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HIV and Housing Insecurity in Louisiana

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Cover Page Footnote

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ABSTRACT
This study sought to assign the parishes in Louisiana into distinctive spatial-temporal clusters based on their trends in HIV prevalence and percentages of households with severe housing problems and to assess the parish's resilience and susceptibility to HIV infection given its pre-existing sociodemographic conditions. Results revealed that trends in the HIV prevalence rates and percentages of households with severe housing problems differed across the five distinct spatial-temporal clusters. The percentage of households with severe housing problems and the percentage of non-Hispanic Black population were positively associated with the HIV prevalence rate while the reverse was true for the percentage of population below 18 years of age and physician density. Efforts to minimize the detrimental effects of HIV infection and/or housing insecurity should focus on Allen, East Baton Rouge, East Feliciana, Orleans, Iberville, and West Feliciana parishes.

KEYWORDS
Cluster analysis, HIV, housing insecurity, spatial regression

INTRODUCTION

The Lower Mississippi Delta (LMD) is comprised of Arkansas, Louisiana, Mississippi, and Tennessee. Decades after the Civil Rights Movement, persistent problems like low income and education, high rates of poverty, stagnant economies, inequality, rural isolation, and poor health (Green, Greever-Rice, and Glass 2015; Reif et al. 2015) might be attributable to the longstanding historical and cultural factors, and the lack of coordination among stakeholders (Liew 2016).

The southern United States has had the highest rate of human immunodeficiency virus (HIV) diagnoses in the nation for years, although a downward trend has been observed. In 2014, the diagnoses rate was 16.9 compared to 12.6 nationally and in 2018, the diagnoses rate was 15.6 compared to 11.5 nationally (Center for Disease Control 2020). In 2018, Louisiana had the highest rate of HIV diagnoses at 25.2 compared to Mississippi at 19.2, Tennessee at 13.4, and Arkansas at 11.2 (Center for Disease Control 2020). In 2017, Louisiana ranked fourth in the nation for HIV diagnoses and third for AIDS rates (Louisiana Department of Health 2019). Consequently, HIV infection is a major public health challenge in Louisiana. The number of persons living with HIV infection increased from 15,257 in 2008 to 21,419 in 2017 (Louisiana Department of Health 2018). Among the largest metropolitan areas in the nation, New Orleans and Baton Rouge ranked second and third for HIV case rates (33.3 and 30.2 per 100,000 respectively) (Louisiana Department of Health 2018). Racial and ethnic minorities bore the overwhelming burden of HIV infections. In 2018, African American men and women represented about 63 and 82 percent of persons living with HIV infection, followed by Whites (about 30 percent for men and 14 percent for women), and Hispanics (about 5.3 percent for men and 3 percent for women) (Louisiana Department of Health 2018). In 2018, those aged 24 and under constituted about 23 percent of the new HIV diagnoses (Louisiana Department of Health 2019).

Socioeconomic and demographic associations with HIV infection have been well documented in the U.S. For example, studies have shown associations between HIV infection and age (Reif et al. 2015), race (Song et al. 2011; Reif et al. 2015; Ibragimov et al. 2019), lower income (Arnold, Fisher, and McFarland 2011; Sutton et al. 2017), lower education (Song et al. 2011), residential segregation (Ibragimov et al. 2019), and unemployment (Sutton et al. 2017).

Higher HIV rates were associated with residing in a rural or suburban location (Reif et al. 2015) and areas with low physician density (Sutton et al. 2017). These factors were compounded by issues of transportation to medical centers and doctors who provide HIV specific services (Reif, Golin, and Smith 2005; Reif et al. 2015). A lack of insurance coverage was also a barrier to accessing HIV prevention services among those with risky income sources such as drug or sex related work (Underhill et al. 2014).

Additionally, unstable housing conditions were believed to contribute to the risk of contracting HIV, largely because of the risky behaviors that were more likely to occur in these conditions (Corneil et al.

2006; Weir et al. 2007). These conditions included overcrowding, unsanitary conditions such as insufficient plumbing, and unaffordable housing (Corneil et al. 2006; Weir et al. 2007; Dickson-Gomez et al. 2009; Dickson-Gomez et al. 2011).

To date, published works in Louisiana on HIV have focused on a variety of topics including nonadherence to high active antiretroviral therapy (Mohammed et al. 2004), examining the determinants of HIV disclosures (Mohammed and Kissinger 2006), examining the interrelationships among race, incarceration, and risky sexual behaviors (Arp 2009), assessing the effectiveness of partner counseling and referral services (Shrestha et al. 2009), hospital length of stay among infected individuals (Santella, Shi, and Campbell 2010), examining the interrelationships between discrimination and HIV-related risk behaviors (Kaplan et al. 2016), preferences for home-based testing (Robinson, Zarwell, and Gruber 2013), exploring the accessibility of HIV medical care (Dickson-Gomez et al. 2009; Brewer et al. 2018), and durable viral suppression among criminal justice-involved African American men (Brewer et al. 2019a).

Previous studies used broadly defined housing variables such as stable or unstable housing and homelessness (Aidala et al. 2005; Weir et al. 2007; Brewer et al. 2019a) but did not objectively and consistently capture elements like quality of the housing unit or affordability, which as noted above, were believed to play a role in risky behaviors that may lead to HIV contraction. Of the studies reviewed that focused only on Louisiana data, two incorporated a housing component; they included homelessness (Brewer et al. 2019a) and housing discrimination (Brewer et al. 2019b).

Most studies used data from the Centers for Disease Control and Prevention (CDC) National HIV Surveillance System and the American Community Survey at the individual and or county level (Song et al. 2011; Reif et al. 2015; Sutton et al. 2017) and some focused on region with an emphasis on southern states (Reif et al. 2015; Sutton et al. 2017). Others collected primary data from a specific state or city (Reif et al. 2005; Arnold et al. 2011). The studies specific to Louisiana relied on primary or secondary level data at the individual level from persons who were infected, adults at risk (Mohammed and Kissinger 2006; Kaplan et al. 2016; Robinson et al. 2013; Brewer et al. 2018) adults at risk in the criminal justice system (Arp 2009; Brewer et al. 2019a), and patients in treatment (Mohammed et al. 2004; Santella et al. 2010).

Geographic location may also be important to understanding HIV rates. Prior studies have found that transient or mobile maritime workers tend to be at greater risk for contracting HIV (Seeley and Allison 2005; Tansey et al. 2010). Port communities face structural and environmental vulnerabilities such as poverty, separation from one's regular partner, and limited access to health services which create a high-risk environment for contracting HIV (Tansey et al. 2010). Citizens in bordering communities are also subsequently at increased risk as they often share similar characteristics with the port community (Egbe et al. 2020). However, none of the existing quantitative research on HIV/AIDS and housing quality took the geographical context (county in this case) into account (Mohammed et al. 2004; Reif et al. 2005; Mohammed and Kissinger 2006; Corneil et al. 2006; Weir et al. 2007; Shrestha et al. 2009; Dickson-Gomez et al. 2011; Song et al. 2011; Arnold et al. 2011; Mondal and Shitan 2013; Sutton et al. 2017; Robinson et al. 2017; Brewer et al. 2018; Brewer et al. 2019a; Brewer et al. 2019b; Masiano et al. 2019). Thus, it is worthwhile ascertaining whether spatial dependency existed for the changes in HIV prevalence rates and its predictors in Louisiana parishes. It is plausible that the change in HIV prevalence rate in one parish might be systematically related to the change in HIV prevalence rate in other neighboring parishes. It is also plausible that changes in HIV prevalence rates might be differentially affected by not only the socio-demographic characteristics of a given parish but also the socio-demographic characteristics of the neighboring parishes. In addition, it was imperative in the present study to do spatial temporal cluster analysis to see how trends in HIV infection and housing insecurity have been clustered together over time. These approaches might help policymakers and practitioners tailor their delivery approaches according to the socio-demographic characteristics and the spatial temporal trends of the different parishes in Louisiana.

The present study adds to the current body of literature examining HIV rates in Louisiana by using data on the parish level that assesses parish wide demographic, economic, and health care related variables and by including an objective measure of housing quality that includes crowding, affordability, and adequate kitchen and plumbing facilities. In addition, no known studies to date, either nationally or specific to Louisiana, have used spatial-temporal cluster analysis to assess trends in the HIV prevalence rates. This study:

1. Examines how the longitudinal changes in HIV prevalence rates differ across the parishes of Louisiana by assigning each to distinctive spatial-temporal clusters and examine whether the pre-

existing sociodemographic conditions vary across these distinctive spatial-temporal clusters.

2. Provides recommendations for the trends in HIV prevalence rates across the parishes of Louisiana.
3. Looks at the role of pre-existing sociodemographic conditions and adequacy of housing facilities in determining the parish's resilience and susceptibility to HIV infection.

METHODS

Measures and Data Sources

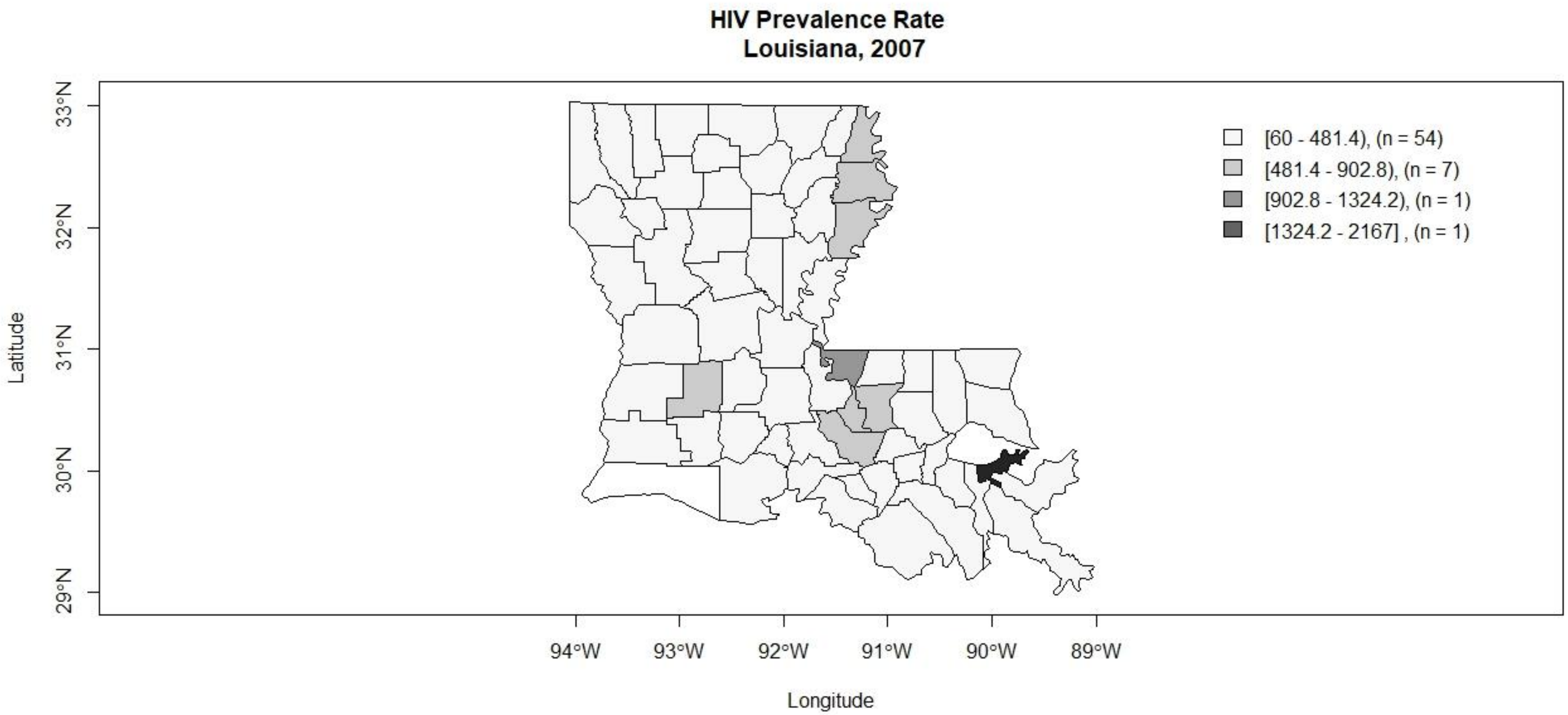
Measures pertaining to HIV prevalence rates and pre-existing sociodemographic characteristics were obtained from the County Health Rankings website maintained by the University of Wisconsin Population Health Institute (County Health Rankings 2021). The data available through the County Health Rankings website originated from a number of external and reputable data sources. The variables used in this study are described below and their original sources named.

The variable, HIV prevalence rates, represented the number of people aged 13 years and older living with a diagnosis of HIV infection per 100,000 in the population. Annual data on HIV prevalence rates from 2007 to 2017 originated from the National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention (NCHHSTP). The 2007 and 2017 HIV prevalence rates are shown in Figures 1 and 2. The 2017 HIV prevalence rate was used as the dependent variable in the ordinary least squares and spatial regression models described below.

The temporal precedence of the independent variables was selected to be between five to ten years prior to the dependent variable to better assess the influence of these variables on the dependent variable. Other measures included the 2009 estimates of the population at the state and parish levels, as well as the percentage of the population below 18 years of age, and the percentage of the population who are non-Hispanic Black or African American. Data for these variables originated from the Census Bureau's Population Estimates Program (PEP). Lastly, the percentage of the population living in a rural area originated from the 2010 estimates of the Census's PEP program.

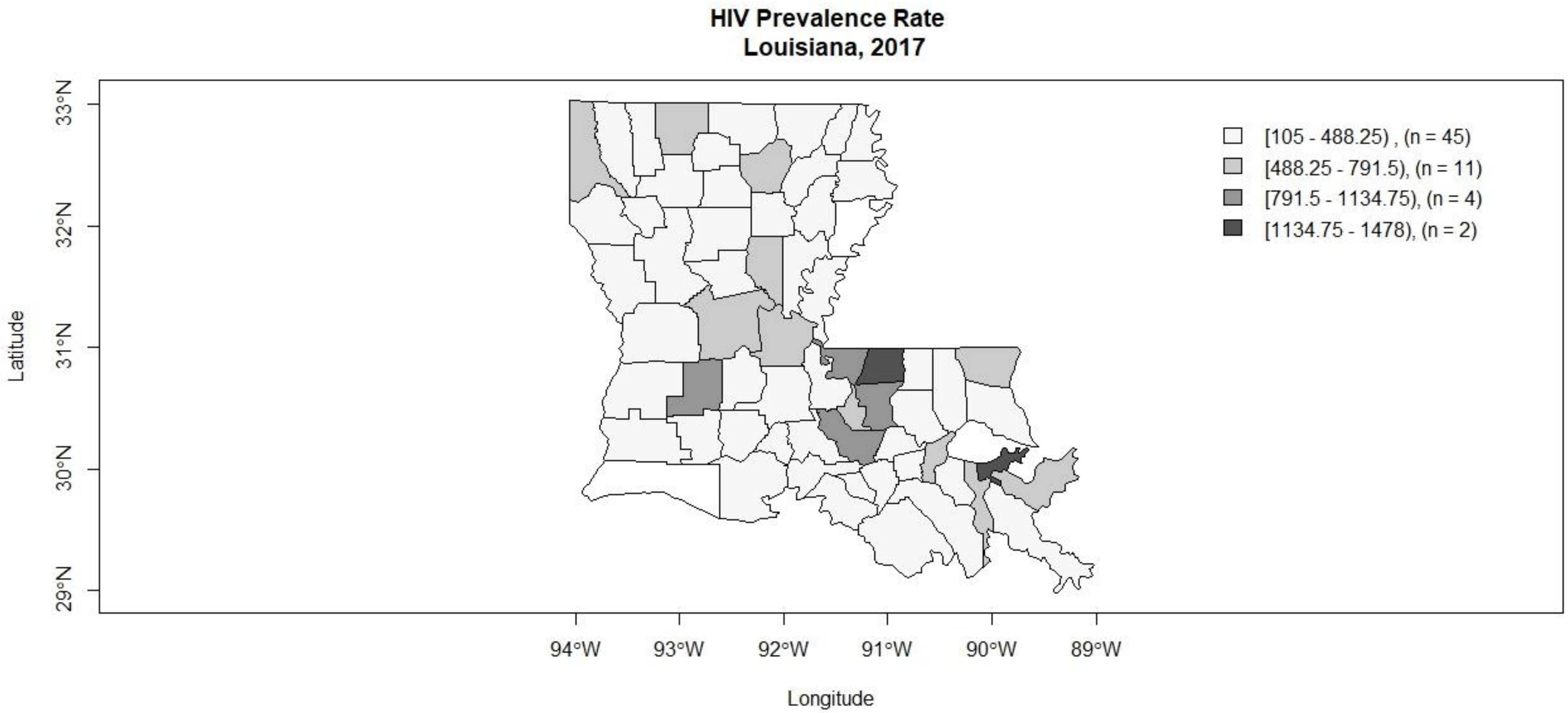
The ratio of the population to primary care physicians originated from the 2009 data of the Area Health Resource File; because data was not available for Cameron and Tensas parishes, 2008 estimates were used. The percentage of the population ages 16 and older who were unemployed but seeking work originated from the 2009 estimates of The

Figure 1: HIV Prevalence Rate in Louisiana, 2007



Note: White denoted no data for that parish

Figure 2: HIV Prevalence Rate in Louisiana, 2017



Note: White denoted no data for that parish

Local Area Unemployment Statistics program of the Bureau of Labor Statistics.

Information pertaining to income inequality originated from the five-year estimates (i.e. 2009-13) of the American Community Survey (ACS). Income inequality was measured as the ratio of household income at the 80th percentile to income at the 20th percentile. The Black-White segregation indices originated from the five-year estimates (i.e. 2010-14) of the ACS. This index measured the extent of dissimilarity in residential segregation between Black and White residents in a given parish, where higher values indicated greater extent of Black-White segregation in a given parish. The percentage of the population under age 65 without health insurance coverage originated from the 2009 U.S. Census Bureau's Small Area Health Insurance Estimates. Information pertaining to the percentage of adults ages 25-44 with some college education originated from the five-year estimates (i.e. 2009-13) of the ACS. Information pertaining to housing insecurity originated from the five-year estimates of the 2009-2013 Comprehensive Housing Affordability Strategy data and included the percentage of households reporting one or more of the following housing issues: incomplete kitchen or plumbing facilities, overcrowded, or severely cost burdened (where monthly housing costs exceed 50 percent of monthly income).

Analytic Strategies

The first objective was addressed through spatial-temporal cluster analysis and the last research question was addressed using spatial lag regression analysis.

Spatial-temporal cluster analyses

All analyses were conducted using the R Statistical Programming Software. Spatial-temporal cluster analysis is an unsupervised learning tool that classifies and assigns trends into their distinctive clusters based on their similarities in time and space as determined by the dynamic time warping (DTW) metric. This technique proceeded in three steps. The *diss* function was first used to calculate the dissimilarity measures / distances among the trends in HIV prevalence rates and the percentages of households with severe housing problems of these parishes using the DTW metric. DTW was an appropriate metric for the purposes of this study because it sought to compare two time series by identifying the best alignment that minimizes the dissimilarities or distances between them in a given distance matrix. Because of that, DTW provided more robust measures of dissimilarities / distances than the Euclidean method as it facilitated a way to compare two time series over similar time frames even if their trends did not "sync up" perfectly.

After that, the Elbow Method and the Silhouette Analysis were used to determine the optimal number of clusters. The Silhouette Analysis was performed using the *pamk* function. The Silhouette Analysis suggested two and three as the optimal number of clusters for HIV infection and housing insecurity respectively. When the Elbow method was used to determine the optimal number of clusters, it seemed that there was an "elbow" at two clusters even though the total within-clusters sum of squares changed slowly and less so after five clusters for both HIV infection and housing insecurity. Finally, hierarchical agglomerative clustering was performed using the *hclust* function to classify and assign the different parishes into five distinctive spatial-temporal clusters based on their longitudinal changes in HIV infection and housing insecurity. Out of the 64 parishes in Louisiana, HIV prevalence rates were not available for two parishes, Cameron and Tensas. These parishes were dropped, leaving 62 parishes for use in the spatial-temporal cluster analysis and ordinary least squares (OLS) and spatial lag regression models described below.

Multivariate regression analyses

OLS and spatial lag models were used to assess the change in HIV infection rates, and thus the resiliency and susceptibility to HIV infection, given the pre-existing sociodemographic conditions of each parish. These pre-existing sociodemographic conditions made up the independent variables and included the percentage of households experiencing one or more of the following: lacking kitchen facilities, plumbing facilities, being overcrowded, or severely housing cost burdened from 2009 to 2013, the percentage of non-Hispanic Black population in 2009, the percentage of population below 18 years of age in 2009, the percentage of population living in rural areas in 2010, the 2009 ratio of the population to primary care physicians, the 2009-13 ratio of household income at the 80th percentile to income at the 20th percentile, the 2010-14 Black-White Segregation Index, the percentage of uninsured adults in 2009, and the percentage of adults with some college education from 2009 to 2013. The unit of analysis was at the parish level.

Since the principal concern of this analysis was to examine the potential impacts of severe housing problems on HIV prevalence, the analysis began by including the 2009-13 percentages of households with severe housing problems in the first (baseline) model. The second model built on the first model to add the percentage of non-Hispanic Black population in 2009, the percentage of population below 18 years of age in 2009, the percentage of population living in rural areas in 2009, the 2009 ratio of the population to primary care physicians, the 2009-13 ratio of household income at the 80th percentile to income at the 20th percentile, the 2010-14 Black-White Segregation Index, the percentage of uninsured adults in 2009, and the percentage of adults with some college education from 2009 to 2013.

The OLS regression was formulated as $y_i = \beta X_i + \varepsilon_i$, where y_i, the dependent variable, was the change in the HIV prevalence rate for the i^{th} parish, β was the vector of regression coefficients of X_i, X_i was the vector of independent variables, and ε_i was the error term with mean=0 and variance=σ^2. Because the independent and dependent variables tended to cluster geographically, spurious correlation could happen, and the independence of observation assumption might not hold. Therefore, the Moran I's test was used to test the null hypothesis of no spatial dependence versus the alternative hypothesis of spatial dependence. The Moran I's statistic for both the reduced and full models were 0.194 and 0.042 respectively and was significant for the reduced model (i.e. p=.008), which suggested some evidence of spatial autocorrelation among parishes in the reduced model. Next, the Lagrange Multiplier (LM) diagnostics for spatial dependence was run to determine if a spatial error regression model or a lag regression model was a better alternative to the OLS regression. The LM tests were significant for both the error dependence (p=.020) and the spatially lagged dependent variables in the reduced model (p=.031) but not the full model (p=.613 for error dependence and p=.119 for spatially lagged dependent variables). The robust LM test for the full model was significant for the spatially lagged dependent variables (p=.050). Both the LM and robust LM tests suggested that the spatial lag regression model was deemed a better alternative for use with the OLS regression than the spatial error regression model for both the reduced and full models.

Accounting for the margin of error for each parish could be difficult because aggregated data was used for the dependent and independent variables. Therefore, bootstrapping was used to estimate the standard errors for the adjusted R-square and coefficients of the OLS regression models to minimize the possibility of a sampling error resulting from the use of aggregated data.

The spatial lag model was based on the assumption that the HIV prevalence rate in one parish was affected by the HIV prevalence rates in the neighboring parishes (Moscone, Knapp, and Tosetti 2007). Because of that, a spatial lag parameter was included as one of the independent variables in the regression model to account for the spatial dependency as evidenced by the Moran I's statistic. It was formulated as $y_i = \rho w_{ij} y_j + \beta X_i + \varepsilon_i$, where y_i was the dependent variable (i.e. the HIV prevalence rate in 2017) for the i^{th} parish, ρ (rho) was the spatial lag parameter, w_{ij} was the spatial weight matrix for the lag terms, β was a vector of coefficients for X_i, the spatial clustering of the independent variables, and ε_i was the vector of independent error terms specified in autocorrelation form. $w_{ij} y_j$ represented the neighboring parish's HIV prevalence rate. In this model, spatial autocorrelation was modeled using a linear relationship between the effects of the spatial lag parameter (ρ) on the HIV prevalence rate in 2017 (Chi and Zhu 2008). Spatial lag models for both the full and reduced models were estimated using the *lagsarlm* function.

RESULTS

Spatial-temporal Cluster Analyses

Spatial-temporal cluster analysis yielded five distinct clusters based on the trends in HIV prevalence rates and percentages of households with severe housing problems. Cluster assignment of each parish was provided in Table 1. As shown in Figure 3, nearly half of the parishes were assigned to the first cluster, characterized by *mild* increases in HIV prevalence rates over time. The HIV prevalence rates for these parishes were no more than 200 in 2007 (except for Caldwell and Richland) but increased to no more than 300 in 2017.

Thirteen parishes were assigned to the second cluster and were characterized as having *somewhat moderate but slow increases* in HIV prevalence rates over time. With the exception of La Salle, the HIV prevalence rates for these parishes remained somewhat unchanged during the period of observation. The HIV prevalence rates for these parishes, with the exception of Calcasieu, were no more than 300 in 2007 but increased to no more than 500 in 2017 (see top panel of Figure 4). Changes in HIV prevalence rates were somewhat noticeable for La Salle: they more than doubled from 2007 to 2009, remained unchanged over the next two years from 2009 to 2011, increased somewhat from 2011 to 2013, declined somewhat from 2013 to 2016, and slightly increased from 2016 to 2017.

As shown in the bottom panel of Figure 4, two-thirds of the parishes assigned to the third cluster experienced either *moderate but slow* (i.e. Avoyelles, Jefferson, Ouachita, Rapides, St. Bernard, and Washington) or *drastic* (i.e. Caddo and Claiborne) increases in HIV prevalence rates.

Another three experienced *moderate but drastic declines* in HIV prevalence rates (i.e. East Carroll, Madison, and Winn) while the rates *remained moderate but relatively unchanged* in West Baton Rouge. The HIV prevalence rates for these parishes were no more than 400 in 2007 (except for East Carroll, Madison, and West Baton Rouge) but increased to no more than 600 in 2017.

Allen, East Baton Rouge, East Feliciana, Iberville, and West Felicia were assigned to the fourth cluster, characterized as having *somewhat high* HIV prevalence rates in 2007 but *somewhat slow increases* over time (see top panel of Figure 5). Except for West Feliciana, HIV prevalence rates nearly doubled during the period of observation. HIV prevalence rates remained relatively unchanged from 2007 to 2013, slightly increased thereafter until 2016, and somewhat declined from 2016 to 2017 in West Feliciana. Orleans was assigned to the fifth cluster, characterized by *relatively high but declining* HIV prevalence rates over time. As shown in the bottom panel of Figure 5, HIV prevalence rates decreased from slightly over 2,100 in 2007 to about 1,500 in 2017.

Figure 6 shows near one-fifth of the parishes were assigned to the first cluster, characterized by *low* percentages of severe housing problems. Trends in these percentages declined from 10 to 5 percent in West Carroll and slightly fluctuated between 10 to 15 percent for the other parishes during the period of observation.

Thirteen parishes were assigned to the third cluster, characterized by moderate percentages of households with severe housing problems (see the bottom panel of Figure 7). These percentages fluctuated between 14 to 19 percent during the period of observation. Upward trends were somewhat noticeable in Claiborne (14 to 19 percent), Evangeline (14 to 17 percent), and Madison (14 to 18 percent), and downward trends were somewhat noticeable in Morehouse (19 to 15 percent) and St. John the Baptist (19 to 15 percent).

Four parishes were assigned to the fourth cluster, characterized by high and fluctuating percentages of households with severe housing problems (see top panel of Figure 8). The percentages fluctuated between 18 and 22 for East Baton Rouge, and East Carroll declined from 22 to 18 for Lincoln and Natchitoches during the period of observation. Orleans was assigned to the fifth cluster, characterized by high and declining percentages of households with severe housing problems. As shown in the bottom panel of Figure 6, these percentages declined from 28 to 26 during the period of observation.

Table 1: Descriptive Statistics Pertaining to Louisiana Parishes, Mean (Standard Deviation)

Variables	**Cluster 1 (n=31)**	**Cluster 2 (n=13)**	**Cluster 3 (n=12)**	**Cluster 4 (n=5)**	**Cluster 5 (n=1)**
% of household with severe housing problems (2009-13)	13.06% (2.26%)	14.00% (3.67%)	15.83% (2.62%)	13.00% (3.94%)	28.00% (NA)
% of non-Hispanic Black population (2009)	24.63% (10.64%)	35.63% (10.88%)	38.43% (14.78%)	42.16% (10.37%)	62.30% (NA)
% of population below 18 years of age (2009)	25.73% (1.77%)	25.44% (1.31%)	25.06% (1.94%)	21.74% (2.93%)	21.50% (NA)
% of population living in rural areas (2010)	51.70% (28.42%)	46.42% (26.81%)	37.40% (26.52%)	67.10% (38.26%)	0.6% (NA)
Ratio of population to primary care physician (2009)	3,044 (1,609)	2,190 (1,703)	3,295 (3,166)	2,059 (816)	615 (NA)
% of population ages 16 and older unemployed but seeking work (2009)	7.80% (2.33%)	8.63% (2.45%)	8.08% (1.93%)	8.00% (1.50%)	8.40% (NA)
Extent of income inequality (2009-13)	5.22 (0.70)	5.45 (0.61)	5.27 (0.46)	5.44 (0.42)	6.90 (NA)
Index of Black-White segregation (2010-14)	43.90 (13.56)	45.46 (7.29)	48.25 (14.40)	29.60 (16.50)	68.00 (NA)
% of adults under age 65 without health insurance (2009-13)	20.52% (2.23%)	20.23% (2.09%)	22.92% (4.52%)	21.00% (3.00%)	27.00% (NA)
% of adults ages 25-44 with some college education (2009-13)	45.69% (9.83%)	45.56% (9.07%)	45.19% (10.94%)	45.68% (12.76%)	66.70% (NA)

Figure 3: Louisiana Parishes with *Mild Increases* in HIV Prevalence Rates (Cluster 1)

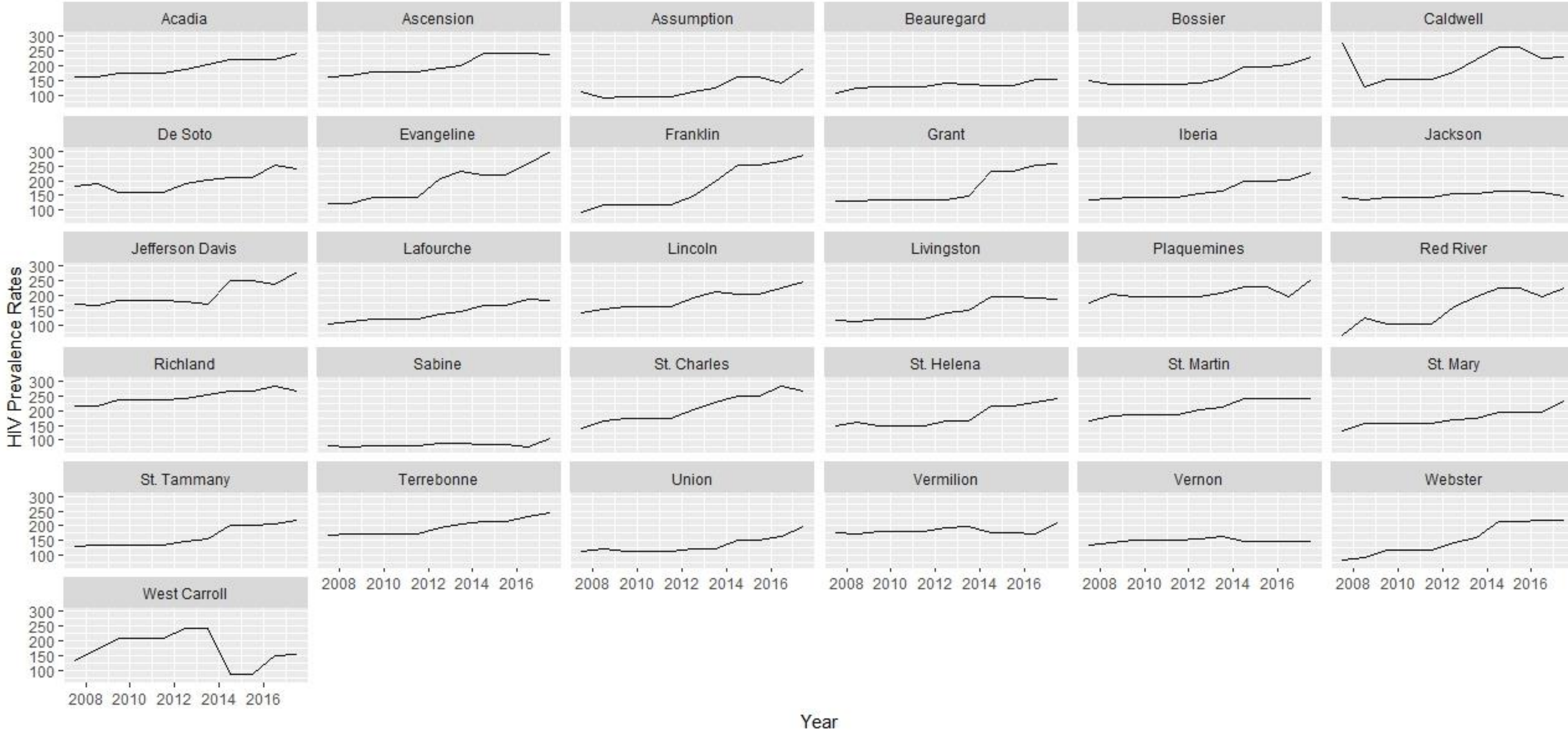
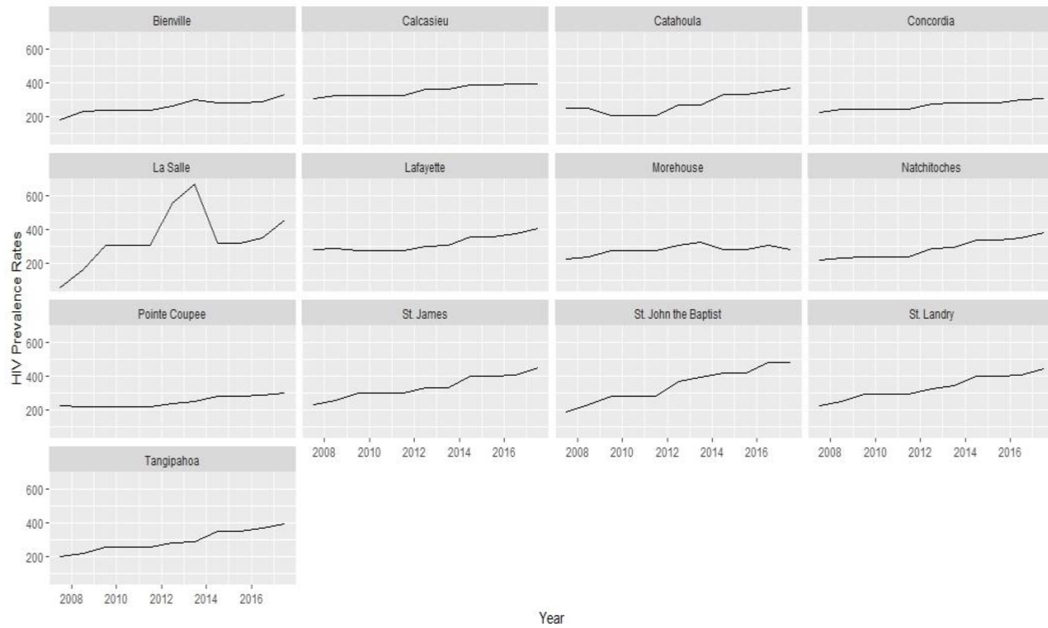


Figure 4: Louisiana Parishes with *Somewhat Moderate but Slow Increases in* (top – Cluster 2) and *Moderate* (bottom – Cluster 3) HIV Prevalence Rates)

Cluster 2



Cluster 3

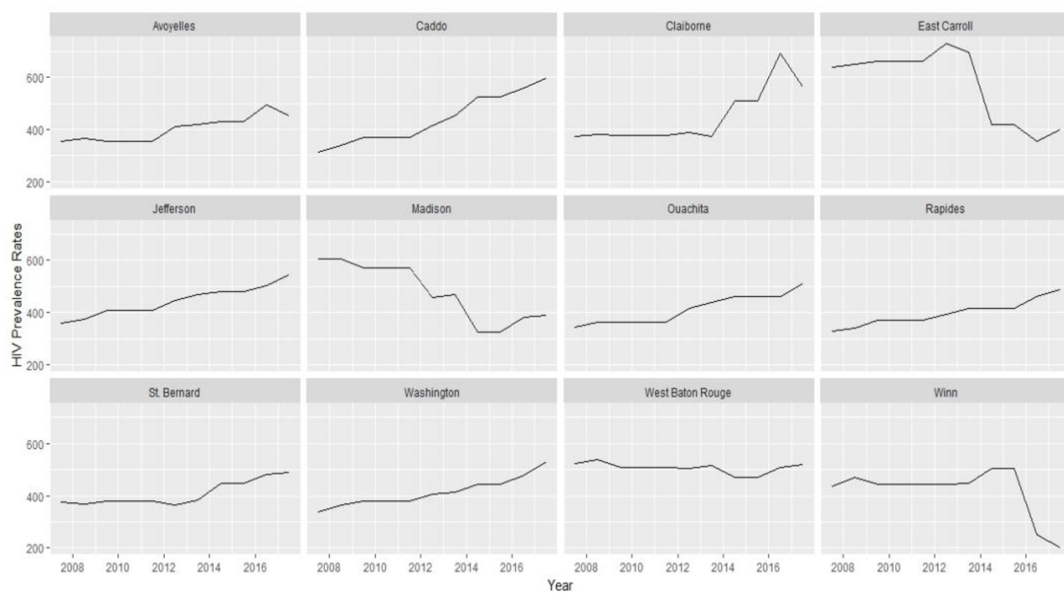
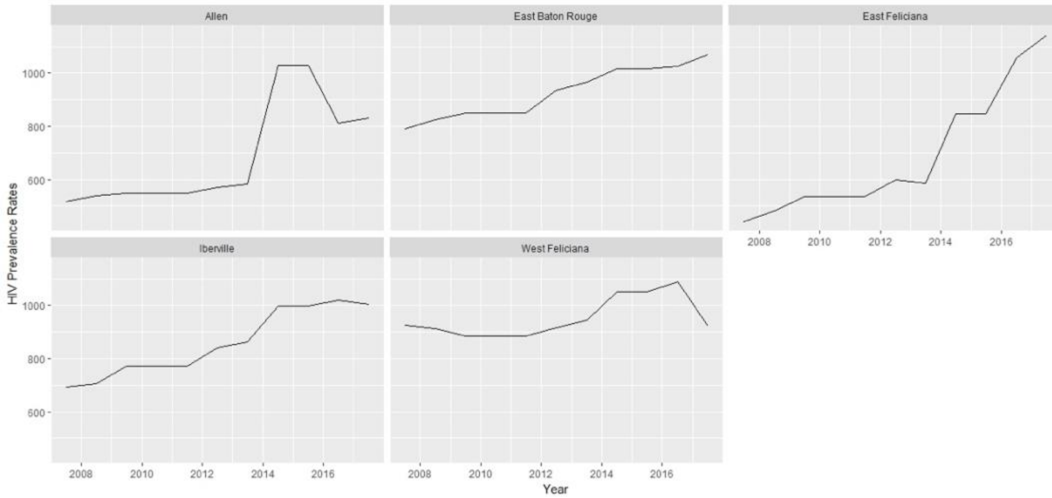


Figure 5: Louisiana Parishes with *High and Drastic Increases in* (Cluster 4) and *Relatively High but Declining* HIV Prevalence Rates (Cluster 5)

Cluster 4



Cluster 5

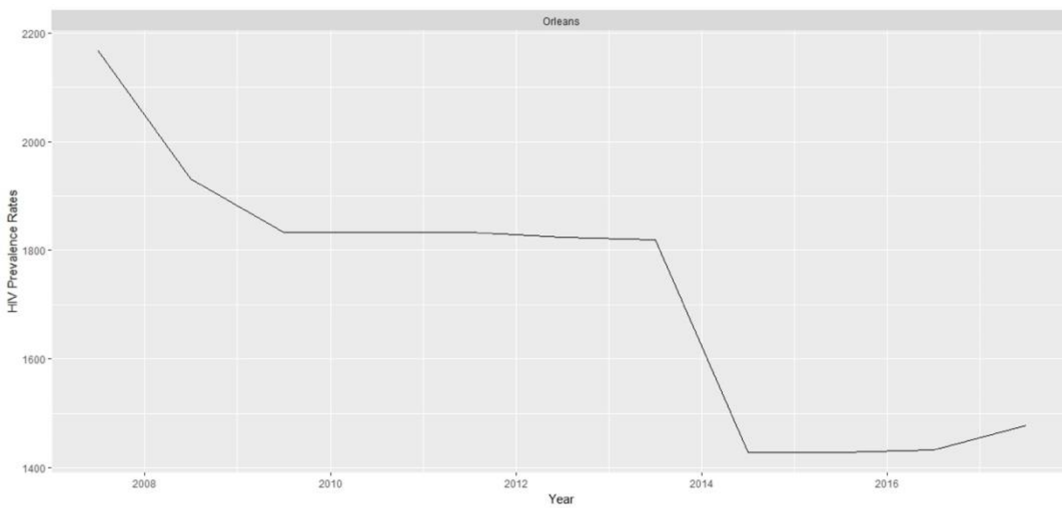


Figure 6: Louisiana Parishes with *Low* Percentages of Households with Severe Housing Problems (Cluster 1)

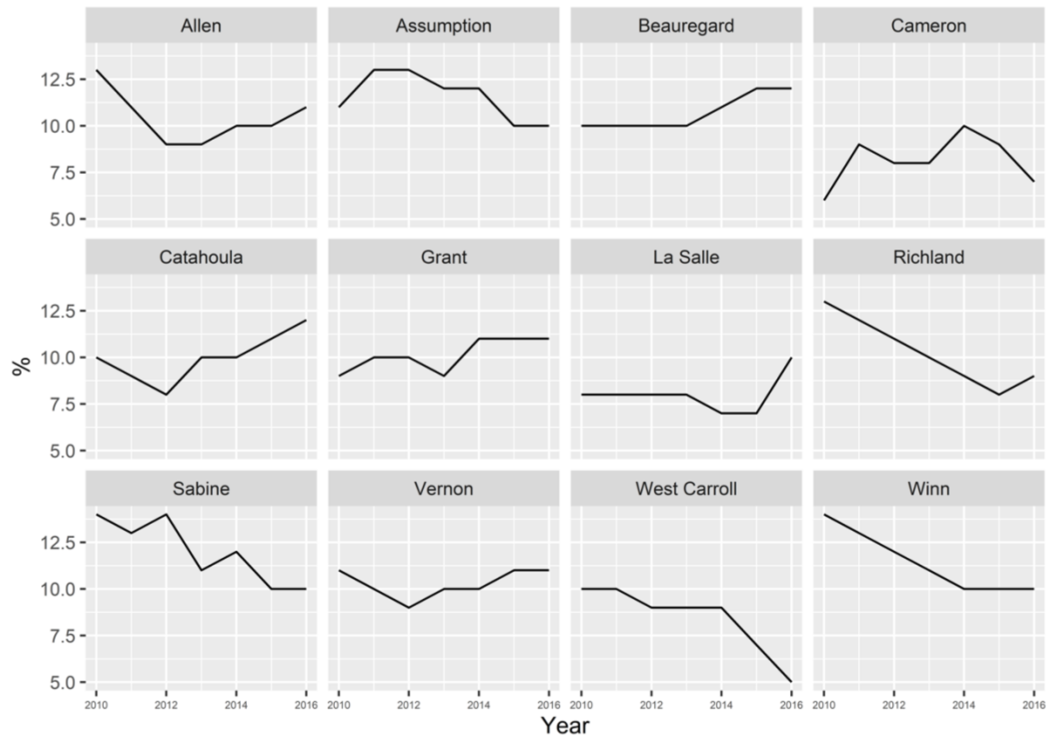
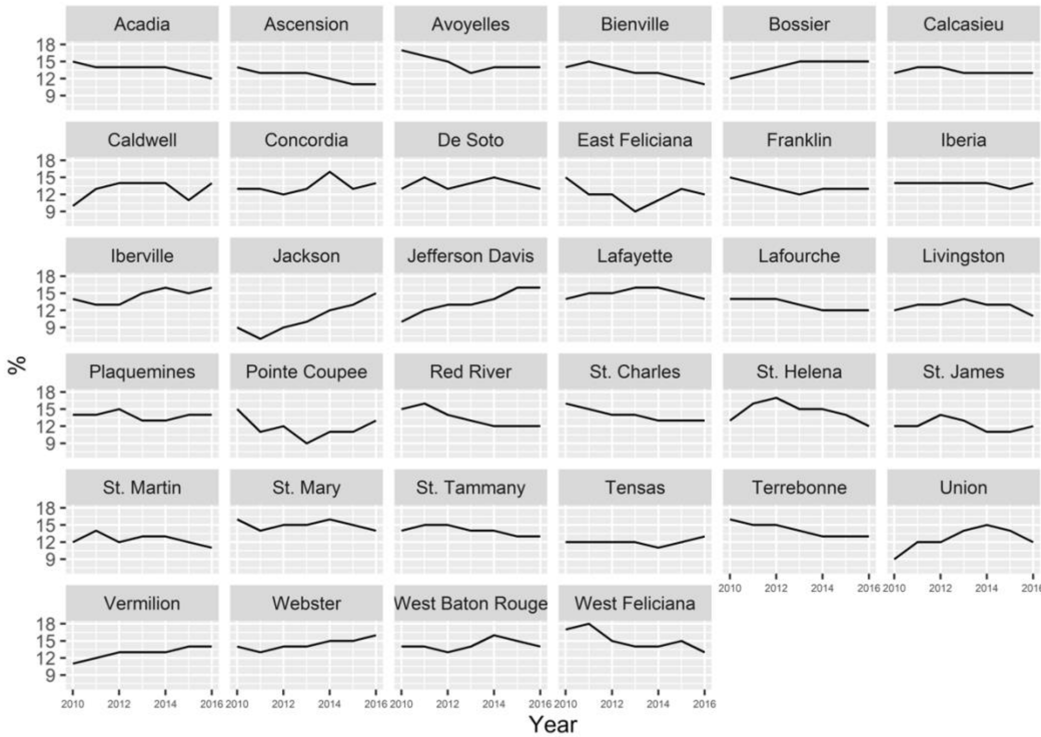


Figure 7: Louisiana Parishes with *Moderately Low* (Cluster 2) and *Moderate* (Cluster 3) Percentages of Households with Severe Housing Problems

Cluster 2



Cluster 3

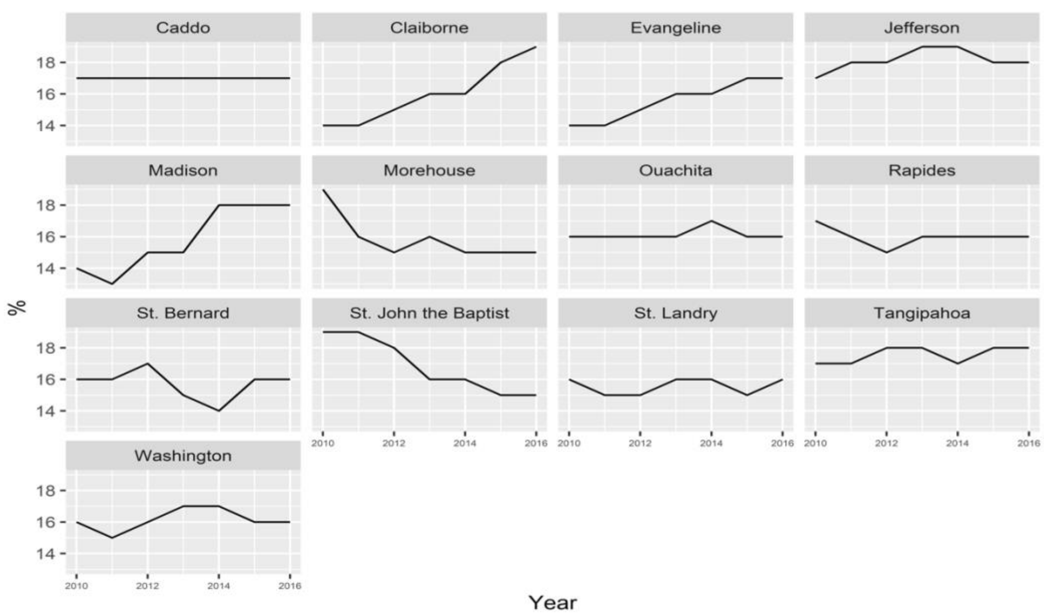
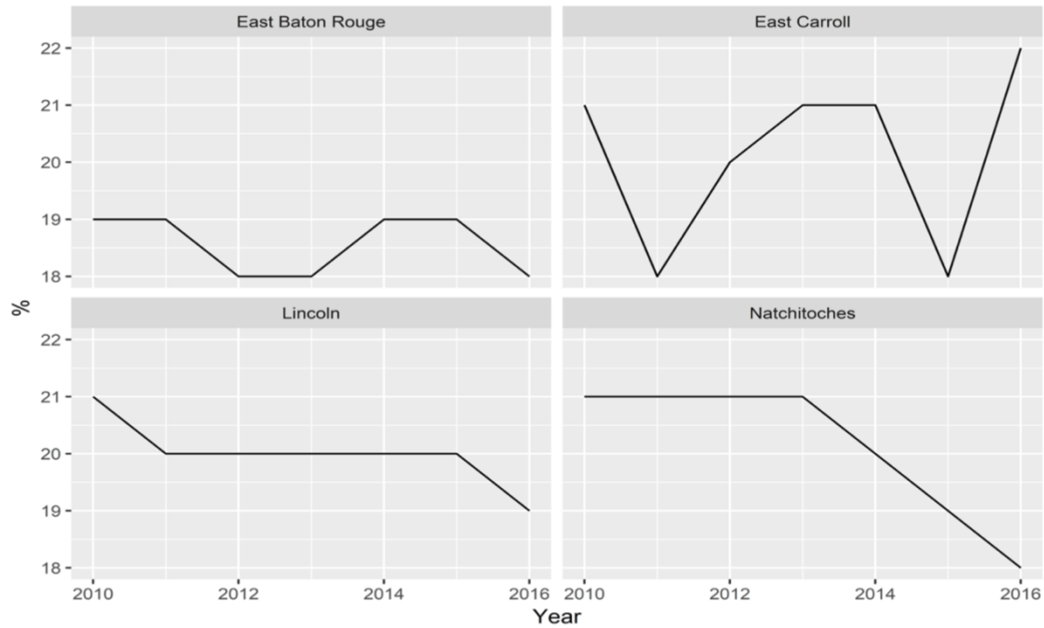
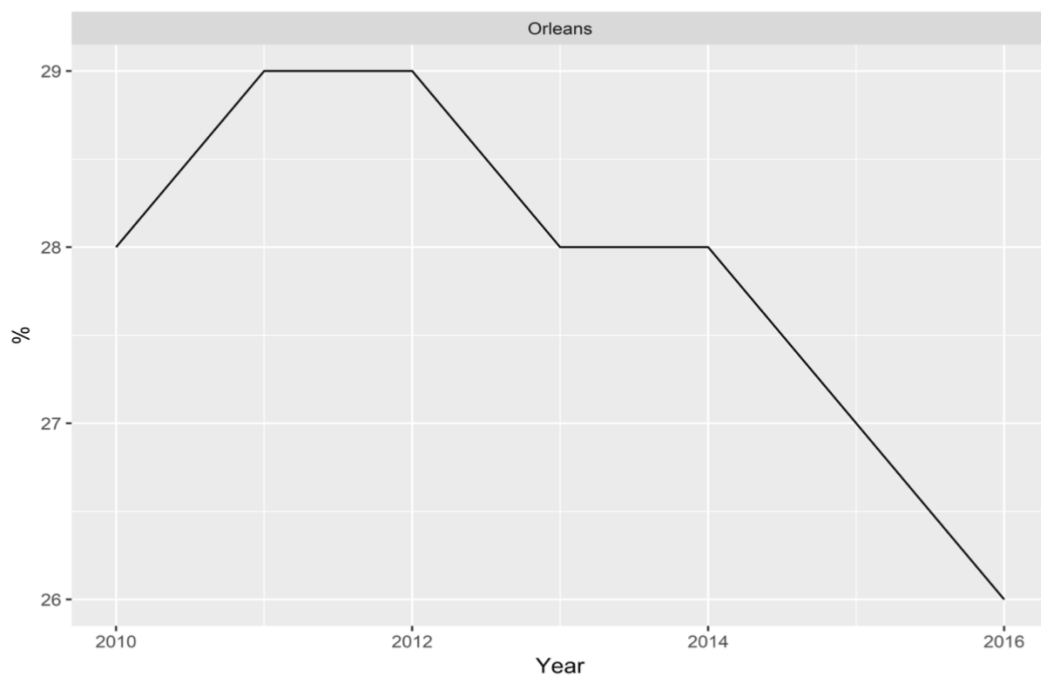


Figure 8**:** Louisiana Parishes with *High and Fluctuating* (Cluster 4), and *High and Declining* (Cluster 5) Percentages of Households with Severe Housing Problems

Cluster 4



Cluster 5



Descriptive Statistics

As shown in Table 2, the percentage of households with severe housing problems was relatively high for the sole parish assigned to the fifth cluster (i.e. Orleans). The percentage of non-Hispanic Black population was also relatively high in Orleans and in

Table 2: Results from OLS Regression on the 2017 HIV Prevalence Rates in Louisiana Parishes

Variables	**OLS regression**	
	Model 1	**Model 2**
Intercept	89.494	1,240.684^{+}
% of households with incomplete kitchen facilities, plumbing facilities, overcrowded, or severely cost burdened (2009-13)	33.413*	1.348
% of non-Hispanic Black population (2009)		9.083*
% of population below 18 of age (2009)		-45.043*
% of population living in rural areas (2010)		-0.943
Ratio of population to primary care physician (2009)		-0.031*
% of population ages 16 and older unemployed but seeking work (2009)		-22.756
Extent of income inequality (2009-13)		-29.089
Index of Black-White segregation (2010-14)		0.079
% of adults under age 65 without health insurance (2009)		13.716
% of adults ages 25-44 with some college education (2009-13)		3.097
Moran I's	0.194*	0.042
LM (error)	5.403*	0.256
LM (lag)	4.644*	2.437
Robust LM (error)	0.759	1.603
Robust LM (lag)	0.001	3.784*
Adj. R Squared	0.174	0.407
Rho		
Wald statistic		
Log likelihood		
Maximum likelihood estimates of residual variance		
AIC	889.450	887.560

*p<=.05; $^{+}$.05<p<.10

parishes assigned to the fourth cluster. In general, the percentages of population below 18 years of age were somewhat similar across clusters. The percentage of the population living in rural areas was somewhat higher for parishes assigned to the fourth cluster while the reverse was true for Orleans and for parishes assigned to the third cluster. The ratios of patients to primary care physicians (PCP) were relatively low for Orleans and somewhat higher for parishes assigned to the first and third clusters and somewhat similar for parishes assigned to the other three clusters. In general, the percentages of unemployed population were somewhat similar across clusters. The extent of income inequality was slightly higher for Orleans and somewhat similar for parishes assigned to the other four clusters. On average, the Black-White segregation indices were relatively high for Orleans, somewhat lower for parishes assigned to the fourth cluster and somewhat similar for the other three clusters. The percentages of adults who were uninsured and who had some college education were relatively high in Orleans and somewhat similar across the other four parishes.

Multivariate Analyses

Results from the first spatial lag regression model in Table 3 suggested that the 2009-13 percentage of households with severe housing problems was significantly associated with the 2017 HIV prevalence rate. The effect of the percentage of households with severe housing problems became insignificant with the addition of the percentages of non-Hispanic Black population, population below 18 years old, population living in rural areas, unemployed population, uninsured adults, and adults with some college education, as well as the ratio of population to primary care physician and the extent of income inequality and Black-White segregation in the second spatial lag regression model. This suggested that these variables exerted a mediating effect between the percentage of households with severe housing problems and HIV prevalence rate. Results from the second model also revealed that HIV prevalence rates increased with the percentages of non-Hispanic Black population while the reverse was true for the percentage of population below 18 years old and the ratio of population to primary care physician.

The last two columns of Table 3 also showed that the likelihood ratio (LR) tests of the spatial lag parameters (ρ's) were positive and significant in the reduced model but not the full model. The p-values associated with the Wald tests were significant at $p <= .05$ in the reduced model but not the full model, meaning that the alternative hypothesis that the ρ's were not zero was only confirmed in the reduced model. This provided evidence that similar expected HIV prevalence rates tended to cluster together in these parishes to a certain extent in the reduced model. In other words, the expected HIV prevalence rates in a given parish increased when the expected HIV prevalence rates in neighboring parishes increased, controlling for the other variables in the reduced model.

Table 3: Results from Spatial Lag Regression on the 2017 HIV Prevalence Rates in Louisiana Parishes

Variables	**Spatial lag regression**	
	Model 1	**Model 2**
Intercept	-206.924	1,151.545^{+}
% of households with incomplete kitchen facilities, plumbing facilities, overcrowded, or severely cost burdened (2009-13)	33.587*	2.860
% of non-Hispanic Black population (2009)		10.890*
% of population below 18 of age (2009)		-57.033*
% of population living in rural areas (2010)		-1.274
Ratio of population to primary care physician (2009)		-0.041*
% of population ages 16 and older unemployed but seeking work (2009)		-25.592
Extent of income inequality (2009-13)		-18.510
Index of Black-White segregation (2010-14)		0.718
% of adults under age 65 without health insurance (2009)		13.433
% of adults ages 25-44 with some college education (2009-13)		2.128
Rho	0.300*	0.224
Wald statistic	4.254*	2.506
Log likelihood	-439.782	-424.921
Maximum likelihood estimates of residual variance	53,329	33,844
AIC	887.560	875.840

*p<=.05; $^{+}$.05<p<.10

A comparison of coefficients in the second model from both the OLS and spatial lag regression suggested that the inclusion of the spatial lag dependence (ρ) from the regression equation only changed the magnitudes but not the significance of the percentage of non-Hispanic Black population and the ratio of population to primary care physician.

This suggested that the inclusion of ρ did not exert either a mediating or suppressing effect on the HIV prevalence rate in the full model.

DISCUSSION

This pioneering study used spatial-temporal cluster analysis to examine how trends in HIV prevalence rates and the percentages of households with severe housing problems differed across 62 parishes in Louisiana and whether the pre-existing sociodemographic conditions varied across these distinctive spatial-temporal clusters. It also used a spatial lag regression model to assess the parish's resilience and susceptibility to HIV infection given these pre-existing sociodemographic conditions. Results from this study may provide guidance to health policymakers and practitioners as they can tailor policies and delivery according to the pre-existing sociodemographic conditions in each cluster.

The significant and positive association between the 2012-16 percentage of households with severe housing problems and the 2017 HIV prevalence rate hinged on whether individuals living with these housing conditions were disproportionately affected by the HIV epidemic due to their lack of financial means to afford health coverage as well as other health enhancing and protective resources. This finding resonated with prior literature that demonstrates a connection between unstable housing conditions and increased risk of contracting HIV (Corneil et al. 2006; Weir et al. 2007; Dickson-Gomez et al. 2009; Dickson-Gomez et al. 2011). Priorities should be given to Claiborne, East Carroll, Lincoln, and Orleans, parishes which reported higher percentages of households with one or more of these housing issues: overcrowding, high housing costs, and incomplete kitchen and plumbing facilities. However, the significance of the relationship between percentage of households with severe housing problems and the HIV prevalence rate appears to be driven by mediating factors including the percentage of non-Hispanic Black population. Minority households, such as Black households, have been found to have higher housing costs and lower quality housing compared to White households (Owens and Tegeler 2007; U.S. Census Bureau 2017; Goodman, Li, and Zhu 2018). Improving the affordability and housing quality for racial minority groups may contribute to improving their health outcomes (Swope and Hernandez 2019). Prior research has found that providing more affordable housing may act as an intervention to HIV infection **(**Dickson-Gomez et al. 2011) and when housing is affordable, residents are less likely to put off health care (Meltzer and Schwartz 2016). Living in higher quality housing may also allow minority households to devote more monetary resources to maintaining good health and seeking care when faced with risky behaviors or encounters that could increase the threat of contracting HIV.

The significant and positive association between the percentage of non-Hispanic Black population and the HIV prevalence rate might imply that individuals living in parishes that were predominantly Black faced barriers and constraints during the period under investigation that prevented the adoption of safe and protected sexual behaviors. These barriers and constraints might include suboptimal geographic accessibility to healthcare facilities (Reif et al. 2005; Reif et al. 2015; Masiano et al. 2019) which might have prevented someone from obtaining adequate information on HIV testing, screening, and treatment, which may have led to the possibility of undiagnosed HIV infection or untreated AIDS. Thus, it is imperative for policymakers and practitioners in Louisiana to increase the delivery of comprehensive care for persons with HIV and those at risk of contracting HIV. This is especially needed in parishes that were predominantly Black with relatively high HIV prevalence rates during the period under review such as East Carroll, Madison, and Orleans (all three parishes were at least 60 percent rural in 2009).

The significant and negative association between the ratio of population to primary care physician and the change in HIV prevalence rate suggested that more physicians are needed to combat HIV infection through education, screening, and treatment. This is especially so for parishes with a relatively low population to primary care physician ratio but increasing trends in HIV prevalence rates (i.e. Orleans, East Baton Rouge, and West Feliciana). This finding echoed the results from a cross-national study in the U.S. that found that increased physician density had the potential to slow the spread of HIV/AIDS (Mondal and Shitan 2013). It is imperative for institutes of higher education in Louisiana, such as Tulane University which has programs in public health and Louisiana State University which is well known for their health-related programs, to collaborate with healthcare facilities and the state government to address the shortage and mal-distribution of medical professionals and to develop plans to recruit and retain physicians and clinical professionals. In fact, attempts to recruit and retain primary care physicians have been underway since Hurricane Katrina (Rigby et al. 2009), but are still inadequate as the findings from this research demonstrated. Greater emphasis should be placed on encouraging students of gender and racial/ethnic minorities to enroll in medical education programs. Strategies to recruit and retain physicians and clinical professionals can include reimbursement reform, increased scholarship funds for Graduate Medical Education, increased funding for training in medical and nursing schools, and improvements to existing medical school debt relief programs.

CONCLUSION

Efforts to integrate HIV service with other health services and improve affordability and accessibility of HIV testing (Sutton et al. 2010) and viral suppression among HIV-positive individuals (Hess and Hall 2018) should focus on Allen, East Baton Rouge, East Feliciana, Orleans, Iberville, and West Feliciana parishes. The susceptibility for housing insecurity was also high in East Baton Rouge and Orleans parishes and should be monitored and improved where possible. Future research should consider HIV rates in conjunction with the use and availability of antiretroviral therapy (ART). It may be that parishes with higher HIV prevalence rates that are also more urban would have a lower ratio of primary care physicians to those diagnosed with HIV and consequently have increased access to ART. However, those living in parishes with lower HIV prevalence rates and a higher ratio of primary care physicians to those diagnosed with HIV may be less likely to have sufficient access to ART.

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Appendix Table 1: Cluster Assignment of Louisiana Parishes

Parish	**HIV Cluster**	**SHP Cluster**
Acadia	Mild	Moderately Low
Allen	High & drastic increase	Low
Ascension	Mild	Moderately Low
Assumption	Mild	Low
Avoyelles	Moderate	Moderately Low
Beauregard	Mild	Low
Bienville	Somewhat moderate	Moderately Low
Bossier	Mild	Moderately Low
Caddo	Moderate	Moderate
Calcasieu	Somewhat moderate	Moderately Low
Caldwell	Mild	Moderately Low
Cameron	Mild	Low
Catahoula	Somewhat moderate	Low
Claiborne	Moderate	Moderate
Concordia	Somewhat moderate	Moderately Low
De Soto	Mild	Moderately Low
East Baton Rouge	High & drastic increase	High & fluctuating
East Carroll	Moderate	High & fluctuating
East Feliciana	High & drastic increase	Moderately Low
Evangeline	Mild	Moderate
Franklin	Mild	Moderately Low
Grant	Mild	Low
Iberia	Mild	Moderately Low
Iberville	High & drastic increase	Moderately Low
Jackson	Mild	Moderately Low
Jefferson	Moderate	Moderate
Jefferson Davis	Mild	Moderately Low
Lafayette	Somewhat moderate	Moderately Low
Lafourche	Mild	Moderately Low
La Salle	Somewhat moderate	Low
Lincoln	Mild	High & fluctuating
Livingston	Mild	Moderately Low

Appendix Table 1. Cont.

Parish	HIV Cluster	SHP Cluster
Madison	Moderate	Moderate
Morehouse	Somewhat moderate	Moderate
Natchitoches	Somewhat moderate	High & fluctuating
Ouachita	Moderate	Moderate
Orleans	Relatively high but declining	Relatively high but declining
Plaquemines	Mild	Moderately Low
Pointe Coupee	Somewhat moderate	Moderately Low
Rapides	Moderate	Moderate
Red River	Mild	Moderately Low
Richland	Mild	Low
Sabine	Mild	Low
St. Bernard	Moderate	Moderate
St. Charles	Mild	Moderately Low
St. Helena	Mild	Moderately Low
St. James	Somewhat moderate	Moderately Low
St. John the Baptist	Somewhat moderate	Moderate
St. Landry	Somewhat moderate	Moderate
St. Martin	Mild	Moderately Low
St. Mary	Mild	Moderately Low
St. Tammany	Mild	Moderately Low
Tangipahoa	Somewhat moderate	Moderate
Tensas	Mild	Moderately Low
Terrebonne	Mild	Moderately Low
Union	Mild	Moderately Low
Vermilion	Mild	Moderately Low
Vernon	Mild	Low
Washington	Moderate	Moderate
Webster	Mild	Moderately Low
West Baton Rouge	Moderate	Moderately Low
West Carroll	Mild	Low
West Feliciana	High & drastic increase	Moderately Low
Winn	Moderate	Low