Journal of Rural Social Sciences

Volume 37
Issue 2 *Space, Place, and COVID-19*

Article 3

June 2022

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Recommended Citation

Sun, Yue, Kent Jason Cheng, and Shannon Monnat. 2022. "Rural-Urban and Within-Rural Differences in COVID-19 Mortality Rates." *Journal of Rural Social Sciences*, 37(2): Article 3. Available At: https://egrove.olemiss.edu/jrss/vol37/iss2/3

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Cover Page Footnote

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ABSTRACT
Since late-2020, COVID-19 mortality rates have been higher in rural than in urban America, but there has also been substantial within-rural heterogeneity. Using CDC data, we compare COVID-19 mortality rates across the rural-urban continuum as well as within rural counties across different types of labor markets and by metropolitan adjacency. As of October 1, 2021, the cumulative COVID-19 mortality rate was 247.0 per 100,000 population in rural counties compared to 200.7 in urban counties. Higher COVID-19 mortality rates in rural counties are explained by lower average educational attainment and lower median household income. Within rural counties, mortality rates have been highest in farming-dependent counties and lowest in recreation-dependent counties. Those differences are similarly explained by differences in educational attainment and median household income. Our findings have implications for ongoing COVID-19 prevention and vaccination efforts as well as for informing preparation efforts for future infectious disease outbreaks.

KEYWORDS
COVID-19, labor markets, mortality, rural U.S.

INTRODUCTION
As of October 2021, there had been over 42.6 million COVID-19 infections and over 693,760 deaths in the U.S. In the early phase of the COVID-19 outbreak (March-June 2020), infections and deaths were predominantly clustered in urban areas. By late-summer and early-fall, cases and deaths started to increase at a faster pace in rural areas, but urban cases and

death rates remained higher. By December 2020, rural death rates had surpassed those in urban areas and have remained higher ever since.

Higher urban COVID-19 infection and mortality rates during the early part of the pandemic were largely attributable to higher population density and location of transportation hubs that facilitated quick spread (Karim and Chen 2020; Paul et al. 2021; Sun 2020; Zhang and Schwartz 2020). However, in the pandemic's later phases, cases quickly spread to rural communities, with large outbreaks clustered in counties with among the smallest populations (Leatherby 2020). Moreover, vaccination rates have been lower in rural than in urban areas, especially in farming and mining-dependent counties (Sun and Monnat 2021). The costs of COVID-19 to individuals and families have been monumental. COVID-19 has also had detrimental consequences to local public health systems and economies. Therefore, it is critical to understand which types of places have been most affected and what factors are driving these differences.

Accordingly, this article 1) describes rural-urban differences in COVID-19 mortality rates as well as variation within rural counties by categories of economic dependence and metropolitan adjacency, and 2) identifies the factors that explain these differences.

We found significantly higher mortality rates in rural counties than in urban counties overall. We also found substantial variation within rural counties, with the highest mortality rates in farming-dependent counties and the lowest rates in recreation-dependent counties. Both rural-urban and within-rural differences in COVID-19 mortality rates are explained by differences in educational attainment composition and median household income. Our findings have implications for ongoing COVID-19 prevention and vaccination efforts as well as for informing preparation efforts for future infectious disease outbreaks.

The Rural Mortality Penalty as a Backdrop for Rural-Urban Differences in COVID-19 Mortality

Rural America has long faced a mortality disadvantage (Cosby et al. 2008, 2019; Elo et al. 2019; James 2014; James and Cossman 2017; James, Cossman, and Wolf 2018; Singh and Siahpush 2014; Monnat 2020a; Vierboom, Preston, and Hendi 2019). The gap has grown over the past couple of decades and is pervasive across multiple disease and injury categories (Monnat 2020a). The rural mortality penalty is grounded in the literature on ecological determinants of population health, which include individual-level risk factors and behaviors, community contexts (e.g., economic and employment conditions, health care infrastructure), and macro-level conditions (e.g., state policies, industrial restructuring, population loss) that increase risk of or protect against adverse health outcomes and premature mortality. Rural areas have historically faced higher mortality rates from infectious disease outbreaks (Paynter, Ware, and Shanks 2011; Shanks 2019) and regularly experience higher annual rates of influenza mortality (U.S. Centers for Disease Control and Prevention 2021). Many of the same risk factors for worse health outcomes and higher rates of mortality in rural areas overall also apply to COVID-19.

Compositionally, rural populations are older and face a higher chronic disease burden than urban populations, drastically increasing their risk of high rates of COVID-19 mortality (Monnat 2020b; Johnson 2020; Peters 2020). Nearly 20 percent of rural residents are age 65 or older compared to 15 percent of urban residents, and 65 percent of the U.S.'s small nonmetro counties (identified as rural-urban continuum codes 8 and 9) are considered "older age" counties where more than 20 percent of the population is age 65 or older (Monnat 2020b). Because older adults are at greater risk of dying from COVID-19, rural communities with larger shares of older adults are at risk of higher mortality rates. Moreover, rural populations are socioeconomically vulnerable, with higher rates of poverty (Thiede, Lichter, and Slack 2018) and underemployment (Jensen and Slack 2003; Slack, Thiede, and Jensen 2020), and lower levels of education (Carr and Kefalas 2009) and health insurance coverage (Gong et al. 2019). These factors may influence health care access, prevention behaviors, and COVID-19 vaccination rates. A recent study found that county-level education, poverty, and racial/ethnic composition are strongly associated with COVID-19 mortality rates (Albrecht 2021). Lower county-level educational attainment also partially explains lower COVID-19 vaccination rates in rural counties compared to urban counties (Sun and Monnat 2021).

Rural communities also face several contextual disadvantages that put their populations at risk, including less robust health care and public health infrastructures, labor market disadvantages, and weaker state-level COVID-19 spread mitigation policies. In terms of health care infrastructure, since January 2005, 181 rural hospitals have closed, with a record 19 closures in 2020 alone (Cecil G. Sheps Center 2021). Many of the rural hospitals that are available have less capacity to deal with surges in cases, limited medical personnel, and less access to ventilators and personal protective equipment for healthcare providers. Especially relevant for COVID-19 is that only one percent of the U.S.'s intensive care unit beds are located in rural areas (Society of Critical Care Management 2020). COVID-19 testing and vaccination rates have also been lower in rural areas (Monnat 2020b; Souch and Cossman 2021; Sun and Monnat 2021), increasing risk of community spread.

Differences in labor markets and working conditions may also place rural residents at increased risk. For example, rural workers were more likely to continue working during the pandemic and were less likely to work remotely (Brooks et al. 2021; Callaghan et al. 2021), and schools were more likely to remain open or operated remotely for much shorter periods (Gross and Opalka 2020). Government-deemed essential industries like meatpacking, agriculture, and prisons are disproportionately located in rural areas, placing workers at increased risk of infections (Hooks and Sawyer 2020; Peters 2020; Taylor, Boulos, and Almond 2020).

In addition, differences in political ideology and partisanship may contribute to higher rural mortality rates. Rural counties had much higher vote shares for Trump in the 2020 Presidential election, and county Trump vote share has been found to be associated with both lower vaccination rates (Sun and Monnat 2021) and higher COVID-19 case rates (Albrecht 2021). Rural residents have also been less likely than their urban peers to adopt COVID-19 prevention behaviors, such as physical distancing, avoiding dining out, and wearing face masks (Bruine de Bruin, Saw, and Goldman 2020; Callaghan et al. 2021; Probst et al. 2020; Haischer et al. 2020). In addition, rural residents are less likely than their urban peers to report being worried about getting sick and are more likely to say that the severity is exaggerated (Kirzinger et al. 2021).

State-level COVID-19 mitigation policies may have also played a role. For example, governors in rural states (those with lower population density) were slower to enact statewide state-at-home orders (Lin et al. 2021) and were less likely to enact physical distancing mandates (Adolph et al. 2021) than governors in more urban states.

Within-Rural Variation in COVID-19 Vulnerability

For all of the reasons described above, we would expect rural communities in general to face a COVID-19 mortality penalty. However, rural areas are not homogenous. Just as the overall mortality penalty varies across rural areas (James 2014; Monnat 2020a), so too should we expect that COVID-19 mortality rates would vary across different types of rural communities.

Evidence suggests that infection trends have varied by adjacency to metro areas (Cheng, Sun, and Monnat 2020; Sun 2020; Zhang and

Schwartz 2020) and across different types of rural labor markets (Cohen 2020; Cromartie et al. 2020; Hooks and Sawyer 2020; Waltenburg et al. 2020; USDA Economic Research Service 2021).

In terms of adjacency to metro areas, metro adjacent rural counties are at increased risk of COVID-19 spillover effects due to employment and recreation commuting patterns from neighboring urban hubs. The USDA Economic Research Service (ERS) classifies counties into economic dependency types based on wages and employment from specific industries. Their six mutually exclusive categories include farming, mining, manufacturing, government, recreation, and nonspecialized. Research on all-cause and cause-specific mortality trends finds substantially higher rates for most types of mortality in mining-dependent counties and comparatively lower rates in farming-dependent counties (Monnat 2020a). Recent research also shows that vaccination rates have been highest in recreation dependent counties and lowest in farming and mining dependent counties (Sun and Monnat 2021).

Specifically related to COVID-19 mortality rates, on the one hand, we might expect lower rates in farming-dependent counties due to lower population density which would reduce spread. On the other hand, farming-dependent counties face many of the risks described above. Many farming-dependent counties in the middle of the U.S. scored high on a community susceptibility scale developed by Peters (2020) in the early months of the pandemic. Their populations are older and more health compromised and have comparatively lower educational attainment and median household income. Moreover, farming is essential work that cannot be done remotely. The agriculture industry often relies on undocumented laborers who might not be able to afford to miss work or are afraid to miss work if they are sick. Farm workers also have high uninsured rates, and health care availability is limited in these communities (Becot et al. 2020). Finally, states with large shares of farming-dependent counties have governors who were slow to enact stay-at-home and physical distancing mandates (and mandates were short-lived) (Li et al. 2021).

Mining-dependent rural counties might also be expected to have increased COVID-19 mortality risk given their higher rates of poverty, lower education, higher rates of chronic diseases, and higher mortality rates from cancer, heart, and respiratory diseases (Esch and Hendryx 2011; Hendryx, Fedorko, and Halverson 2010; Liu et al. 2021; Monnat 2020a). Environmental byproducts of mining, such as dust and other hazardous waste, harm respiratory health, exacerbating the effects of a respiratory disease like coronavirus. Rural counties dominated by mining and farming have also historically been more politically conservative (Scala and Johnson 2017; Kaufman 2016; Lewin 2019) than other rural areas, which might drive up COVID-19 mortality rates for the same reasons outlined above.

Manufacturing-dependent counties may also be at risk of having higher COVID-19 mortality rates (Peters 2020). Counties with meat processing plants have experienced large COVID-19 outbreak clusters (Cromartie et al. 2020; USDA ERS 2021; Waltenburg et al. 2020). As of July 2020, 23 states had reported outbreaks at meat and poultry processing plants (Waltenburg 2020), including in rural communities in Arkansas, Georgia, Nebraska, North Carolina, and South Dakota (Paschal 2020; Smith-Nonini 2020; Steinberg et al. 2020). An outbreak in two facilities in Nebraska was tied to 3,438 cases among workers alone, who then spread the disease to family and community members. Hispanic workers have been disproportionately affected due to their large concentration as workers in these types of facilities (Champlin and Hake 2006; Peters 2020). Working conditions (crowded, moist, cold) in meat processing plants and other manufacturing facilities are ideal for coronavirus spread (Reuben 2020). Moreover, many meat processing plants were found to be negligent in enacting safety measures (e.g., mandatory face masks and social distancing) in the early months of the pandemic and do not provide employees with paid sick leave or health insurance (Paschal 2020; Smith-Nonini and Paschal 2020). Because meat processing plants were classified as essential infrastructure, very few closed or reduced worker capacity during the pandemic (Paschal 2020; Smith-Nonini and Paschal 2020).

Much attention has been paid to outbreaks in prisons and the communities in which they are located (Hershow et al. 2021; Hooks and Sawyer 2020; Lewis et al. 2021; Ollove 2020; Schumaker 2020). Many rural communities have embraced prisons as an economic development strategy, and as a result, the nation’s prisons are disproportionately located in rural areas (Lichter and Ziliak 2017). The USDA ERS includes prisons in the government-dependent employment category. Because of the crowded and unsanitary living conditions, the high prevalence of chronic health conditions among incarcerated people, and lack of personal protective supplies, prisons and jails were susceptible to coronavirus outbreaks (Ollove 2020; Schumaker 2020). For example, as of October 27, 2020, almost half of the incarcerated population in South Dakota had contracted COVID-19 (Schumaker 2020). Cohen (2020) showed similar

COVID-19 outbreaks in the early months of the pandemic that were linked to state prisons in rural counties in Arkansas, Kentucky, Louisiana, Tennessee, and Virginia. COVID-19 outbreaks in prisons have spillover effects in the local community, as prison workers carry the disease home with them after their shifts (Ollove 2020).

Unlike counties dominated by high-risk industries such as agriculture, mining, manufacturing, and government employment described above, communities that rely on recreation and services may have been protected against COVID-19. Recreation and services, such as restaurants, bars, and entertainment venues, were considered non-essential businesses by most state governments. Therefore, when stay-at-home and business closure mandates were enacted, these businesses closed, reducing employees' and customers' exposure and community spread. Irrespective of government mandates, residents generally reduced their visits to these places, particularly during periods when case rates were increasing (Goolsbee and Syverson 2021). A recent study showed that recreation dependent rural counties had the highest vaccination rates among all rural labor market types (Sun and Monnat 2021), implying that the residents of these types of counties were more likely to take precautionary measures to prevent coronavirus spread. As a result, we might expect COVID-19 mortality rates to be lower in rural communities dependent on recreation.

DATA AND METHODS

This study included 3,142 U.S. counties. The dependent variable was the cumulative COVID-19 mortality rate (deaths per 100,000 population) as of October 1, 2021. Mortality data are from USA Facts (USA Facts 2021). Because COVID-19 mortality rates were normally distributed, we used ordinary least squares (OLS) regression for analyses. We focused on death counts instead of confirmed COVID-19 cases because the latter is susceptible to geographic bias in underreporting due to geographic disparities in testing, especially in resource-constrained rural areas (Peters 2020; Souch and Cossman 2021). However, we replicated all analyses using confirmed cases as the outcome (see Appendix Table 3 and 5). An important caveat of the CDC case data is that they include only new instances of reported cases, not instances when someone has been infected more than once.

In the first set of analyses, we compared COVID-19 mortality rates across the nine-category rural-urban continuum, using the USDA ERS Rural-Urban Continuum Codes (RUCC) for 2013 (USDA ERS 2020).

Counties with RUCCs 4-9 are considered rural. We first ran models that adjusted only for state fixed effects to adjust for the clustering of counties within states and to account for unobserved variation in time invariant state characteristics, such as pre-COVID-19 policies and political orientation. Next, we introduced several county-level factors that may explain rural-urban variation in COVID-19 mortality rates in stepwise models. Sociodemographic composition factors included county percent non-Hispanic Black, percent Hispanic, percent age 65+, percent age 25+ with a bachelor's degree or more, median household income, and percentage without health insurance from the U.S. Census Bureau American Community Survey 2015-19 (ACS 2021). Health care resources included whether the county is a health professional shortage area and physicians per 100,000 population from the Area Health Resource Files, 2019-2020 (HRSA 2020). To account for political ideology and Trump influence, we included the 2020 Trump vote share from Dave Leip's Atlas of U.S. Elections (Leip 2021). We generated quartiles for variables that were not normally distributed (percent non-Hispanic Black, percent Hispanic, and physician rate). We z-score standardized continuous variables (mean=0; standard deviation=1). In the main text, we present coefficients from the unadjusted and fully adjusted models. In a series of stepwise models shown in the Appendix, we determine which factors contribute most to rural-urban differences in COVID-19 mortality rates. Means and standard deviations for all variables are presented in Appendix Table 1.

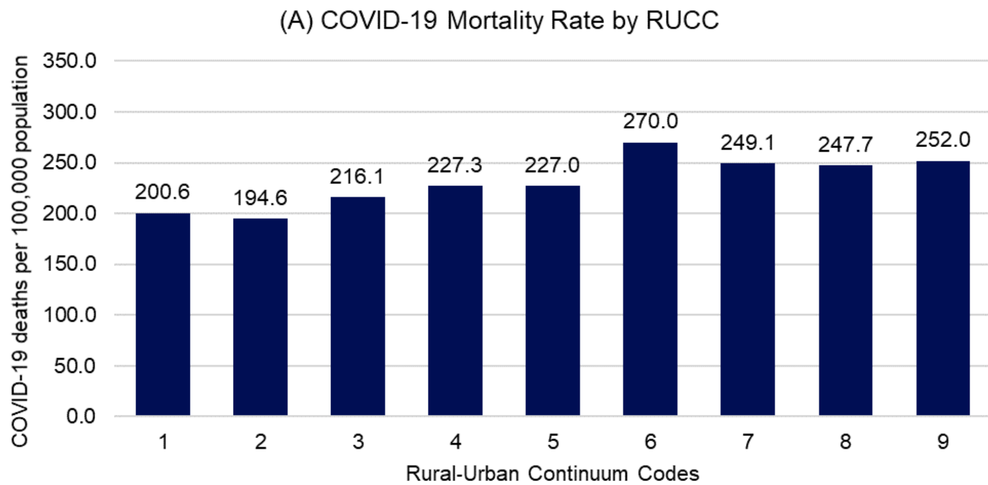
In our second set of analyses, we restricted our sample to rural counties (N=1,976) to examine how county labor market type (economic dependence) and adjacency to metropolitan areas are associated with COVID-19 mortality rates. We classified labor markets based on the USDA ERS County Typology Codes (USDA ERS 2019), which include six mutually exclusive and exhaustive categories: nonspecialized, farming, mining, manufacturing, government, and recreation/services (reference group). The ERS determines its categorization based on the share of employment and earnings coming from each industry. For example, farming dependent counties are those with farm earnings accounting for an annual average of 25 percent or more of total county earnings or farm employment accounting for 16 percent or more of total employment in 2010-12. Each type has its own threshold of earnings and employment. Details about each type are provided in the ERS County Typology documentation (USDA ERS 2019). Metro adjacent counties are those with RUCCs of 4, 6, or 8. We apply the same regression modeling strategy applied above to identify differences in COVID-19 mortality rates by labor market dependence and metro adjacency and identify the factors contributing to those differences.

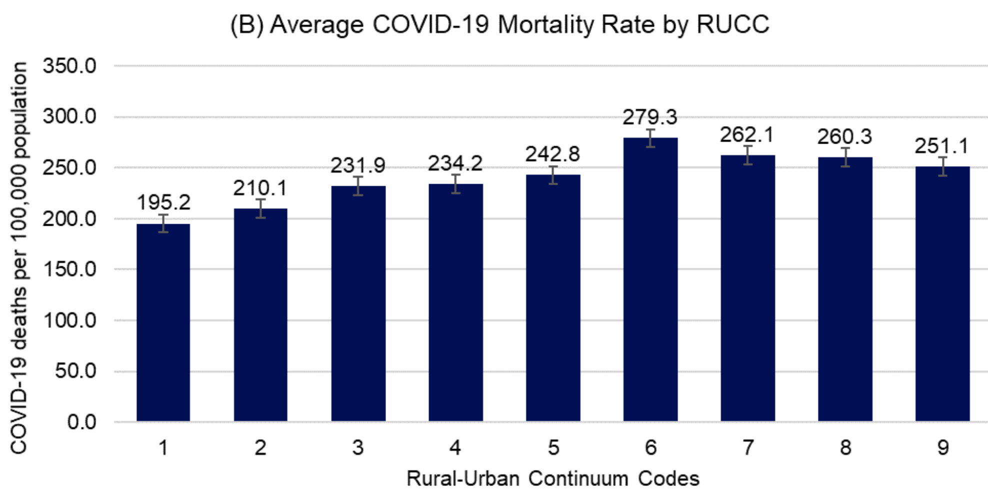
RESULTS

As of October 1, 2021, the cumulative COVID-19 mortality rate was 247.0 per 100,000 population in rural counties compared to 200.7 in urban counties. Figure 1 shows the cumulative COVID-19 death rates (deaths per 100,000 population) by RUCC (Panel A) and average COVID-19 death rates by RUCC (Panel B). In general, rural counties (RUCCs 4-9) have higher COVID-19 mortality rates than urban counties (RUCCs 1-3). RUCC 2 counties have the lowest mortality rate (194.6 deaths per 100,000 population), while RUCC 6 have the highest mortality rate (270.0 deaths per 100,000 population).

The first column of Table 1 presents regression coefficients from OLS models for each predictor, controlling only for state fixed effects. Controlling for state fixed effects. COVID-19 mortality rates generally increase with increasing rurality. RUCC 1 counties have the lowest mortality rates, while RUCC 6, 7, and 9 counties have the highest mortality rates. Collectively, RUCC and state fixed effects explain about 40 percent of the county-level variation in mortality rates, with state fixed effects contributing the most to between county variation. In terms of demographic and socioeconomic composition, mortality rates are significantly lower in counties with larger shares of Blacks and Hispanics, larger shares of adults with a Bachelor’s degrees of higher, and counties with higher median household income. Rates are significantly higher in counties with larger shares of older adults and those with higher rates of uninsured residents. In terms of health care infrastructure, mortality rates are significantly higher in counties identified as health professional shortage areas and in those with fewer physicians per capita. Finally, higher Trump vote share is associated with significantly higher average COVID-19 mortality rates.

Figure 1. Cumulative COVID-19 Mortality Rates (deaths per 100,000 population) by RUCC (N=3,142)





Note: Mortality rates are current as of October 1, 2021.

The model that includes all predictors is presented in the second column of Table 1. The only significant difference that remains is for RUCC 2; counties in RUCC 2 continue to have a significantly lower average COVID-19 mortality rate than counties in RUCC 1. Other factors that remain significant in the full model include percent of residents age 65+, percent with a Bachelor's degree or more, median household income, percent without health insurance, and physicians per capita (which are associated with higher average mortality rates, perhaps because severe COVID-19 cases were transported to counties with larger hospitals and more physicians).

Stepwise models, shown in Appendix Table 2, demonstrate that the primary contributors to rural-urban variation in COVID-19 mortality rates that we observed in the unadjusted model are education composition and median household income. The introduction of these variables dramatically reduced the RUCC coefficients and rendered all but RUCC 2 nonsignificant. Small metro (RUCC 3) and rural counties (RUCCs 4-9) have lower average educational attainment and lower average median household income than large urban (RUCC 1) counties. Both factors are associated with higher COVID-19 mortality rates. In fact, the introduction of educational composition and median household income reversed the sign for RUCCs 8 and 9. Although the coefficients are not significant, the reversal suggests that if small rural counties had the same education and income composition as large urban counties, small rural counties would actually have lower COVID-19 mortality rates, holding all else constant. The introduction of health care variables and Trump vote share did not lead to any additional meaningful changes in the RUCC coefficients, suggesting that they are not the primary contributors to rural-urban differences in COVID-19 mortality rates.

In supplemental analysis presented in Appendix Table 3, we examined rural-urban differences in COVID-19 infection rates. There are important differences from the mortality analysis. First, in models that adjusted only for state fixed effects, cumulative average case rates were significantly higher in RUCCs 3-7, but significantly lower in RUCC 9 compared to RUCC 1. In the model that included all predictors, only RUCCs 5-7 continued to have significantly higher case rates compared to RUCC 1. In the adjusted model, case rates are also significantly higher in counties with larger shares of Hispanics, more physicians per capita, and larger Trump vote shares. Case rates are significantly lower in counties with larger shares of residents ages 65 and older, larger shares with a BA or higher, higher median household income, and larger shares without health insurance. The higher infection rates we observed for RUCCs 4-7 in the unadjusted model were explained in large part by differences in socioeconomic composition (lower educational attainment and lower median household income) compared to large urban counties. Some additional attenuation was due to higher Trump vote share in rural compared to urban counties. Nonetheless, the variables we included in the model were unable to fully explain higher infection rates in RUCCs 5-7. We caution readers against over-interpreting these findings, as case rates are prone to substantially more bias than mortality rates due to differences across counties in testing and reporting.

Table 1: Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for U.S. Counties Overall

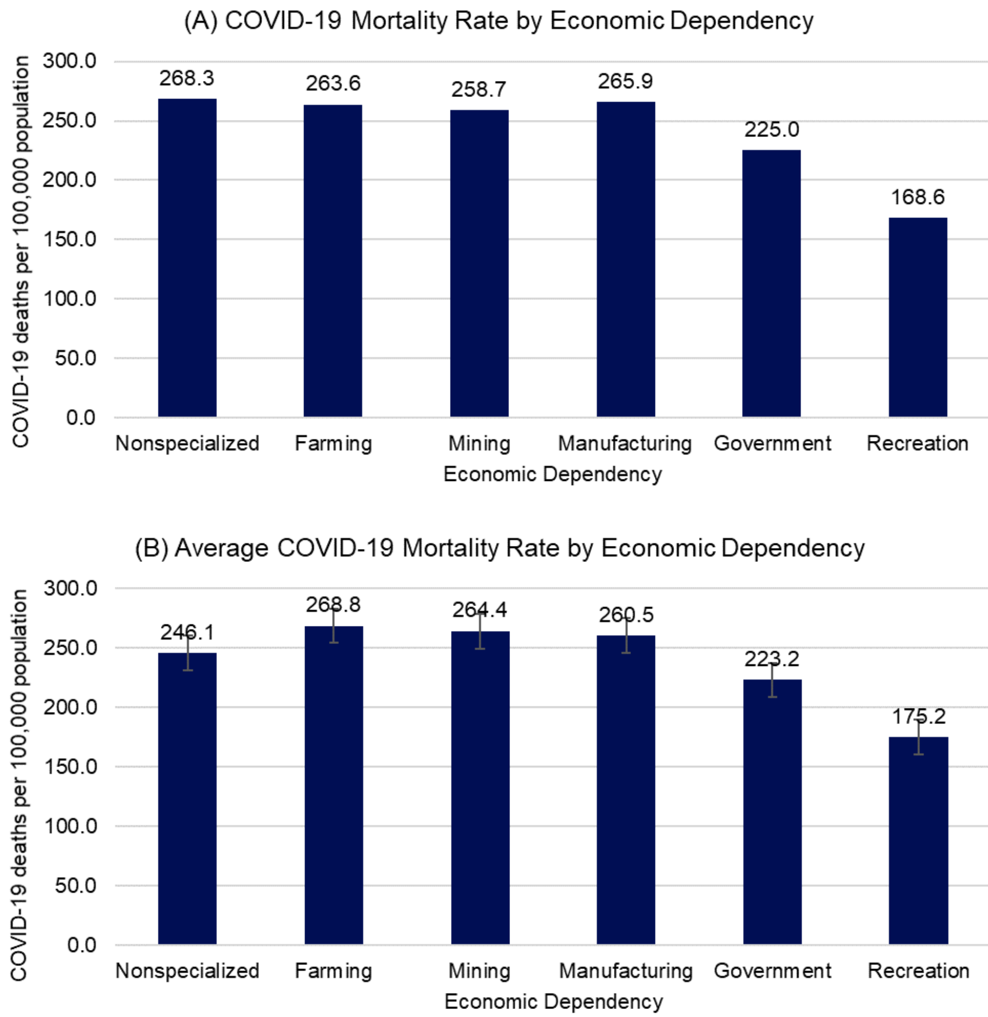
	Unadjusted models				Adjusted model		
	Coefficient	SE	*p*	R^2	Coefficient	SE	*p*
RUCC (Ref: 1)				0.398			
2	17.27*	7.23	0.017		-14.99*	7.23	0.038
3	37.26***	7.36	<0.001		-5.42	7.60	0.476
4	52.16***	8.55	<0.001		-2.29	8.95	0.798
5	57.29***	11.85	<0.001		2.72	11.84	0.819
6	76.39***	6.56	<0.001		5.99	7.50	0.424
7	78.13***	7.27	<0.001		3.85	8.35	0.645
8	63.19***	8.56	<0.001		-11.92	9.62	0.216
9	76.28***	7.61	<0.001		-2.76	9.19	0.764
% Non-Hispanic Black (Ref: Q1)				0.359			
Q2	-19.19***	5.48	<0.001		-2.73	5.23	0.601
Q3	-25.25***	5.92	<0.001		6.40	5.92	0.280
Q4	-16.74*	7.46	0.025		12.89	7.84	0.100
% Hispanic (Ref: Q1)				0.362			
Q2	-17.17**	5.47	0.002		-0.20	5.19	0.969
Q3	-33.78***	5.81	<0.001		-1.44	5.75	0.802
Q4	-30.58***	7.14	<0.001		5.77	7.24	0.426
% residents age 65+	20.23***	1.92	<0.001	0.377	11.02***	2.32	<0.001
% residents age 25+ with bachelor degree+	-41.23***	1.93	<0.001	0.438	-29.52***	3.50	<0.001
Median household income	-43.40***	2.04	<0.001	0.437	-18.33***	3.42	<0.001
% No health insurance	24.02***	2.65	<0.001	0.371	6.86*	2.85	0.016
Health professional shortage area (Ref: no)	28.76***	6.32	<0.001	0.359	-2.67	6.03	0.658
Physicians per 100,000 population (Ref: Q1)				0.361			
Q2	3.34	5.25	0.525		10.36*	4.95	0.036
Q3	-4.16	5.30	0.432		16.27**	5.24	0.002
Q4	-24.44***	5.46	<0.001		24.17***	6.03	<0.001
% Trump vote, 2020	17.82***	2.26	<0.001	0.367	-1.04	2.98	0.728
Constant					306.96***	15.84	<0.001
R^2					0.466		

Notes: N=3,141 counties. ***p<0.001, **p<0.01, *p<0.05. Q=quartile. Mortality rates are current as of October 1, 2021. All models control for state fixed effects. R^2=0.354 when the model includes only state fixed effects.

Within-Rural Variation in COVID-19 Mortality Rates

The remainder of our analysis was restricted to rural counties. Figure 2 shows cumulative COVID-19 mortality rates (deaths per 100,000 population) by ERS economic dependence category for rural counties (Panel A) and average COVID-19 death rates by economic dependence for rural counties (Panel B). Recreation-dependent counties have the lowest *aggregate* mortality rate (168.6 deaths per 100,000 population), while nonspecialized counties have the highest aggregate mortality rates (268.3 deaths per 100,000 population). Recreation counties also have the lowest *average* mortality rate (175.2 per 100,000 population), while the average mortality rate is highest among farming-dependent counties (268.8 deaths per 100,000 population).

Figure 2. Cumulative COVID-19 Mortality Rates (deaths per 100,000 population) by Economic Dependency for Rural Counties (N=1,976)



Note: Mortality rates are current as of October 1, 2021.

Results from OLS regression models predicting COVID-19 mortality rates by economic dependence type for rural counties are presented in Table 2. The first column presents regression coefficients for each predictor, controlling only for state fixed effects. Non-specialized, farming dependent, and manufacturing dependent counties have higher average COVID-19 mortality rates than recreation dependent counties. Together, labor market type and state fixed effects explain about 42 percent of the county-level variation in rural mortality rates, with nearly all of the between-county variation explained by state fixed effects rather than economic dependence. Adjacency to a metro area is not significantly associated with COVID-19 mortality rates.

In terms of demographic and socioeconomic composition, controlling only for state fixed effects, COVID-19 mortality rates are significantly higher in rural counties with larger shares of adults age 65+ and larger shares of residents without health insurance. Rates are significantly lower in counties with larger shares of adults with a Bachelor's degree or higher and in counties with higher median household income. Health care infrastructure factors and Trump vote share were not significantly associated with COVID-19 mortality rates in rural counties.

In the model that includes all predictors (second column of Table 2), non-specialized, farming, and manufacturing counties continue to have higher average COVID-19 mortality rates than recreation counties, but farming is the only type that remained statistically significant ($p<.05$). Holding all else constant, rural farming counties have an average COVID-19 mortality rate that is 24.3 deaths per 100,000 population higher than rural recreation counties.

Stepwise regression models (show in Appendix Table 4) revealed that higher COVID-19 mortality rates in non-specialized, farming, and manufacturing counties that we observed in the unadjusted model were driven by lower educational attainment and lower median household income.

We conducted supplemental analysis on within-rural differences in infection rates, with results presented in Appendix Table 5. In the model that includes only state fixed effects, non-specialized, mining, manufacturing, and government dependent counties all had significantly higher case rates than recreation counties. The introduction of demographic predictors (racial/ethnic and age composition) explained the

Table 2: Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for Rural Counties

	Unadjusted models				Adjusted model		
	Coefficient	SE	*p*	R^2	Coefficient	SE	*p*
Economic Dependence (Ref: Recreation)				0.424			
Non-specialized	36.06***	9.11	<0.001		18.77	9.91	0.058
Farming	42.23***	10.26	<0.001		24.35*	10.96	0.026
Mining	13.00	11.72	0.267		-1.04	12.69	0.935
Manufacturing	22.01*	10.13	0.030		10.35	11.00	0.347
Federal/ State Government	11.52	10.33	0.265		0.97	11.16	0.930
Adjacent to metro (Ref: Not Adjacent to metro)	-7.06	5.34	0.186	0.416	-2.06	5.36	0.700
% Non-Hispanic Black (Ref: Q1)				0.418			
Q2	-19.42**	6.61	0.003		-11.16	6.56	0.089
Q3	-10.35	7.69	0.179		-4.67	7.84	0.552
Q4	-4.31	11.14	0.698		-4.98	11.68	0.670
% Hispanic (Ref: Q1)				0.415			
Q2	-6.87	6.95	0.323		1.43	6.82	0.834
Q3	-6.29	7.82	0.421		10.82	7.89	0.170
Q4	-7.08	9.92	0.476		6.74	10.31	0.513
% residents age 65+	7.54**	2.67	0.005	0.417	5.89	3.31	0.075
% residents age 25+ with bachelor degree+	-37.24***	3.80	<0.001	0.443	-27.25***	5.24	<0.001
Median household income	-43.54***	4.19	<0.001	0.446	-27.12***	5.40	<0.001
% No health insurance	12.12***	3.21	<0.001	0.419	3.98	3.56	0.264
Health professional shortage area (Ref: no)	10.03	9.25	0.279	0.415	-5.85	9.14	0.522
Physicians per 100,000 population (Ref: Q1)				0.416			
Q2	6.38	6.55	0.330		13.96*	6.40	0.029
Q3	7.50	6.79	0.269		23.02***	6.84	0.001
Q4	-2.63	7.64	0.731		23.80**	8.07	0.003
% Trump vote, 2020	4.40	3.46	0.203	0.415	-0.38	4.10	0.926
Constant					298.39***	24.00	<0.001
R^2					0.465		

Notes: N = 1,976 rural counties. ***p<0.001, **p<0.01, *p<0.05. Q=quartile. Mortality rates are current as of October 1, 2021. All models control for state fixed effects. R^2=0.415 when model includes only state fixed effects.

disadvantage for both mining and government dependent counties and drastically attenuated the disadvantage for manufacturing dependent and non-specialized counties. The additional inclusion of socioeconomic composition factors (particularly educational attainment) changed the direction of the sign for farming and mining dependent counties. This implies that holding all else constant, if farming and mining dependent counties shared the same educational attainment profile as recreation counties, mining and farming counties would actually have significantly (and substantively) lower COVID-19 case rates than recreation counties. Of course, educational attainment may be serving as a proxy for differences in types of jobs that can be done remotely versus jobs that can only be done in person. Unlike with the analysis of rural-urban continuum differences in infection rates, Trump vote share did not contribute to within-rural variation in infection rates.

DISCUSSION

Rural America has long faced a mortality disadvantage (Cosby et al. 2008, 2019; Elo et al. 2019; James 2014; James and Cossman 2017; James et al. 2018; Singh and Siahpush 2014; Monnat 2020a; Vierboom et al. 2019), so it is no surprise that rural communities would also be disproportionately impacted by COVID-19 mortality (Monnat 2020b). The objective of this study was to describe rural-urban and within-rural variation in COVID-19 mortality rates. There are several important takeaways.

As of October 1, 2021, the cumulative COVID-19 mortality rate was about 23 percent higher in rural than in urban counties. In models that adjusted only for state fixed effects, mortality rates increased in a nearly monotonic relationship with rurality. However, our stepwise models showed that there does not appear to be anything about rural residence per se (e.g., health care factors) driving the rural COVID-19 mortality disadvantage. Instead, we found that the rural mortality disadvantage is explained by lower educational attainment and lower median household income in rural counties. These findings are consistent with those of another recent study (Albrecht 2021) and highlight the importance of aggregate level human capital and socioeconomic resources for preventing COVID-19 infection and deaths. This should come as no surprise as these same place-level factors are associated with geographic differences in mortality rates from many causes of death (Graetz and Elo 2021; James and Cossman 2017). In terms of protection against COVID-19, at the individual level, education and income shape preventive behaviors, such as mask use, social distancing, and vaccine uptake, as well as access to health care resources (Brough, Freedman, and Phillips 2021; Griffith, Evans, and Bor 2017; Khubchandani et al. 2021; Mondal, Sinharoy, and Su 2021; Papageorge et al. 2021). These findings are also in line with fundamental cause theory, which posits that SES embodies an array of resources, such as money, knowledge, and power that protect health in the face of multiple disease threats (Link and Phelan 1995; Phelan, Link, and Tehranifar 2010). Educational attainment also influences access to different types of employment. Rural residents are more likely to work in occupations that do not require a college degree, but also that cannot be done remotely. Rural workers were more likely to continue working during the pandemic and were less likely to work remotely (Brooks et al. 2021; Callaghan et al. 2021). This may have increased the risk of community spread. Given that our analyses are ecological we must be cautious about attributing individual behaviors to the relationships we observed, but it is possible that places with more highly educated and affluent residents enjoyed both structural advantages (such as greater ability to work from home) and greater community-level uptake of preventive behaviors.

We extend the prior research on rural-urban continuum differences in COVID-19 mortality (Albrecht 2021) by also examining mortality differences between rural counties by metro adjacency and across different types of labor markets. Contrary to our expectations, adjacency to a metro area was not associated with COVID-19 mortality (or infection) rates. However, there are important differences across different types of labor markets. We found that rural counties dependent on farming or manufacturing, as well as those categorized as non-specialized, have had higher COVID-19 mortality rates than recreation dependent rural counties. Service-related business closures and event cancellations early in the pandemic likely protected residents of service and recreation-heavy areas against COVID-19 spread. However, the picture is not completely rosy. Business closures and high rates of unemployment may have long-term economic consequences in these communities which could affect population health for years to come. In a recent study focused on the rural West (where many recreation-dependent counties are located), Mueller et al. (2021) found severe impacts of COVID-19 on unemployment, overall life satisfaction, mental health, and economic outlook. In a study using national data conducted in spring 2021, Monnat (2022) found that residents of rural counties were more likely than their large urban peers to report seeking treatment for anxiety or depression due to COVID-19, to be late paying rent, mortgage, and other bills, and to not be able to afford groceries or other necessities. These findings portend future consequences to population health in these communities despite being comparatively protected from COVID-19 itself.

We found that much of the rural farming disadvantage and all of the rural manufacturing and non-specialized county disadvantage was explained by lower educational attainment and lower median household income in these types of rural counties, potentially for the same reasons posited above. But education and income may also be proxies for job characteristics and work settings. Farming and manufacturing jobs do not require higher education and also come with comparatively low wages. Farming and manufacturing cannot be done remotely, and workers in both of these industries were deemed essential throughout the pandemic. The agriculture industry often relies on undocumented laborers who might not be able to afford to miss work or are afraid to miss work if they are sick. Factories in rural areas were vectors for COVID-19 outbreaks early on in the pandemic due to their tight quarters and lax safety measures (Cromartie et al. 2020; Paschal 2020; Reuben 2020; Smith-Nonini and Paschal 2020; Steinberg et al. 2020; Waltenburg et al. 2020; USDA ERS 2021).

Finally, in supplemental analysis, we examined rural-urban and within-rural differences in COVID-19 infection rates. In the case of infections, rates are higher overall in counties with larger shares of Hispanics, more physicians per capita, and larger Trump vote shares, and are lower overall in counties with larger shares of older residents (suggesting that residents of these counties may have engaged in more preventive behaviors to protect older adult residents), higher educational attainment, higher median household income, and larger shares without health insurance (suggesting that insurance coverage may influence testing rates). Within rural counties, recreation counties had the lowest infection rates, with much of this advantage explained by differences in racial/ethnic and age composition and educational attainment. However, we caution readers against over-interpreting these findings, as case rates are prone to substantially more bias than mortality rates due to differences across counties in testing and reporting.

COVID-19 will have profound long-term implications for rural population health. The pandemic has exacerbated existing challenges with health care availability in rural areas. Many rural hospitals, already stretched thin before the pandemic, may not survive from the financial fallout, leading to increases in the already rapid rate of rural hospital closures (Goodhill 2021). There are also potential longer-term consequences for economic security. About 18 percent of small nonmetropolitan counties are economically dependent on recreation compared to only 10 percent of large metropolitan counties. Massive layoffs of employees working in restaurants and bars, hotels, entertainment, and other hospitality venues during the early stages of COVID-19, along with current labor shortages in these industries, could lead to increases in small business closures, economic instability, and worker stress, with disproportionate effects on rural communities that have limited capacity to pivot to other economic development strategies.

Several interventions are needed to reduce continued spread and to prepare for future pandemics. In the immediate term, efforts must be made to increase vaccination rates in rural communities. Recent research shows that rural counties (especially those reliant on mining or farming) have significantly lower vaccination rates than urban counties, explained mostly by differences in Trump vote share and educational attainment (Sun and Monnat 2021). This suggests the need to combat misinformation to reduce vaccine resistance in these types of places, especially now that children age 5 and up are eligible for the vaccine. Recent polls suggest that rural residents trust their primary care physicians to provide reliable information about the COVID-19 more than the FDA, CDC, or local public health departments (Kirzinger et al. 2021). This means physicians are ideal messengers for communicating the importance of getting vaccinated. The National Rural Health Association has provided several tools for rural community, health care, agricultural, and faith leaders to help reduce vaccine resistance, including talking points, op-ed templates, and public service announcements (NRHA 2021). Upticks in adult vaccination rates shortly after the mandates went into effect suggest that government and employer mandates may have played a critical role (Hsu 2021). Rural communities must also prepare for future pandemics. This includes stepping up the testing and contact tracing apparatus in places that we know are at high risk of communicable disease spread (including those with essential businesses and crowded working environments). Such efforts will require state and federal governments to invest resources to strengthen rural health care systems and public health infrastructure.

Limitations

Findings should be considered in light of some limitations. First, this study is ecological, and causality cannot be established. Second, data availability restricted us to examining variation at the county level, but counties may not be the most appropriate spatial scale for understanding geographic heterogeneity in mortality or infection rates. Just as there is variation between counties, there is also variation within counties, with certain population pockets at greater risk than others. Counties vary dramatically by size, and this is particularly relevant for rural counties. Eastern rural counties are comparatively small, whereas rural counties in the West are large and often separated by natural barriers, such as mountains and lakes. This gives rise to the well-known modifiable areal unit problem, where conclusions may be different depending on the spatial scale at which the outcome is aggregated. Third, because we restricted our sub-analysis to rural counties, we did not account for spatial spillover across neighboring counties. Because COVID-19 is an infectious disease, there is certainly spatial autocorrelation in the distribution of COVID-19 infections and deaths. Fourth, state-level variation in COVID-19 mitigation policies may have contributed to metropolitan status differences in mortality rates. There was widespread variation in the adoption and timing of stay-at-home orders, mask mandates, and non-essential business closures. Our inclusion of state fixed effects controls for non-time varying unobserved state level differences, but cannot account for policy variation during the pandemic. Much of the unexplained between-county variation in mortality and infection rates may be due to different state policy choices. Studies exploring the effects specific state COVID-19 mitigation policies and geographic differences in COVID-19 spread are warranted.

CONCLUSION

We found large rural-urban and within-rural variation in COVID-19 mortality and infection rates in the U.S. as of October 21, 2021. COVID-19 mortality rates have been higher in rural counties, overall, with the highest rates observed in farming-dependent counties and the lowest rates in recreation-dependent counties. Higher rural COVID-19 mortality rates threaten to exacerbate the existing long-running rural mortality penalty and may have long term economic implications for rural areas. Federal, state, and local governments should enact economic and health policies that support access to health care resources and vaccines to reduce COVID-19 mortality disparities. Governments, local public health professionals, and employers must also work to increase vaccine uptake among those who remain resistant and prepare for future pandemics by establishing better protections for essential workers and implementing more uniform spread mitigation policies and procedures.

ACKNOWLEDGMENTS

The authors thank anonymous reviewers for suggestions on this manuscript and editorial team for their supports.

DISCLOSURE STATEMENT
No potential conflict of interest was reported by the authors.

FUNDING
The authors acknowledge support from two research networks funded by the National Institute on Aging (R24 AG065159 and 2R24 AG045061), the NIA-funded Center for Aging and Policy Studies at Syracuse University (P30AG066583), the National Institute on Drug Abuse (U01DA055972), the NICHD-funded Population Research Institute at Penn State (P2CHD041025), the USDA Agricultural Experiment Station Multistate Research Project: W4001, Social, Economic and Environmental Causes and Consequences of Demographic Change in Rural America, and the Syracuse University Lerner Center for Public Health Promotion.

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APPENDIX

Table 1: Means and Standard Deviations for Predictors by Rural-Urban Continuum Code (RUCC)

	Full Sample	RUCC1	RUCC2	RUCC3	RUCC4	RUCC5	RUCC6	RUCC7	RUCC8	RUCC9
% Non-Hispanic Black	8.9 (14.4)	12.2 (14.0)	10.8 (13.7)	9.4 (12.4)	8.3 (12.9)	7.9 (14.8)	10.1 (16.2)	7.0 (14.5)	10.3 (18.8)	3.7 (10.2)
% Hispanic	9.4 (13.9)	11.0 (11.7)	10.5 (14.8)	8.6 (11.5)	10.0 (14.2)	13.2 (18.2)	9.3 (15.1)	10.5 (16.2)	5.3 (8.8)	7.6 (12.7)
% age 65+	18.8 (4.7)	15.6 (3.3)	17.3 (4.0)	17.7 (4.7)	18.1 (3.6)	16.5 (3.8)	19.3 (3.4)	19.4 (4.4)	22.0 (4.7)	22.2 (5.3)
% with Bachelor degree or higher	22.0 (9.6)	30.9 (12.6)	25.5 (9.2)	24.0 (9.2)	21.8 (7.8)	23.7 (8.7)	17.2 (6.1)	19.5 (7.3)	17.4 (5.9)	19.3 (6.9)
Median household income ($)	53475.9 (14192.5)	71153.7 (18454.0)	57218.0 (11390.7)	54462.8 (9768.3)	50968.8 (8976.8)	52217.0 (12235.8)	47933.5 (9678.7)	48414.9 (11111.6)	47135.4 (10230.7)	49048.3 (11089.1)
% No health insurance	9.6 (5.1)	8.1 (3.9)	8.8 (4.3)	8.8 (4.0)	9.0 (4.3)	10.1 (4.7)	10.5 (5.3)	10.4 (5.7)	10.3 (4.9)	10.7 (6.5)
Health professional shortage area	89.5%	80.1%	90.2%	89.0%	87.9%	89.1%	91.2%	89.6%	98.2%	92.5%
Physicians per 100,000	51.9 (37.2)	62.2 (37.9)	59.8 (33.5)	61.0 (48.6)	53.1 (22.0)	69.9 (28.5)	44.2 (25.0)	56.2 (29.5)	27.2 (26.5)	41.3 (49.2)
% Trump vote, 2020	64.8 (16.2)	53.3 (18.0)	58.7 (14.9)	62.1 (14.4)	62.1 (12.3)	61.4 (15.2)	68.4 (13.1)	68.8 (14.7)	69.7 (15.8)	74.6 (14.2)
N	3142	432	378	356	214	92	593	433	220	424

Table 2: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for U.S. Counties Overall

	Unadjusted Model			Demographic Predictors			Socioeconomic Predictors		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
RUCC (Ref: 1)									
2	17.27*	7.23	0.017	14.34*	7.24	0.048	-14.37*	7.21	0.046
3	37.26***	7.36	<0.001	32.44***	7.39	<0.001	-5.22	7.52	0.488
4	52.16***	8.55	<0.001	48.40***	8.58	<0.001	-1.63	8.84	0.854
5	57.29***	11.85	<0.001	54.60***	11.80	<0.001	8.10	11.72	0.490
6	76.39***	6.56	<0.001	65.79***	6.83	<0.001	7.10	7.41	0.338
7	78.13***	7.27	<0.001	66.33***	7.58	<0.001	7.24	8.15	0.375
8	63.19***	8.56	<0.001	43.21***	9.19	<0.001	-15.88	9.47	0.094
9	76.28***	7.61	<0.001	53.82***	8.52	<0.001	-4.69	8.91	0.599
% Non-Hispanic Black (Ref: Q1)									
Q2				-8.37	5.46	0.126	-3.80	5.22	0.467
Q3				-0.01	6.14	0.998	5.25	5.88	0.372
Q4				16.40*	7.69	0.033	12.23	7.46	0.101
% Hispanic (Ref: Q1)									
Q2				-7.08	5.42	0.192	0.62	5.19	0.905
Q3				-14.36*	5.94	0.016	0.29	5.73	0.960
Q4				-2.81	7.44	0.706	10.16	7.14	0.155
% residents age 65+				13.25***	2.28	<0.001	9.97***	2.21	<0.001
% residents age 25+ with bachelor degree+							-24.34***	2.66	<0.001
Median household income							-21.99***	3.09	<0.001
% No health insurance									
Health professional shortage area (Ref: no)									
Physicians per 100,000 population (Ref: Q1)									
Q2									
Q3									

Table 2: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for U.S. Counties Overall

	Unadjusted Model			Demographic Predictors			Socioeconomic Predictors		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
Q4									
% Trump vote, 2020									
Constant	298.05***	13.13	<0.001	302.00***	15.20	<0.001	315.48***	14.57	<0.001
R^2	0.398			0.408			0.462		

Table 2 cont: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for U.S. Counties Overall

	Health Care Predictors			Trump Vote Share		
	b	SE	*p*	b	SE	*p*
RUCC (Ref: 1)						
2	-15.24*	7.20	0.034	-14.99*	7.23	0.038
3	-5.84	7.51	0.437	-5.42	7.60	0.476
4	-2.67	8.88	0.764	-2.29	8.95	0.798
5	2.24	11.76	0.849	2.72	11.84	0.819
6	5.58	7.40	0.451	5.99	7.50	0.424
7	3.26	8.17	0.690	3.85	8.35	0.645
8	-12.36	9.53	0.195	-11.92	9.62	0.216
9	-3.50	8.94	0.696	-2.76	9.19	0.764
% Non-Hispanic Black (Ref: Q1)						
Q2	-2.76	5.22	0.597	-2.73	5.23	0.601
Q3	6.51	5.91	0.271	6.40	5.92	0.280
Q4	13.64	7.53	0.070	12.89	7.84	0.100
% Hispanic (Ref: Q1)						
Q2	-0.25	5.18	0.962	-0.20	5.19	0.969
Q3	-1.51	5.75	0.793	-1.44	5.75	0.802
Q4	5.90	7.22	0.414	5.77	7.24	0.426
% residents age 65+	10.89***	2.28	<0.001	11.02***	2.32	<0.001
% residents age 25+ with bachelor degree+	-28.91***	3.03	<0.001	-29.52***	3.50	<0.001
Median household income	-18.73***	3.22	<0.001	-18.33***	3.42	<0.001
% No health insurance	7.05*	2.80	0.012	6.86*	2.85	0.016
Health professional shortage area (Ref: no)	-2.68	6.03	0.657	-2.67	6.03	0.658
Physicians per 100,000 population (Ref: Q1)						
Q2	10.38*	4.94	0.036	10.36*	4.95	0.036
Q3	16.29**	5.24	0.002	16.27**	5.24	0.002

Table 2 cont: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for U.S. Counties Overall

	Health Care Predictors			Trump Vote Share		
	b	SE	*p*	b	SE	*p*
Q4	24.24***	6.03	<0.001	24.17***	6.03	<0.001
% Trump vote, 2020				-1.04	2.98	0.728
Constant	306.70***	15.82	<0.001	306.96***	15.84	<0.001
R^2	0.466			0.466		

Notes: N = 3,141 counties. *** p<0.001, ** p<0.01, * p<0.05. Q, quartile.
Mortality rates are current as of October 1, 2021.
All models control for state fixed effects. R^2=0.354 when model includes only state fixed effects.

Table 3: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for U.S. Counties Overall

	Unadjusted Model			Demographic Predictors			Socioeconomic Predictors		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
RUCC (Ref: 1)									
2	351.14	216.76	0.105	719.41***	210.04	0.001	251.95	213.62	0.238
3	587.74**	220.67	0.008	1,076.43***	214.45	<0.001	446.09*	222.89	0.045
4	971.13***	256.30	<0.001	1,438.36***	249.00	<0.001	574.58*	262.07	0.028
5	1,593.60***	355.20	<0.001	1,856.96***	342.24	<0.001	1,087.53**	347.33	0.002
6	852.27***	196.73	<0.001	1,721.70***	198.09	<0.001	610.86**	219.63	0.005
7	1,033.51***	217.88	<0.001	1,979.11***	219.80	<0.001	919.53***	241.59	<0.001
8	-486.59	256.76	0.058	1,033.33***	266.73	<0.001	-76.95	280.75	0.784
9	-712.71**	228.21	0.002	943.05***	247.20	<0.001	-124.77	264.14	0.637
% Non-Hispanic Black (Ref: Q1)									
Q2				196.15	158.50	0.216	304.65*	154.64	0.049
Q3				360.37*	178.07	0.043	520.58**	174.25	0.003
Q4				-83.84	223.15	0.707	-27.28	221.13	0.902
% Hispanic (Ref: Q1)									
Q2				81.87	157.36	0.603	241.38	153.85	0.117
Q3				-141.88	172.49	0.411	169.17	169.86	0.319
Q4				566.21**	215.93	0.009	810.62***	211.64	<0.001
% residents age 65+				-926.96***	66.28	<0.001	-965.61***	65.36	<0.001
% residents age 25+ with bachelor degree+							-754.15***	78.83	<0.001
Median household income							-159.50	91.52	0.081
% No health insurance									
Health professional shortage area (Ref: no)									
Physicians per 100,000 population (Ref: Q1)									
Q2									
Q3									
Q4									

Table 3: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for U.S. Counties Overall

	Unadjusted Model			Demographic Predictors			Socioeconomic Predictors		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
% Trump vote, 2020									
Constant	15,526.82***	393.75	<0.001	14,646.39***	441.05	<0.001	14,793.44***	431.91	<0.001
R^2	0.424			0.470			0.497		

Table 3 cont: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for U.S. Counties Overall

	Health Care Predictors			Trump Vote Share		
	b	SE	*p*	b	SE	*p*
RUCC (Ref: 1)						
2	174.22	212.50	0.412	79.56	212.80	0.709
3	387.29	221.59	0.081	225.94	223.63	0.312
4	486.40	262.12	0.064	338.62	263.23	0.198
5	914.02**	347.14	0.009	729.18*	348.33	0.036
6	597.04**	218.47	0.006	435.10*	220.59	0.049
7	853.63***	241.16	<0.001	624.16*	245.49	0.011
8	145.48	281.42	0.605	-25.88	282.96	0.927
9	62.49	263.91	0.813	-223.12	270.27	0.409
% Non-Hispanic Black (Ref: Q1)						
Q2	253.78	154.19	0.100	242.32	153.71	0.115
Q3	402.02*	174.43	0.021	444.90*	174.11	0.011
Q4	-216.83	222.39	0.330	74.86	230.56	0.745
% Hispanic (Ref: Q1)						
Q2	255.28	153.01	0.095	237.27	152.56	0.120
Q3	236.57	169.60	0.163	209.26	169.15	0.216
Q4	923.03***	213.25	<0.001	974.32***	212.85	<0.001
% residents age 65+	-1,063.19***	67.40	<0.001	-1,115.94***	68.15	<0.001
% residents age 25+ with bachelor degree+	-969.39***	89.43	<0.001	-732.10***	103.00	<0.001
Median household income	-183.46	95.02	0.054	-338.72***	100.55	0.001
% No health insurance	-374.02***	82.73	<0.001	-300.83***	83.98	<0.001
Health professional shortage area (Ref: no)	218.84	177.96	0.219	217.15	177.38	0.221
Physicians per 100,000 population (Ref: Q1)						
Q2	442.78**	145.95	0.002	450.75**	145.49	0.002
Q3	616.98***	154.66	<0.001	625.60***	154.16	<0.001
Q4	869.66***	177.98	<0.001	893.63***	177.48	<0.001
% Trump vote, 2020				403.80***	87.80	<0.001

Table 3 cont: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for U.S. Counties Overall

	Health Care Predictors			Trump Vote Share		
	b	SE	*p*	b	SE	*p*
Constant	14,201.55***	466.99	<0.001	14,097.93***	466.01	<0.001
R^2	0.505			0.508		

Notes: N = 3,141 counties. ***p<0.001, **p<0.01, *p<0.05. Q=quartile. Infection rates are current as of October 1, 2021. All models control for state fixed effects.

Table 4: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for Rural Counties

	Economic Dependence			Metro Adjacency			Demographic Predictors		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
Economic Dependency (Ref: Recreation)									
Non-specialized	36.06***	9.11	<0.001	36.76***	9.12	<0.001	45.13***	9.56	<0.001
Farming	42.23***	10.26	<0.001	41.88***	10.26	<0.001	44.96***	10.43	<0.001
Mining	13.00	11.72	0.267	12.57	11.72	0.284	23.77	12.33	0.054
Manufacturing	22.01*	10.13	0.030	22.98*	10.15	0.024	32.45**	10.68	0.002
Federal/ State Government	11.52	10.33	0.265	11.88	10.33	0.250	21.75*	11.03	0.049
Adjacent to metro (Ref: Not Adjacent to metro)				-7.56	5.36	0.158	-5.95	5.38	0.269
% Non-Hispanic Black (Ref: Q1)									
Q2							-15.74*	6.70	0.019
Q3							-4.51	8.00	0.573
Q4							0.10	11.50	0.993
% Hispanic (Ref: Q1)									
Q2							-3.20	7.00	0.648
Q3							2.21	8.04	0.783
Q4							4.68	10.54	0.657
% residents age 65+							9.33**	3.08	0.002
% residents age 25+ with bachelor degree+									
Median household income									
% No health insurance									
Health professional shortage area (Ref: no)									
Physicians per 100,000 population (Ref: Q1)									
Q2									
Q3									
Q4									
% Trump vote, 2020									
Constant	337.07***	19.37	<0.001	342.23***	19.71	<0.001	333.35***	21.96	<0.001
R^2	0.424			0.424			0.429		

Table 4 cont: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Mortality Rates for Rural Counties

	Socioeconomic Predictors			Health Care Predictors			Trump Vote Share		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
Economic Dependence (Ref: Recreation)									
Non-specialized	17.93	9.69	0.064	18.68	9.86	0.058	18.77	9.91	0.058
Farming	17.53	10.60	0.098	24.18*	10.80	0.025	24.35*	10.96	0.026
Mining	-3.46	12.50	0.782	-1.16	12.62	0.927	-1.04	12.69	0.935
Manufacturing	8.21	10.78	0.447	10.25	10.94	0.349	10.35	11.00	0.347
Federal/ State Government	-2.49	10.97	0.820	0.92	11.15	0.934	0.97	11.16	0.930
Adjacent to metro (Ref: Not Adjacent to metro)	-3.46	5.26	0.511	-1.99	5.30	0.707	-2.06	5.36	0.700
% Non-Hispanic Black (Ref: Q1)									
Q2	-11.15	6.53	0.088	-11.18	6.55	0.088	-11.16	6.56	0.089
Q3	-4.74	7.79	0.543	-4.67	7.84	0.552	-4.67	7.84	0.552
Q4	-7.26	11.21	0.517	-4.71	11.31	0.677	-4.98	11.68	0.670
% Hispanic (Ref: Q1)									
Q2	2.53	6.83	0.710	1.43	6.82	0.834	1.43	6.82	0.834
Q3	12.28	7.88	0.119	10.81	7.88	0.171	10.82	7.89	0.170
Q4	8.97	10.29	0.383	6.78	10.30	0.511	6.74	10.31	0.513
% residents age 65+	4.26	3.05	0.163	5.83	3.24	0.072	5.89	3.31	0.075
% residents age 25+ with bachelor degree+	-23.28***	4.59	<0.001	-27.07***	4.86	<0.001	-27.25***	5.24	<0.001
Median household income	-29.24***	4.99	<0.001	-27.27***	5.13	<0.001	-27.12***	5.40	<0.001
% No health insurance				4.03	3.52	0.252	3.98	3.56	0.264
Health professional shortage area (Ref: no)				-5.86	9.13	0.521	-5.85	9.14	0.522
Physicians per 100,000 population (Ref: Q1)									
Q2				13.97*	6.40	0.029	13.96*	6.40	0.029
Q3				23.04***	6.84	0.001	23.02***	6.84	0.001
Q4				23.83**	8.06	0.003	23.80**	8.07	0.003
% Trump vote, 2020							-0.38	4.10	0.926
Constant	311.60***	21.65	<0.001	298.22***	23.92	<0.001	298.39***	24.00	<0.001
R^2	0.461			0.465			0.465		

Notes: N=1,976 rural counties. ***p<0.001, **p<0.01, *p<0.05. Q=quartile. Mortality rates are current as of October 1, 2021. All models control for state fixed effects.

Table 5: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for Rural Counties

	Economic Dependence			Metro Adjacency			Demographic Predictors		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
Economic Dependence (Ref: Recreation)									
Non-specialized	1,552.26***	273.80	<0.001	1,551.63***	274.27	<0.001	618.41*	276.21	0.025
Farming	367.96	308.38	0.233	368.28	308.55	0.233	-144.34	301.19	0.632
Mining	1,211.26***	352.25	0.001	1,211.65***	352.46	0.001	-81.08	356.21	0.820
Manufacturing	2,155.58***	304.42	<0.001	2,154.70***	305.19	<0.001	960.30**	308.46	0.002
Federal/ State Government	1,611.52***	310.56	<0.001	1,611.19***	310.73	<0.001	469.49	318.63	0.141
Adjacent to metro (Ref: Not Adjacent to metro)				6.90	161.13	0.966	-160.36	155.41	0.302
% Non-Hispanic Black (Ref: Q1)									
Q2							209.32	193.50	0.280
Q3							527.15*	231.16	0.023
Q4							-540.75	332.25	0.104
% Hispanic (Ref: Q1)									
Q2							161.72	202.10	0.424
Q3							-8.68	232.24	0.970
Q4							645.45*	304.27	0.034
% residents age 65+							-989.59***	88.83	<0.001
% residents age 25+ with bachelor degree+									
Median household income									
% No health insurance									
Health professional shortage area (Ref: no)									
Physicians per 100,000 population (Ref: Q1)									
Q2									
Q3									
Q4									
% Trump vote, 2020									

Table 5: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for Rural Counties

	Economic Dependence			Metro Adjacency			Demographic Predictors		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
Constant	13,762.93***	582.28	<0.001	13,758.22***	592.72	<0.001	15,276.70***	634.36	<0.001
R^2	0.415			0.415			0.466		

Table 5 cont: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for Rural Counties

	Socioeconomic Predictors			Health Care Predictors			Trump Vote Share		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
Economic Dependence (Ref: Recreation)									
Non-specialized	91.95	284.65	0.747	-141.75	288.74	0.624	-180.94	290.25	0.533
Farming	-742.84*	311.48	0.017	-816.34**	316.46	0.010	-886.44**	320.96	0.006
Mining	-736.73*	367.19	0.045	-946.96*	369.59	0.010	-996.62**	371.49	0.007
Manufacturing	405.49	316.88	0.201	209.57	320.46	0.513	168.31	321.97	0.601
Federal/ State Government	74.48	322.25	0.817	-140.07	326.46	0.668	-161.35	326.81	0.622
Adjacent to metro (Ref: Not Adjacent to metro)	-159.21	154.49	0.303	-167.30	155.30	0.281	-138.35	156.86	0.378
% Non-Hispanic Black (Ref: Q1)									
Q2	307.98	191.99	0.109	227.14	191.89	0.237	220.24	191.93	0.251
Q3	542.89*	228.76	0.018	392.37	229.68	0.088	393.28	229.64	0.087
Q4	-646.17*	329.34	0.050	-820.81*	331.17	0.013	-709.48*	341.99	0.038
% Hispanic (Ref: Q1)									
Q2	261.23	200.55	0.193	256.50	199.68	0.199	256.70	199.65	0.199
Q3	157.07	231.41	0.497	209.21	230.92	0.365	202.10	230.94	0.382
Q4	643.18*	302.26	0.033	701.74*	301.65	0.020	716.44*	301.80	0.018
% residents age 65+	-1,039.09***	89.75	<0.001	-1,160.28***	94.80	<0.001	-1,186.52***	96.91	<0.001
% residents age 25+ with bachelor degree+	-730.05***	134.82	<0.001	-930.69***	142.43	<0.001	-856.53***	153.39	<0.001
Median household income	-126.39	146.49	0.388	-238.37	150.15	0.113	-303.28	158.20	0.055
% No health insurance				-421.93***	103.09	<0.001	-401.42***	104.27	<0.001
Health professional shortage area (Ref: no)				95.85	267.49	0.720	89.48	267.49	0.738
Physicians per 100,000 population (Ref: Q1)									
Q2				358.72	187.49	0.056	362.78	187.48	0.053
Q3				533.63**	200.27	0.008	539.19**	200.28	0.007
Q4				569.64*	236.13	0.016	580.54*	236.23	0.014
% Trump vote, 2020							155.98	119.91	0.193

Table 5 cont: Stepwise Ordinary Least Squares Regression Models Predicting COVID-19 Infection Rates for Rural Counties

	Socioeconomic Predictors			Health Care Predictors			Trump Vote Share		
	b	SE	*p*	b	SE	*p*	b	SE	*p*
Constant	15,167.38***	636.17	<0.001	14,928.98***	700.66	<0.001	14,856.20***	702.76	<0.001
R^2	0.478			0.485			0.486		

Notes: N=1,976 rural counties. ***p<0.001, **p<0.01, *p<0.05. Q=quartile. Infection rates are current as of October 1, 2021. All models control for state fixed effects.