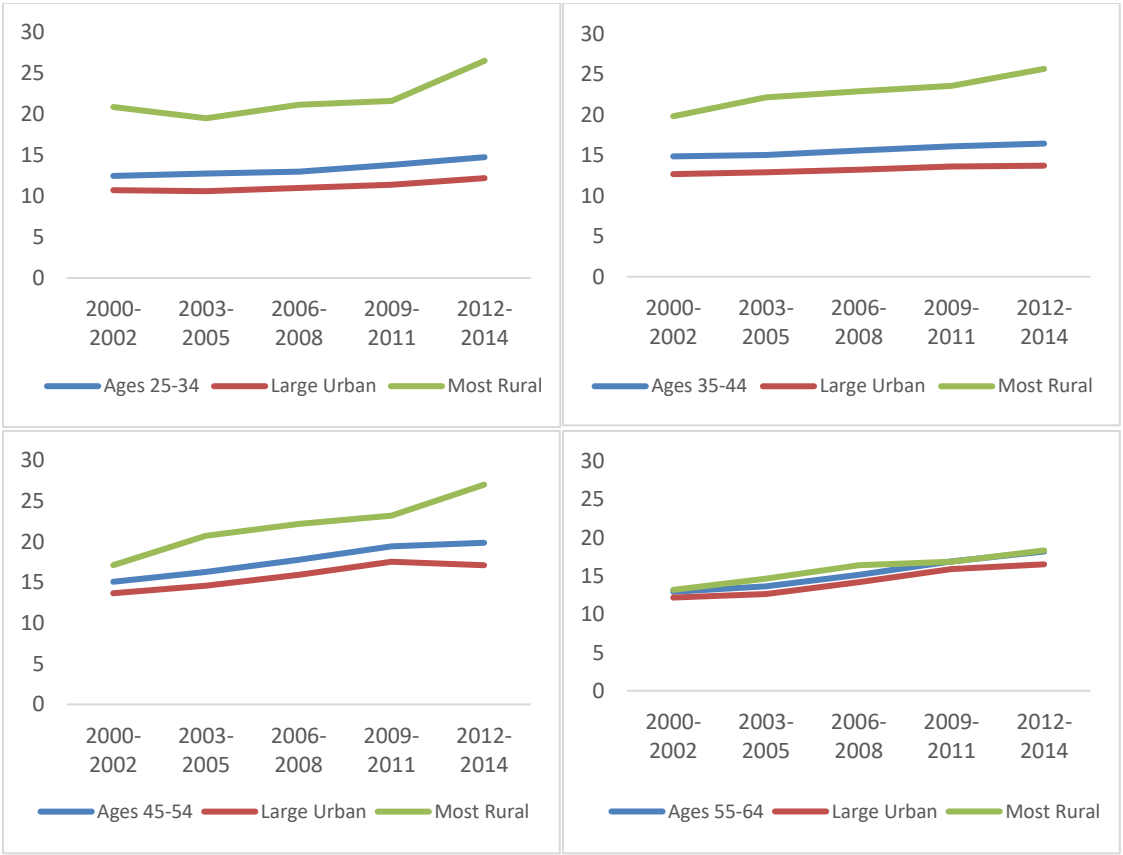
Figure 6. Male and Female Suicide Rates by Large Metro and Rural County Types over Time



Additional differences were seen when rural location was analyzed by gender and age (see Figures 6 and 7, and Appendix B). Male suicide rates were increasing from 2000 to 2014 at a rate of anywhere from .30 to .69, depending on the RUCC classification.

Female suicide rates were increasing at a rate of anywhere from .13 to .43, depending on RUCC classification. The percent change in female rates is more telling, where all non-metro suicide rates increased by 40% or more from the 2000-2002 period to the 2012-2014 period. Most extreme, the RUCC 8 category (rural adjacent) increased at a slope of .43, up from 5.89 in 2000-2002 to 10.82 in 2012-2014, an 83.7% increase. The highest percentage increase among male suicide rates by RUCC was 35.7% increase for those living in RUCC 3 areas, small metro counties. Figure 6 shows increasing rates over time for males (a) and females (b) by the most rural and most urban RUCC categories.

Figure 7. Age Group Suicide Rates by Large Metro and Rural County Type over Time



Examining age by RUCC category showed that the older age groups are driving the changes in overall RUCC suicide rates, as the slopes were highest among the older groups (see Appendix B). Slopes ranged from .40 to .63 and .33 to .72 for the 55 to 64 and 45 to 54 age groups respectively, whereas they ranged from .13 to .47 and .09 to .42 for the 25 to 34 and 35 to 44 age groups respectively. Figure 7 has a panel for each age group and shows the overall, most rural, and most urban RUCC categories suicide rates across time. For the 55 to 64 age group, there was little difference between rural and urban areas; the most rural rates were only 1.08 times higher in 2000-2002 and 1.11 times higher in 2012-2014 than the large metro counties. However, the youngest age group had a much larger difference between rural and urban areas, with the most rural areas being 1.9 times higher and 2.2 times higher than the large metro counties in 2000-2002 and 2012-2014 respectively. The gap between rural and urban reduced as the study age groups increased; the largest gap was 2.2 for ages 25 to 34, then 1.9 for ages 35 to 44, then 1.6 for ages 45 to 54 and finally only 1.1 for ages 55 to 64 in the 2012-2014 period.

Factors Associated with Suicide Rates

Contextual variables.

A total of 45 variables were collected from multiple data sources and reduced to examine how they relate to suicide rates in the United States. Appendix C provides summary information on the individuals variables used in the model and in the PCA described below.

Principal component analysis.

Four separate PCAs were conducted: one on variables representing socio-economic deprivation, one for social fragmentation, one for social capital, and one for provider availability. Appendix D shows factor loadings for each variable on to the final component for each concept.

The PCA for socioeconomic deprivation began with 22 variables. After checking correlations across the variables, four variables were removed because they were highly correlated with other variables in the model. Median rent and mortgage were highly associated with both home value and median income, poverty at 150% was highly correlated with family poverty, and greater than high school education was highly correlated with less than high school education. Two additional variables were removed because they did not have factor loadings of .2 or higher on the component other variables loaded onto. Percent of houses occupied by owner and houses with four rooms or more were removed, leaving a total of 16 variables in the PCA. Not only did owner occupied houses have a small factor loading, it was also a linear combination of the renter occupied houses in the social fragmentation variable. This also led to the removal of the variable to help distinguish the two indices. Three components resulted from the analysis, but only the first component had all variables loading on it at .40 or higher. The two additional factors reflected high housing costs and lack of affordable housing within counties rather than area socio-economic deprivation, so they were not maintained for study analysis.

The second PCA included four variables that represented social fragmentation. Two factors were produced by the initial analysis and they both explained a similar amount of the overall variance across the four variables. Both resulting factors also had similar factor loadings from the four variables with one key exception. The first factor had a negative factor loading for divorced and single person households and a positive loading for the other variables while the second factor showed positive factor loadings for all variables. Since social fragmentation is expected to increase with higher amounts of each of the four variables, the second factor was maintained for the study as it fit with the prior use of this index.

Similarly, the eight social capital variables also resulted in two distinct components, but all variables loaded at .40 or better on the first component. Religious groups loaded more strongly on the second component, but not enough to justify maintaining two components or excluding religious groups from the first component.

Finally, PCA was conducted on the provider variables. Several of the provider variables ended up working best as dichotomous variables due to the limited availability across the nation (i.e. community health centers, federally qualified health centers, psychiatric hospitals). These variables were removed since all variables included in a PCA should have similar scales of measurement (Abdi & Williams, 2010; Jolliffe, 2002). Five variables were included in the final PCA and resulted in a single component, with all variables loading at .3 or higher. However, since prior research has not used an index for provider availability, multiple individual provider variables were also examined in the longitudinal models.

Longitudinal data analysis.

Prior to deciding what type of model to run, counts of suicide were examined to determine if Poisson or negative binomial regression was appropriate and whether adjustment was required for zero counts. Negative binomial regression fit the count of suicides due to the over dispersion of counts, but a zero-inflation adjustment was not required. The log of the population within a county was included as an offset variable in all the models to allow for interpretation as a suicide rate rather than count (Osgood, 2000).

Before examining how contextual variables related to suicide rates, two unconditional models were examined that looked at variation in suicide rates across counties and across time. The unconditional means model, examining differences across counties, is presented as Model A in Table 6 and the unconditional growth model, examining differences across counties and time, is presented as Model B. Both models demonstrated that while the variations across counties and time were small, significant differences did exist and examining additional variables was appropriate. Without accounting for other factors, the unconditional growth model showed an approximate 6.5% increase in suicide rates with time ($e^{0.03} = 1.06$). This model also reduced the variance within-counties by over 97% compared to the means model, indicating that while time explains within-county variations, a great deal of variation remained between counties.

Table 6. Longitudinal Model Estimates, Standard Error, and Model Fit Statistics

	Model A			Model B			Model C			Model D		
	β	SE	p-value	β	SE	p-value	β	SE	p-value	β	SE	p-value
Fixed Effects												
Intercept	-8.584	.0059	<.001	-8.716	.0066	<.001	-9.16	.029	<.001	-9.19	.030	<.001
Time				.063	.0014	<.001	.054	.004	<.001	.051	.004	<.001
Median age							.007	.001	<.001	.008	.001	<.001
RUCC												
1 (large metro)							0.00			0.00		
2							.018	.018	.33	.025	.022	.27
3							.054	.019	.01	.060	.023	.01
4							.048	.020	.02	.061	.026	.02
5							.082	.019	<.001	.096	.023	<.001
6 (most rural)							.094	.028	<.001	.063	.032	.05
Deprivation							.063	.006	<.001	.046	.009	<.001
Fragmentation							.046	.005	<.001	.047	.005	<.001
Social Capital							-.036	.007	<.001	-.030	.007	<.001
Psychiatrist Ratio							-.023	.006	<.001	-.025	.005	<.001
Veterans							.040	.002	<.001	.041	.002	<.001
Gun Shops							.055	.009	<.001	.120	.035	<.001
Deprivation*Time							-.015	.002	<.001	-.015	.002	<.001
RUCC*Time												
1 (large metro)							0.00			0.00		
2							.012	.004	.003	.012	.004	.01
3							.014	.005	.003	.011	.005	.04
4							.013	.005	.02	.014	.006	.02
5							.013	.005	.01	.014	.005	.01

Continued

	Model A			Model B			Model C			Model D		
	β	SE	p-value	β	SE	p-value	β	SE	p-value	β	SE	p-value
6 (most rural)							.015	.009	.09	.037	.009	<.001
RUCC*Deprivation												
1 (large metro)										0.00		
2										-.005	.015	.75
3										-.034	.017	.05
4										.010	.017	.57
5										.017	.013	.20
6 (most rural)										.116	.017	<.001
RUCC*Gun Shops												
1 (large metro)										0.00		
2										-.021	.047	.66
3										-.011	.045	.81
4										-.039	.046	.40
5										-.048	.038	.21
6 (most rural)										-.108	.038	.005
Variance Components												
Within county	.0081	.0006	<.001	.0002	.0002	.14	.0015	.0004	<.001	.0016	.0004	<.001
In intercept	.0751	.0028	<.001	.0762	.0033	<.001	.0492	.0025	<.001	.0467	.0024	<.001
In rate of change				.0006	.0001	<.001	.0004	.0001	<.001	.0004	.0001	<.001
Covariance				-.0005	.0005	.26	-.0008	.0004	.05	-.0007	.0004	.07
Model Fit												
Deviance	19841.92			18019.74			16838.60			16742.74		
Pseudo AIC	19847.92			18031.74			16886.60			16810.74		
Pseudo BIC	19866.08			18068.05			17031.84			17016.48		

Note. RUCC = Rural Urban Continuum Code; codes 4 and 5, 6 and 7, 8 and 9 were collapsed into three distinct groups.

Since the unconditional models provided evidence that additional variables may be useful, individual contextual variables were examined in the model, followed by interactions with time, and interactions with RUCC. Model C in Table 6 shows the model estimates from the combined model that resulted from including individual and time interaction variables. This model was selected through model fit statistics. While all variables were significant individually, two contextual variables, the provider index and drinking establishments, were removed after multiple variables were included in a single model. Individual variables related to health services were also examined, and one, the ratio of psychiatrist within a county, remained significant and improved model fit when other contextual variables were accounted for in the models. Median age within a county was used as a control variable within both models due to variation in age across the US.

Model D in Table 6 shows model estimates and fit for all variables in Model C along with interaction terms with geographic location. While other interaction terms with RUCC were examined, the inclusion of only two interactions in addition to the Model C variables improved the overall fit of the model. The interactions between deprivation and RUCC and gun shops and RUCC improved the model fit based on the deviance and AIC scores and were chosen to be included in the final model. The primary difference across geographic location existed between the most rural and large metro counties, with no other county type suicide rates significantly differing from large metro counties based on gun shops or based on deprivation. Across all models, while the deviance statistic and AIC scores improve, the random effects for the intercept and slope remain significant

with little change, indicating additional variables that explain differences in suicide rates between and within counties are left out of these models.

Table 7 provides the adjusted incidence rate ratios (IRRs) and 95% confidence intervals (CIs) for Model C. Main effects and a variety of linear combinations from the interactions with time in the model are included to address study objective 2. Social fragmentation, gun shops, percentage of veterans, and median age within a county all had a positive association with suicide incidence rates (IRR=1.05, p<.001; IRR=1.06, p<.001; IRR=1.04, p<.001; IRR = 1.01, p <.001, respectively) while social capital within a county and the psychiatrist ratio had a negative association with suicide incidence rates (IRR = 0.96, p<.001, and IRR = 0.98, p<.001, respectively). Deprivation had a decreasing association with suicide incidence rates across the study time-periods. In the earliest time-period, a one unit increase in deprivation was associated with a 6% increase in suicide incidence rates (IRR=1.06, p <.001) but by the most recent time-period, a one unit increase in deprivation was no longer associated with an increase in suicide incidence rates (IRR=1.00, p = .65).

Overall suicide incidence rates were increasing across the study time-periods. Limited variation in increases over time was seen based on socioeconomic deprivation and geographic location. When deprivation was held at 0, or average levels of deprivation, a one unit increase in time resulted in suicide incidence rates increasing by 7% in all county types (IRR=1.07, p<.001) except large metro counties, which had a slightly lower increase of 6% (IRR=1.06, p<.001). When deprivation was set at 1, an above average level of deprivation, suicide incidence rates increased by 6% in the most

Table 7. Longitudinal Model C without Interactions by Location

	Model C		
	Adjusted IRR	95% CI	p-value
Main Effects			
Median Age	1.01	1.00-1.01	<.001
Fragmentation	1.05	1.04-1.06	<.001
Social Capital	0.96	.95-.98	<.001
Psychiatrist Ratio	0.98	.97-.99	<.001
Gun Shops	1.06	1.04-1.08	<.001
Veterans	1.04	1.04-1.05	<.001
Interaction effects			
One unit increase in deprivation for specific time periods			
Deprivation 0 to 1, Time 0	1.06	1.05-1.08	<.001
Deprivation 0 to 1, Time 1	1.05	1.04-1.06	<.001
Deprivation 0 to 1, Time 2	1.03	1.02-1.04	<.001
Deprivation 0 to 1, Time 3	1.02	1.01-1.03	.004
Deprivation 0 to 1, Time 4	1.00	.99-1.02	.65
One unit increase in time for specific combinations of deprivation and geographic location			
Time 0 to 1, deprivation 0, large metro	1.06	1.05-1.06	<.001
Time 0 to 1, deprivation 0, medium metro	1.07	1.06-1.08	<.001
Time 0 to 1, deprivation 0, small metro	1.07	1.06-1.08	<.001
Time 0 to 1, deprivation 0, large micro	1.07	1.06-1.08	<.001
Time 0 to 1, deprivation 0, small micro	1.07	1.06-1.08	<.001
Time 0 to 1, deprivation 0, most rural	1.07	1.05-1.09	<.001
Time 0 to 1, deprivation 1, large metro	1.04	1.03-1.05	<.001
Time 0 to 1, deprivation 1, medium metro	1.05	1.04-1.06	<.001
Time 0 to 1, deprivation 1, small metro	1.05	1.05-1.07	<.001
Time 0 to 1, deprivation 1, large micro	1.05	1.04-1.06	<.001
Time 0 to 1, deprivation 1, small micro	1.05	1.04-1.06	<.001
Time 0 to 1, deprivation 1, most rural	1.06	1.04-1.07	<.001
Geographic locations compared to most urban at specific time periods			
Most rural to large metro, time 0	1.10	1.04-1.16	<.001
Most rural to large metro, time 2	1.13	1.09-1.18	<.001
Most rural to large metro, time 4	1.17	1.11-1.23	<.001
Small micro to large metro, time 0	1.09	1.05-1.13	<.001

Continued

	Model C		
	Adjusted IRR	95% CI	p-value
Small micro to large metro, time 2	1.11	1.08-1.15	<.001
Small micro to large metro, time 4	1.14	1.10-1.19	<.001
Large micro to large metro, time 0	1.05	1.01-1.09	.01
Large micro to large metro, time 2	1.08	1.04-1.11	<.001
Large micro to large metro, time 4	1.10	1.06-1.15	<.001
Small metro to large metro, time 0	1.06	1.02-1.10	.01
Small metro to large metro, time 2	1.09	1.05-1.12	<.001
Small metro to large metro, time 4	1.12	1.08-1.16	<.001
Medium metro to large metro, time 0	1.02	0.98-1.05	.33
Medium metro to large metro, time 2	1.04	1.01-1.07	.01
Medium metro to large metro, time 4	1.07	1.03-1.10	<.001

Note. IRR = Incident Rate Ratio; CI = Confidence Interval.

rural counties (IRR=1.06, p<.001) and by 4% in the most metro counties (IRR=1.04, p<.001) when time increased by one period.

Differences in suicide rates based on geographic location also varied across time, with greater differences as time increased. The most rural counties were associated with a 10% higher suicide incidence rate than the large metro counties in the 2000-2002 period (IRR=1.10, p < .001), but this increased to an 17% higher suicide incidence rate in the most rural compared to large metro counties in 2012-2014 (IRR=1.17, p <.001). During the first time-period, medium metro counties were not significantly different from large metro areas in suicide incidence rates (IRR=1.02, p = .33), but by the last time-period, medium metro counties were associated with a 7% higher suicide incidence rate than large metro counties (IRR=1.07, p<.001).

Table 8 shows the main effects and linear combinations of all interaction terms from Model D. This model accounts for variations across geographic location and

addresses study objective 3. As was the case in Model C, social fragmentation, percentage of veterans, and median age in a county were associated with increased suicide incidence rates (IRR=1.05, p <.001, IRR= 1.04, p <.001, and IRR = 1.01, p <.001, respectively) while social capital and psychiatrist ratio were associated with decreased suicide incidence rates (IRR=.97, p<.001 and IRR = .98, p <.001, respectively). Time also remains similar to Model C. As the time periods increased, suicide incidence rates also increased. Slightly larger associations existed in the most rural county type than other county types as time increased (deprivation 0: rural counties: IRR = 1.09, p <.001, large metro counties: IRR = 1.05, p <.001; deprivation 1: rural counties: IRR = 1.08, p <.001, large metro counties: IRR = 1.04, p <.001) and when deprivation levels were average rather than above average as time increases (most rural counties: deprivation 0: IRR = 1.09, p<.001, deprivation 1: IRR=1.08, p<.001; large metro counties: deprivation 0: IRR = 1.05, p <.001, deprivation 1: IRR = 1.04, p <.001).

When gun shops were examined across geographic location, a one unit increase in gun shops in an area was significantly associated with increased suicide incidence rates in all areas except the most rural counties (large metro: IRR=1.13, p <.001; medium metro: IRR=1.10, p = .002; small metro: IRR=1.12, p <.001; large micro: IRR=1.08, p = .01; small micro: IRR=1.08, p <.001; most rural: 1.01, p = .42). The biggest increases are seen in the three metro county types where a one unit increase in gun shops was associated with between a 10% and 13% increase in suicide incidence rates.

Deprivation also varied by geographic location in addition to time. While Model C showed deprivation no longer having a significant impact on suicide rates by the final

time-period, Model D indicates this is true in all county types except the most rural. While a one unit increase in deprivation was associated with higher suicide incidence rates across almost all county types in the first time-period (large metro: IRR=1.05, p<.001; medium metro: IRR=1.04, p =.002; small metro: IRR=1.01, p=.44; large micro: IRR=1.06, p <.001; small micro: IRR=1.06, p <.001; most rural: IRR=1.18, p <.001), a one unit increase in deprivation was only associated with higher suicide incidence rates in the most rural counties by the final time-period of the study (large metro: IRR=0.99, p =.19; medium metro: IRR=0.98, p =.18; small metro: IRR=.95, p =.003; large micro: IRR=1.00, p = .83; small micro: IRR=1.00, p =.74; most rural: 1.11, p <.001). While the association between suicide incidence rates and deprivation decreased from 18% to 11% across the study periods for the most rural counties, it was still significant. By the final time-period, increases in deprivation were associated with a 5% decrease in suicide incidence rates in small metro areas (IRR = .95, p = .003), and not associated with suicide rates in other county types.

Since geographic location varied by time, deprivation, and gun shops within a county, Table 8 shows comparisons of all county types to the large metro county type with select fixed time, socioeconomic deprivation, and gun shop rates. With gun shops set at 1 per 10,000 individuals and deprivation at 0, there were no significant differences in county types during the first time-period, but by the final time-period, all county types except medium metro counties had higher suicide incidence rates than the large metro counties (most rural: IRR=1.11, p =.01; small micro: IRR= 1.11, p =.002; large micro: IRR= 1.08, p=.04; small metro: IRR=1.10, p= .02; medium metro: IRR= 1.05, p=.20).

With gun shops still at 1 and deprivation increased to 1, the first time-period also did not show significant differences based on location, although the most rural and the small micro counties compared to large metro counties were just outside of statistical significance (most rural IRR = 1.07, p = .07, small micro IRR = 1.07, p = .06). By the last time-period, the most rural, small micro, and large micro county types showed significant differences compared to large metro counties (most rural IRR = 1.24, p <.001, small micro IRR = 1.13, p =.001, large micro IRR = 1.09, p = .05).

When gun shops were adjusted to .5 per 10,000 individuals (about the average number of gun shops overall in a county) and deprivation was set at 0, small micro and small metro counties had higher suicide incidence rates than large metro counties during the first time-period (IRR=1.07, p < .001, and IRR=1.06, p= .01, respectively), and all counties had higher suicide incidence rate ratios than large metro counties by the final time-period (most rural: IRR= 1.17, p<.001; small micro: IRR=1.14, p<.001; large micro: IRR=1.10, p<.001; small metro: IRR=1.10, p<.001; medium metro: IRR= 1.06, p= .01). When deprivation was increased to 1 and gun shops remained at .5, two county types, most rural and small micro, had higher suicide incidence rates at the first time-period (most rural: IRR = 1.13, p <.001; small micro: IRR = 1.09, p <.001) and three county types had significantly higher suicide incidence rates by the final time-period (most rural: IRR=1.31, p <.001; small micro: IRR=1.16, p <.001; large micro: IRR= 1.11, p =.001). The other two county types, small and medium metro counties, were just beyond statistically significant differences from large metro counties (small metro: IRR = 1.06, p= .06; medium metro: IRR = 1.06, p = .08). The greatest difference across geographic

location was when the most rural and large metro county types were compared with deprivation set at 1 during the final time-period. When gun shops were fixed at .5, the most rural counties had a 31% higher suicide incidence rate than the large metro counties. This value reduced to only 24% higher when the availability of gun shops increases, since gun shops are associated with metro county suicide rates more so than rural county suicide rates.

Table 8. Longitudinal Model D with Interaction by Location

	Model D		
	Adjusted IRR	95% CI	p-value
Main Effects			
Median Age	1.01	1.01-1.01	<.001
Fragmentation	1.05	1.05-1.06	<.001
Social Capital	.97	.96-.98	<.001
Psychiatrist Ratio	.98	.96-.99	<.001
Veterans	1.04	1.04-1.05	<.001
Interaction Effects			
One unit change in gun shops for specific geographic location			
Gun shops 0 to 1, large metro	1.13	1.05-1.21	<.001
Gun shops 0 to 1, medium metro	1.10	1.04-1.18	.002
Gun shops 0 to 1, small metro	1.12	1.06-1.18	<.001
Gun shops 0 to 1, large micro	1.08	1.02-1.15	.01
Gun shops 0 to 1, small micro	1.08	1.05-1.11	<.001
Gun shops 0 to 1, most rural	1.01	.98-1.04	.42
One unit increase in deprivation for specific combinations of time and geographic location			
Deprivation 0 to 1, Time 0, most rural	1.18	1.14-1.21	<.001
Deprivation 0 to 1, Time 0, small micro	1.06	1.04-1.09	<.001
Deprivation 0 to 1, Time 0, large micro	1.06	1.03-1.09	<.001
Deprivation 0 to 1, Time 0, small metro	1.01	.98-1.04	.44
Deprivation 0 to 1, Time 0, medium metro	1.04	1.02-1.07	.002

Continued

	Model D		
	Adjusted IRR	95% CI	p-value
Deprivation 0 to 1, Time 0, large metro	1.05	1.03-1.07	<.001
Deprivation 0 to 1, Time 2, most rural	1.14	1.11-1.17	<.001
Deprivation 0 to 1, Time 2, small micro	1.03	1.01-1.05	.001
Deprivation 0 to 1, Time 2, large micro	1.03	1.00-1.06	.08
Deprivation 0 to 1, Time 2, small metro	0.98	.95-1.01	.25
Deprivation 0 to 1, Time 2, medium metro	1.01	.99-1.04	.37
Deprivation 0 to 1, Time 2, large metro	1.02	1.00-1.03	.07
Deprivation 0 to 1, Time 4, most rural	1.11	1. 08-1.14	<.001
Deprivation 0 to 1, Time 4, small micro	1.00	.98-1.03	.74
Deprivation 0 to 1, Time 4, large micro	1.00	.97-1.03	.83
Deprivation 0 to 1, Time 4, small metro	0.95	.93-.98	.003
Deprivation 0 to 1, Time 4, medium metro	0.98	.96-1.01	.18
Deprivation 0 to 1, Time 4, large metro	0.99	.97-1.01	.19
One unit increase in time for specific combinations of deprivation and geographic location			
Time 0 to 1, deprivation 0, large metro	1.05	1.05-1.06	<.001
Time 0 to 1, deprivation 0, medium metro	1.07	1.06-1.07	<.001
Time 0 to 1, deprivation 0, small metro	1.06	1.05-1.07	<.001
Time 0 to 1, deprivation 0, large micro	1.07	1.06-1.08	<.001
Time 0 to 1, deprivation 0, small micro	1.07	1.06-1.08	<.001
Time 0 to 1, deprivation 0, rural	1.09	1.07-1.11	<.001
Time 0 to 1, deprivation 1, large metro	1.04	1.03-1.05	<.001
Time 0 to 1, deprivation 1, medium metro	1.05	1.04-1.06	<.001
Time 0 to 1, deprivation 1, small metro	1.05	1.04-1.06	<.001
Time 0 to 1, deprivation 1, large micro	1.05	1.04-1.06	<.001
Time 0 to 1, deprivation 1, small micro	1.05	1.04-1.06	<.001
Time 0 to 1, deprivation 1, rural	1.08	1.06-1.10	<.001
Geographic locations compared to most urban, at specific combinations of time, deprivation, and gun shops			
Most rural vs large metro, time 0, deprivation 0, gun 1	.96	.88-1.03	.26
Small micro vs large metro, time 0, deprivation 0, gun 1	1.05	.98-1.12	.15
Large micro vs large metro, time 0, deprivation 0, gun 1	1.02	.95-1.10	.55
Small metro vs large metro, time 0, deprivation 0, gun 1	1.05	.98-1.13	.19
Medium metro vs large metro, time 0, deprivation 0, gun 1	1.00	.93-1.08	.92

Continued

	Model D		
	Adjusted IRR	95% CI	p-value
Most rural vs large metro, time 4, deprivation 0, gun 1	1.11	1.03-1.19	.01
Small micro vs large metro, time 4, deprivation 0, gun 1	1.11	1.04-1.18	.002
Large micro vs large metro, time 4, deprivation 0, gun 1	1.08	1.00-1.16	.04
Small metro vs large metro, time 4, deprivation 0, gun 1	1.10	1.02-1.18	.02
Medium metro vs large metro, time 4, deprivation 0, gun 1	1.05	.97-1.14	.20
Most rural vs large metro, time 0, deprivation 1, gun 1	1.07	.99-1.16	.07
Small micro vs large metro, time 0, deprivation 1, gun 1	1.07	1.00-1.14	.06
Large micro vs large metro, time 0, deprivation 1, gun 1	1.03	.95-1.12	.43
Small metro vs large metro, time 0, deprivation 1, gun 1	1.02	.94-1.10	.71
Medium metro vs large metro, time 0, deprivation 1, gun 1	1.00	.92-1.09	.98
Most rural vs large metro, time 4, deprivation 1, gun 1	1.24	1.14-1.35	<.001
Small micro vs large metro, time 4, deprivation 1, gun 1	1.13	1.05-1.21	.001
Large micro vs large metro, time 4, deprivation 1, gun 1	1.09	1.00-1.19	.05
Small metro vs large metro, time 4, deprivation 1, gun 1	1.06	.97-1.16	.20
Medium metro vs large metro, time 4, deprivation 1, gun 1	1.05	.96-1.14	.31
Most rural vs large metro, time 0, deprivation 0, gun .5	1.01	.95-1.07	.76
Small micro vs large metro, time 0, deprivation 0, gun .5	1.07	1.03-1.12	<.001
Large micro vs large metro, time 0, deprivation 0, gun .5	1.04	1.00-1.09	.06
Small metro vs large metro, time 0, deprivation 0, gun .5	1.06	1.01-1.10	.01
Medium metro vs large metro, time 0, deprivation	1.01	.97-1.06	.51

Continued

	Model D		
	Adjusted IRR	95% CI	p-value
0, gun .5			
Most rural vs large metro, time 4, deprivation 0, gun .5	1.17	1.10-1.24	<.001
Small micro vs large metro, time 4, deprivation 0, gun .5	1.14	1.09-1.18	<.001
Large micro vs large metro, time 4, deprivation 0, gun .5	1.10	1.05-1.15	<.001
Small metro vs large metro, time 4, deprivation 0, gun .5	1.10	1.05-1.15	<.001
Medium metro vs large metro, time 4, deprivation 0, gun .5	1.06	1.02-1.11	.01
Most rural vs large metro, time 0, deprivation 1, gun .5	1.13	1.07-1.20	<.001
Small micro vs large metro, time 0, deprivation 1, gun .5	1.09	1.04-1.14	<.001
Large micro vs large metro, time 0, deprivation 1, gun .5	1.05	1.00-1.11	.06
Small metro vs large metro, time 0, deprivation 1, gun .5	1.02	.97-1.08	.47
Medium metro vs large metro, time 0, deprivation 1, gun .5	1.01	.95-1.07	.74
Most rural vs large metro, time 4, deprivation 1, gun .5	1.31	1.23-1.40	<.001
Small micro vs large metro, time 4, deprivation 1, gun .5	1.16	1.09-1.22	<.001
Large micro vs large metro, time 4, deprivation 1, gun .5	1.11	1.04-1.18	.001
Small metro vs large metro, time 4, deprivation 1, gun .5	1.06	1.00-1.14	.06
Medium metro vs large metro, time 4, deprivation 1, gun .5	1.06	.99-1.13	.08

Note. IRR = Incident Rate Ratio; CI = Confidence Interval.

Chapter 5: Discussion

This study examined patterns and trends of suicide rates over a 15-year period, as well as the contextual factors that are associated with suicide rates. As demonstrated in the maps above, excess suicide risk remains high in states in the Western United States, as well as throughout parts of the Ozarks and Appalachia. During the study, overall suicide rates increased by 23% with the greatest increases (37%) occurring in the most rural counties. Increases were also seen across age groups and by gender.

Several factors were identified as related to suicide rates through longitudinal, negative binomial regression. Increases in social fragmentation, socioeconomic deprivation, veteran population, and gun shops were associated with increases in suicide rates, although some differences varied across time and space. Social capital and psychiatrist ratio were associated with decreases in suicide rates. These analyses help empirically substantiate previous claims about how contextual factors relate to suicide across geographic location while also providing insight into possible suicide prevention strategies.

Patterns and Trends in Suicide

States in the western US have historically had higher suicide rates than other areas of the nation (Miller et al., 2012; "WISQARS," 2018) and this study confirms those findings. However, the SMRs give additional insight, demonstrating that most of the

counties in Arizona, New Mexico, Utah, Nevada, Wyoming, and Montana had at least double (up to quadruple) the number of suicides that would be expected based on the underlying population of the area in the most recent time-period. In particular, females in this area of the US have higher suicide counts than would be expected with drastic increases from 2000-2002 to 2012-2014. The maps also show increased suicide risk around the Ozark region, such as southern Missouri, Arkansas, and Oklahoma. Again, this supports prior research (Woolf et al., 2017), although less focus has been given to this area of the country. Only recently have increasing death and suicide rates come to the forefront in parts of the country with a large population of middle-aged white individuals (Case & Deaton, 2017).

The tables and graphs provided above demonstrate increases in suicide rates across the time-periods in the study. Again, this corresponds to other recent work examining suicide rates by age, gender, and location (Case & Deaton, 2017; Curtin et al., 2016; Hu, Wilcox, Wissow, & Baker, 2008; Ivey-Stephenson et al., 2017; Kegler, 2017; Sullivan, Annest, Luo, Simon, & Dahlberg, 2013). Males still have higher suicide rates than women, around three times higher, and rates are growing at a faster pace among men. Women see a greater percentage change in suicide rates across the study, but the rates remain well below the rates of male suicide. All age groups have increasing rates, but the two older groups increased at a rate of more than double that of either of the two younger groups. The oldest group examined, those aged 55 to 64, started with the second lowest suicide rate but became the second highest, swapping with the 35 to 44 group.

This oldest group saw a suicide rate increase of 40.6 percent, the most profound increase across any rate in Table 5.

Differences across rural and urban locations are most evident among males, although the highest rates among females tend to be in more rural locations as well. The youngest age group also had the greatest differences across rural and urban locations, where suicide rates in the most rural counties were more than double those in large metro areas. The oldest age group barely had a difference across most rural and most urban location, with the highest suicides rates being in the micropolitan county types. The overall geographical differences correspond with previous research among all ages and young adults (Fontanella et al., 2015; Singh & Siahpush, 2002; Ivey-Stephenson et al., 2017), but studies have not looked at ages 55 to 64 specifically across location. A recent report by the CDC shows increasing rates across rurality for both groups 35 to 64 and 65 and up (Ivey-Stephenson et al., 2017), so the idiosyncrasies by location within the oldest 10-year age group seen here likely do not hold once collapsed with other age groups.

The results from the maps and trends indicate that rural areas have higher suicide rates than urban areas, confirming hypothesis 1a. This holds overall, by gender, and across most age groups, although those age 55 to 64 show only slightly higher rates in rural locations than urban ones. Hypothesis 1b is also confirmed, as the rate of increase in the more rural county types is larger than the rate of increase in large metro counties for all groups except the 55-64 age group.

A possible explanation for increasing suicide rates across the nation could be due to the aging population in the United States (Howden & Meyer, 2011; Shrestha &

Heisler, 2011). Suicide rates tend to be higher among the older age groups, so an increasing percentage of the population reaching older age may lead to higher overall suicide rates across the nation. According to decennial census data, 13.4% of the population was aged 45 to 54 and 8.6% was aged 55 to 64 in 2000. These percentages increased in 2010, when 14.6% of the population was aged 45 to 54 and 11.8% was aged 55 to 64. Overall, the percentage of those aged 45 to 64 increased 31.5% from 2000 to 2010 (Howden & Meyer, 2011) and this group is expected to continue to increase in proportion of the overall population. The northeast and Midwest tend to have a higher percentage of those aged 45 to 64 then the south and west (Howden & Meyer, 2011), but the rural population of the nation tends to be older than the urban population, with a median age of 51 compared to 45 (US Census Bureau, 2016). Rural areas have also seen a greater decrease in population overall, with deaths and out-migration outpacing births and in-migration (Cromartie, 2017). Younger generations tend to leave more rural areas for the pursuit of higher education and job opportunities, leaving a smaller population of mostly older adults who tend to have high suicide rates.

The loss of younger adult populations could also contribute to the different suicide rates by geographical area seen in the 25 to 34 group, as suicide rates in rural counties are double what they are in large metro counties. One of the contributing factors is likely the outmigration of young adults from more rural counties. Youth tend to leave rural areas for higher education and job opportunities and fail to return. Those who stay face fewer opportunities and may lack peer support and social connections if many individuals from their peer group have left the area for opportunities elsewhere. This may

especially resonate by the time these individuals are in their late 20s and early 30s and do not have a strong social support group with whom to connect or a great outlook for career growth and opportunity within the rural community.

Contextual Factors Associated with Suicide

The regression analyses provided evidence that a variety of contextual factors are associated with suicide rates. Only two variables were related to decreases in suicide rate, psychiatrist ratio and social capital. The psychiatrist ratio variable replaced the provider index variable that was not significant in the combined model and was not used in previous research. The psychiatrist ratio finding aligns with other research that has shown availability of providers within a community can be helpful in reducing suicide rates (Kawaguchi & Koike, 2016; Kposowa, 2009; Tondo et al., 2006). While this variable does not measure actual use of these services, the availability of providers alone may be indicative of getting individuals in to see these providers. This also relates to the neighborhood resource model, as psychiatrist are a valuable resource and the presence of specialty mental health care can help create connections and support within a community.

Social capital having a negative association with suicide rates agrees with prior research that has shown a variety of measures of social capital can be protective against suicide (Desai et al., 2005; Kelly et al., 2009; Recker & Moore, 2016; Smith & Kawachi, 2014). The index used in the study represents a variety of organizations within a county that allow for the opportunity for individuals to connect with one another and the community. This relates to Durkheim's idea of social integration, where communities that are better integrated and connected have lower suicide rates. While the ecological

aspect of this study and variable do not indicate whether people are using these groups to connect and interact, the presence of these groups alone likely indicates they are being used by the community. Further, the decrease of suicide rates as social capital increases also indicates that despite the limitations of this variable, it does provide some indication of connection within a community. The social capital variable also relates to the neighborhood resource model, as increased resources present more opportunities for people to interact and connect.

The social fragmentation variable was found to be associated with increased rates of suicide, agreeing with previous research using a similar measure (Congdon, 1996, 2011b; Middleton et al., 2003; Whitley et al., 1999). Durkheim's idea of social integration is also captured in the relationship between fragmentation and suicide rates, as his belief was that communities lacking social integration, and thus highly fragmented, had higher suicide rates (Durkheim, 1951). There is also a potential relationship between social fragmentation and social capital. While neither variable over powered the other in this study, social capital can be seen as a method to overcome social fragmentation. An increase in opportunities for individuals to connect and bond with one another through groups and resources can reduce the impacts of a fragmented society. This also aligns with the neighborhood resource model, where the available resources can help connect and engage individuals.

The percent of veterans in a community is also related to suicide rates, with a 4% increase in suicide rates associated with a 1% increase in the veteran population. This confers with prior research (Blow et al., 2012; Fontenot, 2015; McCarthy et al., 2009)

and highlights the concern for the high rates of suicide that have been documented among the nation's veteran population. This particular group has been shown to have higher rates of psychological distress while also having access to lethal means, two factors that can increase their risk for suicide. No significant differences were seen across geographic location based on the veteran population, although rural counties tend to have a higher proportion of veterans which would imply higher suicide rates in rural areas due to a higher veteran population.

Increasing gun availability was also shown to be associated with suicide rates, although when examined across geographic location, an increase in gun shops was not associated with an increase in suicide rates in the most rural counties. Initially, this may appear to go against other research that has documented higher firearm ownership in rural areas and an association between firearm ownership and suicide rates (Kposowa et al., 2016; Miller et al., 2007; Opoliner et al., 2014; Price et al., 2009). But the current study uses gun stores as a measure of firearm availability rather than actual household ownership, and an increase in gun stores is only related to increased suicide rates in metro and micro counties. While additional research into how ownership and gun shops relate is necessary, it may be that availability of gun shops increases ownership in more densely populated counties, but not in the most rural counties. Rural households often already own firearms (Miller & Hemenway, 2013; Miller et al., 2007), so gun shops may not be associated with increased suicide rates in these counties because the guns are already in the homes and the shops do not have an impact on access or availability. Additional

inquiry into whether firearm suicide deaths are related to gun shops is necessary to better understand the relationship between gun shops and suicide across geographic location.

The index for socioeconomic deprivation was also shown to be associated with suicide rates, although the association decreased across time and varied by geographic location. Rural counties were impacted the most by increased deprivation and were the only county type with a significant association between increased deprivation and suicide rates by the final time-period in the study. Prior research has shown deprivation to be related to suicide rates (Lee et al., 2014; Singh et al., 2013; Yoon et al., 2015), but interactions across location and time have not been studied. The theories presented earlier can help explain the relationship between increased deprivation and increased suicide rates. Counties that lack economic opportunities can cause increased stress and role-conflict within and among individuals and families. If it is unlikely additional industries will become available in the county or a nearby area, hopelessness can set in, increasing risks for suicide. Rural counties suffer the most with increasing deprivation as these areas tend to thrive on a single industry (Jensen et al., 2003; Johnson, 2006), and if that industry changes, declines, or is threatened, other economic opportunities often do not exist. New industries do not regularly move to rural areas, whereas more urban counties tend to have the population, skill, and accessibility to draw new companies and employment opportunities.

The lack of significance found between increased deprivation and suicide rates in most counties during later study time-periods does correspond with some previous work that shows deprivation does not impact suicide rates with the inclusion of other variables

(O'Reilly et al., 2008; Zammit et al., 2014). Urban areas may be protected from the local economy and area deprivation because they are more connected to the nation and world, which may lessen the impact of the local area deprivation. The small metro county type showed a relationship between decreased suicide rates and increased deprivation in the last time-period. This is similar to other findings that studied unemployment specifically, finding lower unemployment associated with higher suicide (Bando et al., 2014; Crawford & Prince, 1999). Individual factors could contribute to this unique finding, where if an individual is unable to find work or has high stress in economically prosperous times, the risk for suicide may increase. Additional research is necessary to further understand this finding and to determine if it continues to hold true.

The findings for socioeconomic deprivation also relate to the findings for time. While time is associated with increased suicide rates, suicide rates are increasing more rapidly in the low and average deprived counties than in the highly deprived counties over time, although the difference is small. Controlling for the level of socioeconomic deprivation does not eliminate differences in suicide rates across time or by geographic location. Additional variables are likely contributing to increases in suicide rates over time that were not captured in this study. Again, one possible explanation may be the aging population, as suicide rates are higher among older generations and the US population is aging and did age across the study timeframe.

The differences in suicide rates by county type provide a variety of information due to the interactions. First, from the model estimates in Table 6, all county types have suicide rates increasing at a faster pace than the large metro counties over time, the most

rural county type suicide rates are higher based on similar deprivation and lower based on gun shops then the large metro counties, and the small metro counties have lower suicide rates than the large metro counties based on deprivation. But when all interactions are taken together, the greatest differences between counties are seen in the later time-periods when deprivation is high (see Table 8).

Gun shop availability does not produce much difference across county types when controlling for deprivation, although the incidence rates are higher when the availability of gun shops is low. If the gun shop variable were to measure ownership, the opposite would be expected; suicide rates would increase as gun ownership increased. However, in the current study, availability of gun shops only has an impact in more urban locations, so as gun shops increase, rural and urban suicide rates become more similar due to increasing suicide in these urban areas. While more research is needed to explore whether this holds up among firearm only suicides and how access to guns is impacted by gun shops, this finding does imply that firearm availability is not solely a rural issue. More urban areas are also at increased risk based on firearm availability through higher rates of gun shops.

The most rural county type shows the greatest difference from the large metro county type, particularly during the final time-period of the study (2012-2014). When deprivation is low, rural counties have 17% and 11% higher incidence of suicide depending on whether gun shop availability is low or high and when deprivation is high, rural counties have 31% and 24% higher incidence of suicide depending on whether gun shop availability is low or high. This finding agrees with prior research that shows rural

counties have higher suicide rates than urban counties (Fontanella et al., 2015; Singh & Siahpush, 2002; Snyder, 2016).

While deprivation is shown to have a larger association with suicide in rural areas than large metro areas, this alone does not explain the rural and urban differences. Other possible explanations exist for high rural suicide rates. Again, the rural population tends to be aging, with a higher percentage of older individuals living in these counties, possibly contributing to suicide rates. Individuals and families that have lived in rural areas for a long time and own homes may be unable to sell the properties and start over in more urban locations where cost of living may be higher even if opportunities are better. Houses tend to be older and in poorer condition in rural areas than other locations which may cause reduced sale prices and unwillingness of rural residents to relocate (National Rural Housing Coalition, 2014). Rural individuals may lack the skills to work in a new industry in a different location, and simply may not want to leave the area they call home regardless of outlook. Further, many individuals may be unwilling to leave family homesteads and a way of life that has been in the family for generations even if it is no longer sufficient to meet economic needs.

The culture in rural counties has also been documented to be different from more urban locations and can contribute to increased suicide rates. Self-reliance and taking care of one's self and family are high priority, and stigma often exists against seeking help for mental health issues (Smalley & Warren, 2012). Social norms within rural communities general encourage individuals to take care of themselves, but with declining industries, this is not always possible. The lack of opportunity in rural communities can

lead to increased stress and role conflicts, and an unwillingness to seek help prevents the development of appropriate coping skills which may result in increased risk for suicide throughout the county.

Another factor that could be contributing to increased suicide rates in rural counties is increasing suicide rates among farmers. The profession of farming, in combination with fishing and forestry, was recently documented to have a suicide rate of 85.9 per 100,000 individuals within the occupation, the highest rate among all occupations examined (McIntosh, 2016). The second highest rate was 53.3 per 100,000 individuals in the occupations of construction and extraction, another rural industry that has been declining. Other research has also documented high rates of suicides in farmers nationally and internationally (Klingelschmidt et al., 2018; Ringgenberg, Peek-Asa, Donham, & Ramirez, 2017). Farmers are thought to have high suicide rates due to the stressful lifestyle, increasing economic burden, an unwillingness to seek treatment, isolation, and access to lethal means. The expenses associated with maintaining the land, equipment, and livestock are not always covered by the sale of the product, increasing stress and burden on farmers. This can also produce hopelessness among farmers as they do not see their predicament improving and do not want to leave the farming lifestyle.

Overall, the longitudinal models show that multiple contextual factors are associated with suicide rates. Hypothesis 2a is correct; the three variables relating to fragmentation, firearms, and rural location are all positively associated with suicide in the overall model. The only variable that was not included in the final models was related to

alcohol. While this variable was significant individually, other contextual factors accounted for the relationship between drinking establishments and suicide rates.

The variable for drinking establishments was not associated with suicide even though previous research has shown alcohol consumption is associated with suicide rates (Caces & Harford, 1998; Innamorati et al., 2010; Kerr et al., 2011; Landberg, 2009). This could be due to a limitation in the variable. Alcohol consumption was not able to be measured at the county level, so a proxy was used for drinking establishments. However, drinking establishments do not measure alcohol consumption, as there are additional opportunities to consume alcohol, and the number of establishments does not include the total sales of alcohol. In addition, drinking establishments can be an opportunity for social capital, as individuals often go to bars and clubs to connect with others rather than simply consume alcohol.

After examining interactions between contextual variables and geographic location for objective 3 of the study, only hypothesis 3a can be confirmed. Deprivation does vary with geographic location and produces stronger associations in rural counties than large metro counties. Fragmentation and social capital were both tested to see if they vary geographically with the other variables from Model C, but the interactions were not significant and did they improve the model fit thus there is no evidence to support hypotheses 3b and 3c in this study.

Implications

Although the increasing rates of suicide over time and across geographic location are not completely explained by the findings in this study, several implications can be

drawn from the results for suicide prevention. This study can help identify specific groups of people and components within counties that can be targeted for suicide prevention efforts.

Population groups.

This study can help identify groups of people that are at increased risk for suicide or have high suicide rates compared to other groups. The examination of suicide trends over time indicates that the highest suicide rates in the study population exist among those age 45 to 54 and 55 to 64. Those aged 65 and up have been targeted for suicide prevention based on high suicide rates in the past, but the slightly younger groups have higher suicide rates now ("WISQARS," 2018). Those aged 45 to 64 can be a group targeted for suicide prevention, possibly by adapting suicide prevention programs that already exist for individuals 65 and over.

The trends over time also demonstrate that rural counties tend to have higher suicide rates than more metro and micro counties. Rural counties can be targeted with suicide prevention programs across all age groups and among younger age groups in particular. The age group 25 to 34 showed the greatest differences in suicide rates across rural and urban location. This group could be targeted in rural areas with prevention programs that already exist for high school and college age youth but adapted to fit a setting that is bounded within a county rather than a school or college.

While this study did not examine farmers specifically, they are also a group that could be targeted for suicide prevention efforts based on high suicide rates among farmers and in rural areas. Some companies have begun providing mental health

education and professional help to farmers because of high suicides and these efforts can be adapted to cover a broader spectrum of farmers across the nation ("sowing seeds of hope," 2010; Weingarten, 2017; Weingarten & Mulkern, 2017; Wolfe, 2018). Providing farmers with opportunities to seek help and relate to other farmers experiencing similar struggles could help reduce suicides among this vulnerable group.

Finally, another vulnerable group identified in this study and other studies is veterans. Prevention programs can be implemented in counties to target the veteran population, as these individuals tend to have high ownership of firearms, a great need for mental health services, a risk for PTSD, and can be feel isolated from other community members due to the unique experiences of veterans (SuicidePreventionLifeline.org, 2018; US Department of Veteran Affairs, 2017). Veterans increase suicide rates across the nation, regardless of rural location, and can be targeted for suicide prevention.

Prevention efforts.

Since the current study is ecological and does not examine the individual factors related to suicide, prevention efforts must also primarily focus on community level interventions as well. Fortunately, the CDC recently published a technical package highlighting evidence-based strategies that communities and states can implement to prevent suicide (Stone et al., 2017). They promote seven core strategies with multiple approaches that can be used for implementation. The seven strategies include strengthen economic supports, strengthen access to and delivery of suicide care, create protective environments, promote connectedness, teach coping and problem-solving skills, identify and support people at risk, and lessen harms and prevent future risk. Several of these

strategies can be useful to counter the factors that were associated with increased suicide rates in this study.

Connectedness, part of the technical package described above, was also part of a five-year plan to reduce suicidal behavior (Center for Disease Control, 2009). Building connectedness within a community increases social capital and reduces social fragmentation as individuals become more connected to one another and the community. These connections are ways to increase social support and coping skills while providing information about community resources such as mental health care. Approaches to build connectedness, or social capital, include peer norm programs and community engagement activities (Stone et al., 2017).

An intervention that uses connectedness as part of its approach and is showing promise in high schools is the Sources of Strength suicide prevention program ("Sources of Strength," 2018; Wyman et al., 2010). The program focuses on building relationships among peers; peer leaders are trained to identify individuals at risk and connect them with trustworthy adults to seek help ("Sources of Strength," 2018). An evaluation of the program has shown that trained peer leaders were more likely to reach out to adults for help for a suicidal friend and that students became more accepting toward seeking help for suicidal ideation than students in similar schools without the program (Wyman et al., 2010). This model could be adapted to fit communities, training leaders within the community that are able to use social networks to reach out and identify individuals who might be suicidal and need help. The program promotes help seeking and reducing isolation, important factors for reducing suicide risk. A similar program developed for

American Indian/Alaskan Native youth took a public health approach to reduce suicidal behavior within a community (May, Serna, Hurt, & DeBruyn, 2005). The program included a variety of components including the use of neighborhood volunteers to act as 'natural helpers' and reduce the stigma associated with seeking help. This program was shown to be effective and could be used to model larger community interventions, especially among other groups with high suicide potential.

Another possible way to reduce suicides through connectedness is to increase community engagement. One possible way to do this is through increased greenspace and community gardens. Branas and colleagues showed that adding green space to vacant lots was associated with a reduction in gun assaults and vandalism (2011, 2016). Residents near the green space also reported less stress and more exercise, which could promote healthy lifestyles and reduce suicidal behaviors (Branas et al., 2011). Increasing greenspace and developing community gardens provides opportunities for people to interact and connect, building social capital (Glover et al., 2004; Twiss et al., 2003). Although families and households in rural areas often have a private garden, the development of community gardens may benefit these locations by increasing social capital and creating deeper connections, especially in micro counties with a small population center.

The greenspace concept can also relate to strategies for economic supports. Studies show the greenspaces are associated with decreases in crime and increased exercise among neighboring residents, which can lead to an increase in property values and neighborhood affluence. This would be one possible way to increase the financial

security within a neighborhood by improving the local area. Additional job opportunities would also be useful to improve financial security, along with skills training and financial assistance as communities develop the human capital to draw additional work to the neighborhood. The Neighborhood Stabilization Program is a national program that has been implemented to help with housing foreclosures and abandonment (US Department of Housing and Urban Development, 2018). Making sure communities that are struggling with high deprivation are aware of this program and use it when necessary may help reduce stress from financial issues and decrease risk for suicides.

Creating protective environments is also a strategy to reduce suicide rates with approaches including reducing access to lethal means and changing the policies and culture within a community (Stone et al., 2017). Reducing access to lethal means is not limited to firearm availability and access but also to greater public health concerns such as bridges, railroad tracks, and cliffs. Several systematic reviews have been conducted to examine how effective different intervention techniques are for reducing suicides at local hotspots (Cox et al., 2013; Jin, Khazem, & Anestis, 2016; Pirkis et al., 2015). The four intervention techniques included in the reviews are installing physical barriers, encouraging help-seeking behavior through placement of signs and phone booths, increasing prevention efforts through surveillance, and improving media reporting of suicide. Reducing access to the lethal means through physical barriers shows the most promise in diverting suicides without a substitution effect. The other methods also show promise, but less research is available. While the current study does not examine method of suicide or hotspots for suicide, these prevention methods can still be used by local

communities that know where suicide hotspots tend to be. Additional analyses can also be done to identify potential locations to be targeted with these interventions.

Creating a protective environment can also be done through a change in culture and norms within a community or organization. Acceptance of asking for help and seeking mental health care can reduce stigma related to mental health and allow more individuals to seek services. Shifts in cultural norms and perception can take time, but multiple strategies have shown they can be effective. Leadership buy-in and increased education and training can help to bring about changes in norms.

The United States Air Force implemented a suicide prevention program that focused on reducing stigma from seeking mental health care, increasing understanding of mental health, and changing social norms within the Air Force (Knox, Litts, Talcott, Feig, & Caine, 2003). Multiple evaluations of the program have shown it was successful at reducing suicide risk when it was implemented rigorously (Knox et al., 2010, 2003). A similar program called Together for Life was implemented among Montreal Police and included components that provided training on suicide risk and offering help to colleagues, setting up a helpline for police officers, training supervisors and union reps on risks of suicide, and promoting the program throughout the police department (Mishara & Martin, 2012). Suicide rates reduced within the police department across the 11 years following the study while suicide rates across Quebec did not change. Other programs have been implemented in correctional facilities to successfully reduce suicides among prisoners (Barker, Kõlves, & De Leo, 2014; Hayes, 2013). These programs could be adapted to counties with high suicide rates, especially more rural counties with a

smaller population and cultural norms that go against seeking help for mental health needs. Specific communities within larger counties, especially ones that do not regularly seek mental health care (e.g. immigrant communities) can be targeted for suicide prevention by adapting some of these existing programs for implementation.

Strengthening access to and delivery of care is also an important suicide prevention technique. While only availability of psychiatrists was associated with suicide rates in this study, improved access to other types of care also may be associated with decreased suicides. Improving the density of specialty mental health providers may help reduce community suicide rates. Increases in mental health parity laws (mental health coverage by insurance) have been shown to be related to increased use of mental health services (Harris, Carpenter, & Bao, 2006; Lang, 2013). Coverage of mental health care was not part of the provider variable for this study but it could be an important factor for suicide prevention. It is also something that can be addressed though policy at the state or national level to have an impact on local communities. Additional research is necessary to show that use of these services and mental health insurance coverage are associated with reduced suicide risk.

Additional suicide prevention methods can be implemented at the community level that improve coping skills, reduce stress, teach appropriate management of stress, promote connects among community members, and provide economic supports. Gatekeeper trainings (Isaac et al., 2009; Zalsman et al., 2016) and suicide prevention call or text lines (Zalsman et al., 2016) are promising interventions that could work within communities but need additional research to verify their effectiveness at the community

level. Increasing legislative and financial support for suicide prevention efforts can be an important component to suicide prevention as well (Lubell, Singer, & Gonzalez, 2008). There are often limitations to implementing suicide prevention efforts throughout a community or county without the appropriate funds to do so.

Strengths and Limitations

There are several strengths evident in the current study. First, it examines multiple contextual factors in a single model to determine factors that influence suicide rates. These factors are also examined over time and across different geographic locations to examine why possible variations in suicide rates exist. The inclusion of both longitudinal and geographical data is new to the study of suicide and the current study includes them both. The study also includes all of the United States, rather than limited analyses to the lower 48. It uses county level data to gain a deeper understanding of geographical differences and factors impacting suicide rates.

There are several limitations to this study also. First, while associations are found between contextual variables and suicide rates, this is an ecological study that does not allow for interpretation at the individual level. The findings do not allow for conclusions to be drawn about specific individuals. There are also limitations to many of the variables included in the study. Some of the variables, such as providers, drinking establishments, and gun shops do not provide a prefect measure for the contextual factors that could be driving suicide rate increases (e.g. use of services, consumption of alcohol, ownership of guns). The study was limited to the variables that were available at the county level for all of the US. Some variables were also missing data for the first or second time-period

due to the American Community Survey not being initiated until later. There were additional variables that were not included in this study that may also be associated with suicide rates. The methods of suicide were not examined in the current study nor were factors associated with suicide based on specific age groups or gender. Finally, this study is a correlational study and does not indicate cause and effect. While associations between contextual variables and suicide were found, those contextual factors may not be causing increases in suicide rates.

Conclusion

The current study examined patterns and trends in suicide over time by gender, age, and geographic location. Suicides were shown to be increasing in western states, among all age groups, both genders, and by geographic location. Several contextual factors were associated with increased suicide rates while social capital and psychiatrist availability were associated with decreased suicide rates. While socioeconomic deprivation is associated with higher rates of suicide in more rural areas than urban areas, this alone does not explain the differences in suicide across location. The availability of gun shops tended to have a greater impact in more metro counties while not significantly influencing suicide rates in rural counties. Additional research is still necessary to understand how contextual factors vary across age, gender, and method of suicide.

Based on the findings, suicide prevention efforts can be targeted toward those aged 45 to 64 as the suicide rates are growing most rapidly in this group. Rural residents can also be targeted for suicide prevention, especially those of the farming occupation and those of younger ages as they have much higher rural suicide rates than urban suicide

rates. Economic stabilization and increased connectedness within communities may be effective ways to reduce suicide rates within counties across the nation. Nonetheless, additional research is still important to further understand and implement practices to reduce suicide rates across geographic locations.

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Appendix A. Summary of Collapsed Counties for Longitudinal Analysis

Alaska:

02130, 02195, 02198, 02201, 02275, and 02280 collapsed into 02130

- All counties were collapsed when they existed due to multiple boundary changes that occurred in 2008
    - 280 was divided into 275 and 195
    - 201 was divided into 130, 275, and 198
    - 130 annexed part of 201
    - 275 was created from part of 280 and 201
    - 198 was created from the remainder of 201
    - 195 was created from the remainder of 280

02230, 02105, and 02232 collapsed into 02232

- In 2007, 02232 was divided into 02105 and 20230; counties 02105 and 02230 were combined across all study periods where they existed in the data

Virginia:

51515 and 51019 collapsed into 51019

- counties were combined in 2013; data existing for both counties was collapsed across all study periods

51005 and 51560 collapsed into 51005

- counties were combined in 2001; data existing for both counties was collapsed for the 2000-2002 period.

Appendix B. Suicide Trends by Gender, Age, and RUCC

	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	Slope[a]	p-value
Males							
Age							
25-34	20.51	20.89	21.05	22.21	23.51	.25	<.001
35-44	23.27	23.36	24.04	24.82	25.15	.17	<.001
45-54	23.40	24.82	27.26	29.95	29.90	.60	<.001
55-64	20.97	22.00	24.10	27.04	28.80	.69	<.001
RUCC							
1 (large metro)	19.35	19.76	20.98	22.42	22.49	.30	<.001
2	23.60	24.23	25.81	27.86	29.17	.50	<.001
3	24.51	27.17	28.42	30.99	33.26	.64	<.001
4	27.41	27.47	29.12	31.36	33.69	.55	<.001
5	27.42	28.00	29.70	34.44	35.21	.67	<.001
6	27.70	29.28	29.65	32.73	33.81	.53	<.001
7	29.19	31.33	31.20	34.63	37.44	.66	<.001
8	30.14	30.66	31.16	34.31	35.42	.45	.001
9 (most rural)	30.73	33.13	34.22	35.74	39.84	.69	<.001
Females							
Age							
25-34	4.48	4.72	4.97	5.46	6.05	.13	<.001
35-44	6.56	6.84	7.25	7.47	7.84	.11	<.001
45-54	7.11	8.09	8.73	9.38	10.27	.25	<.001
55-64	5.60	6.01	6.98	7.67	8.52	.25	<.001
RUCC							

Continued

	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	Slope[a]	p-value
1 (large metro)	5.60	5.91	6.31	6.75	7.15	.13	<.001
2	6.45	7.28	7.78	8.29	9.24	.22	<.001
3	6.59	7.19	8.23	8.99	9.87	.28	<.001
4	6.62	7.57	8.06	8.64	9.56	.23	<.001
5	7.08	7.52	8.53	8.99	10.41	.30	<.001
6	6.92	7.15	7.79	8.49	9.75	.24	<.001
7	7.17	7.63	7.89	9.43	10.41	.29	<.001
8	5.89	7.30	9.28	10.13	10.82	.43	<.001
9 (most rural)	6.27	7.01	8.55	8.41	10.71	.34	<.001
Age group 25-34							
RUCC							
1 (large metro)	10.73	10.60	11.00	11.40	12.19	.13	<.001
2	13.32	13.96	13.87	15.36	16.65	.27	<.001
3	14.54	15.76	16.01	17.32	18.53	.32	<.001
4	15.87	16.94	17.84	18.28	18.78	.24	<.001
5	15.34	17.44	15.87	19.67	20.35	.37	.007
6	16.00	17.13	15.97	19.23	20.85	.40	<.001
7	18.81	19.98	18.64	20.31	22.38	.27	.02
8	17.23	16.28	20.00	21.28	19.18	.29	.07
9 (most rural)	20.89	19.50	21.15	21.61	26.52	.47	.02
Age group 35-44							
RUCC							
1 (large metro)	12.67	12.90	13.21	13.62	13.71	.09	<.001
2	16.14	16.10	17.32	17.53	18.22	.19	<.001
3	17.52	17.82	19.24	20.10	21.26	.31	<.001
4	18.44	18.22	18.83	20.91	22.09	.33	<.001
5	19.98	18.72	20.25	21.98	23.83	.38	.003

Continued

	2000-2002	2003-2005	2006-2008	2009-2011	2012-2014	Slope[a]	p-value
6	19.68	20.69	19.92	21.28	20.77	.10	.09
7	19.08	20.05	20.69	23.62	23.91	.46	<.001
8	20.03	20.88	19.35	22.72	26.06	.42	.01
9 (most rural)	19.81	22.13	22.90	23.55	25.66	.42	.003
Age group 45-54							
RUCC							
1 (large metro)	13.66	14.59	15.92	17.53	17.12	.33	<.001
2	16.01	17.41	19.15	20.86	21.93	.51	<.001
3	16.62	18.80	20.03	22.43	24.50	.65	<.001
4	16.96	18.29	19.94	21.64	23.93	.57	<.001
5	17.77	17.81	22.34	23.51	24.65	.61	<.001
6	16.86	18.10	20.68	22.69	23.85	.63	<.001
7	18.33	19.50	19.75	22.98	27.06	.67	<.001
8	18.62	19.99	22.68	23.58	24.37	.52	<.001
9 (most rural)	17.11	20.73	22.19	23.18	27.00	.72	<.001
Age group 55-64							
RUCC							
1 (large metro)	12.18	12.63	14.19	15.88	16.52	.40	<.001
2	13.11	14.33	15.67	17.87	19.60	.54	<.001
3	13.70	14.53	16.40	18.88	20.93	.63	<.001
4	15.06	14.80	16.02	17.14	20.22	.43	<.001
5	13.17	15.21	15.85	20.20	20.46	.63	<.001
6	14.49	14.52	16.50	16.89	20.52	.50	<.001
7	14.06	16.26	17.21	18.84	19.95	.49	<.001
8	13.23	16.76	17.09	19.26	20.45	.55	<.001
9 (most rural)	13.19	14.65	16.40	16.85	18.33	.44	<.001

Note. RUCC = Rural Urban Continuum Code.

[a] slope was calculated based on all 15 years of data.

Appendix C. Descriptive Statistics of Contextual Variables

Variable	Mean	Standard Deviation	Median	Range
Socioeconomic				
Population aged 25+ with less than high school education, %	7.43	4.82	6.24	0-46.29
Population aged 25+ with at least a high school diploma, %	81.36	8.50	82.77	34.7-98.74
Employed persons aged 16+ in white collar occupations, %	52.41	7.51	51.72	14.2-86.17
Civilian labor force population aged 16+ unemployed, %	7.00	3.45	6.49	0-41.67
Median family income, $	50,528.64	14,103.68	48,706.00	14,167-165,430
Gini index	.44	.04	.43	.20-.63
Median home value, $	111,877.41	74,201.41	90,900.00	12,500-1,016,509
Median gross rent, $	574.89	197.81	548	181-2,034
Median monthly mortgage, $ (owner-occupied housing)	1009.4	352.54	947	0-3,615
Median annual real estate taxes, $ (owner-occupied housing)	1,112.55	922.63	866	0-10,001
Families below the poverty level, %	11.40	5.76	10.38	0-55.74
Population below 150% of poverty threshold, %	26.14	9.03	25.36	0-70.80
Single-parent households with children under 18, %	14.63	5.20	13.80	0-55.31

Continued

Variable	Mean	Standard Deviation	Median	Range
Households receiving supplemental security income, %	5.16	2.82	4.54	0-28.76
Households receiving public assistance income, %	2.85	1.96	2.48	0-36.89
Owner-occupied housing units, %	72.99	7.97	74.35	0-94.73
Households without a motor vehicle, %	4.54	4.73	3.20	0-81.80
Households without a telephone, %	3.76	2.84	2.98	0-46.11
Occupied housing units lacking complete plumbing, %	1.44	2.77	.72	0-59.33
Households with more than 1 person per room, %	2.82	2.90	2.06	0-52.50
Median number of rooms per housing unit	5.51	.45	5.50	2.0-7.6
Housing units with 4 or more bedrooms, %	89.32	5.78	90.62	0-100
Social Fragmentation				
Residents not in the same house 1 year ago, %	15.42	4.92	14.90	0-52.25
Single person households, %	20.39	9.46	23.43	1.75-88.73
Divorced residents, %	10.54	2.38	10.49	0-27.51
Renter-occupied housing units, %	27.01	7.98	25.65	5.27-100
Social Capital				
Recreation sites per 10,000 persons	2.07	1.87	1.70	0-41.04
Civic and social associations per 10,000 persons	1.34	1.57	.94	0-23.20
Religious organizations per 10,000 persons	9.40	5.07	8.61	0-49.72
Business and political organizations per 10,000 persons	1.52	1.51	1.22	0-27.39

Continued

Variable	Mean	Standard Deviation	Median	Range
Agents and managers per 10,000 persons	0.20	.46	0	0-10.52
Public charities and foundations per 10,000 persons	12.25	9.33	10.32	0-162.39
Arts and nature facilities per 10,000	0.49	1.08	.17	0-24.91
Beauty facilities per 10,000 persons	1.95	1.85	1.62	0-24.54
Health Services				
Psychiatrist ratio per 100,000 persons	0.44	.87	0	0-15.52
Psychiatric bed ratio per 100,000 persons	0.81	2.12	0	0-42.80
Hospital bed ratio per 100,000 persons	34.97	49.78	23.19	0-1,068.94
Primary care provider ratio per 100,000 persons	4.56	3.28	4.06	0-48.68
Individuals without health insurance, %	19.69	6.58	18.99	0-51.91
Any CMHC, N(%)	1,913	12.19		
Any FQHC, N(%)	6,814	43.43		
Any psychiatric hospital, N(%)	1,202	7.66		
Other Variables				
Veteran population, %	9.20	2.27	9.06	0-37.86
Drinking establishments per 10,000 persons	2.98	4.26	1.67	0-57.52
Gun shops per 10,000 persons	.43	.67	.23	0-11.53
Male percent	50.46	2.90	49.89	39.85-78.68
Median age	39.07	4.94	38.90	20.00-65.30

Appendix D: Summary of Principal Component Analysis Factor Loadings

	Socioeconomic Deprivation	Social Fragmentation	Social Capital	Providers
Population aged 25+ with less than high school education, %	.68			
Employed persons aged 16+ in white collar occupations, %	-.56			
Civilian labor force population aged 16+ unemployed, %	.53			
Median family income, $	-.78			
Gini index	.51			
Median home value, $	-.51			
Median annual real estate taxes, $	-.56			
Families below the poverty level, %	.84			
Single-parent households with children under 18, %	.58			
Households receiving supplemental security income, %	.74			
Households receiving public assistance income, %	.61			
Households without a motor vehicle, %	.53			
Households without a telephone, %	.64			
Occupied housing units lacking complete plumbing, %	.43			
Households with more than 1 person per room, %	.54			
Median number of rooms	-.63			

Continued

	Socioeconomic Deprivation	Social Fragmentation	Social Capital	Providers
per housing unit				
Residents not in the same house 1 year ago, %		.33		
Single person households, %		.47		
Divorced residents, %		.53		
Renter-occupied housing units, %		.63		
Recreation sites per 10,000 persons			.64	
Civic and social associations per 10,000 persons			.58	
Religious organizations per 10,000 persons			.40	
Business and political organizations per 10,000 persons			.53	
Agents and managers per 10,000 persons			.44	
Public charities and foundations per 10,000 persons			.79	
Arts and nature facilities per 10,000			.53	
Beauty facilities per 10,000 persons			.54	
Psychiatrist ratio per 100,000 persons				.77
Psychiatric bed ratio per 100,000 persons				.59
Hospital bed ratio per 100,000 persons				.57
Primary care provider ratio per 100,000 persons				.81
Individuals without health insurance, %				-.38