SPATIAL ANALYSIS OF COVID-19 HEALTH DISPARITIES: MINORITY POPULATIONS OF NEW YORK CITY

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ABSTRACT: *At the onset of the COVID-19 Pandemic, researchers and government officials were overwhelmed with the task of adjusting a thriving and vibrant way of life into that of a dormant and secluded lifestyle. Stay-at-home orders were enforced to curtail the spread of the virus. The virus had a profound effect on the world, as infection and death rates began to soar worldwide. As New York City (NYC) is home to over eight million residents of varying ethnic and racial backgrounds, most of these groups have preexisting health disparities. These disparities have been further intensified by this pandemic. The overall goals of this analysis are to better understand the socio-spatial patterns of COVID-19 in the United States' largest city. Geographically Weighted Regressions (GWR) will help us to investigate underlying Minority Health Disparities (MHD) related to the COVID-19 outbreak in New York City, from April through August of 2020. Based on available data, this study examines all five boroughs at a ZIP-Code level. Along with analyzing three primary minority groups, this study further shows the distinctive differences between those who are native-born, and those who are foreign-born in the same ethnic group.*

Keywords: *COVID-19, minority health disparities, neighborhood, New York City, ZIP-Code*

INTRODUCTION

In November of 2019, the first reported case of SARS-CoV-2 was reported in Hubei Province, a landlocked area in China. While the infection grew in severity within the eastern hemisphere, the western hemisphere did not see much or any activity until January 2020. On January 21st, a Washington state resident became the first person with a confirmed case of COVID-19 in the United States. Ten days later, the World Health Organization (WHO) issued a Global Health Emergency. Throughout February 2020, air travel became restricted, the US declared a Public Health Emergency, and the Centers for Disease Control and Prevention (CDC) announced that they believed the infection is heading towards "Pandemic" status. This came true the following month. On March 11, 2020, COVID-19 was regarded as a Pandemic by the WHO. Following this, travel restrictions were implemented, as well as stay-at-home orders, with only "essential businesses" being allowed to operate under these restrictions. The most obvious implementation was the requirement of individuals to wear masks when going out in public. Offices and most storefronts were closed, and those employed continued to "work from home" (WFH). On May 28th, the 100,000th COVID-19 death was reported, and a few days later, on June 4th, the 2,000,000th confirmed case of COVID-19 was reported (American Journal of Managed Care, 2021).

According to the CDC, New York City was reported as being the epicenter of the COVID-19 Pandemic during the spring of 2020. They claimed the highest rates of COVID-19 cases, hospitalizations, and deaths were concentrated in communities of color, high-poverty areas, among persons aged 75 and higher, and among those with underlying health conditions (CDC, 2020). Given this information, this paper seeks to complete a study to find out where these areas exist within the city, and if there is a correlation between COVID-19 and minority health disparities. Also, according to Reichberg SB et.al (2020), 26,735 persons in the greater New York metropolitan area tested positive for COVID-19 between March 8th and April 10th, 2020, out of 46,793 persons tested (57.1% positivity rate).

To understand the spread of the virus, it is of the upmost importance to understand not only the death and infection rates, but the underlying demographic landscape as well. New York City is a metropolis like no other. As of 2019, there were roughly 8.42 million residents residing within its five boroughs: The Bronx, Brooklyn, Manhattan, Queens, and Staten Island, respectively. Each borough is also a county within New York State. In the largest city on the Eastern Seaboard, 65% of the city's population is comprised of minorities. That amounts to approximately 5.473 million residents. Interestingly, the minority population accounts for more than half of the overall population (nearly two-thirds of it), making non-minorities the minority population in New York City. Considering its total land cover is not that substantial, New York City has a significantly higher population density than the national average of about

93 residents per square mile. The city's populations density is about 27,000 residents per square mile, or roughly 290 times the national average. Apartments and other rental units dominate the housing market in New York City, along with the fact that as of 2017, 67.9% of all city residents rented as opposed to owning (New York City Department of City Planning, n.d.).

As immigrants began to leave Europe around the turn of the 19th century, people came from far and wide, seeking opportunity and a new life in the emerging city. New York City has earned the colloquial nickname of the "Melting Pot" due to the numerous ethnic groups and varying racial backgrounds you can find here. Ethnic and racial groups from all corners of the world have settled within the five boroughs, often settling in proximity to one another. When these groups initially settled over a century ago, they would often locate to an area where they would find people of their own ethnic group or race. Over time, this led to areas of the city being widely known for their high percentages of certain ethnic or racial groups.

For instance, according to Figure 1, the southeastern area of Queens and central Brooklyn are home to a high percentage of black residents, along with a high percentage living in The Bronx, northern Manhattan, and northern Staten Island. According to Figure 2, northern Queens is home to high percentages of native and foreign-born Asians, along with a high percentage living in central Queens, southwest Brooklyn, and lower Manhattan. According to Figure 3, The Bronx is home to a high percentage of Hispanic residents, along with a high percentage living in northeast Queens, the eastern portion of Brooklyn, and the northern portions of Manhattan and Staten Island.

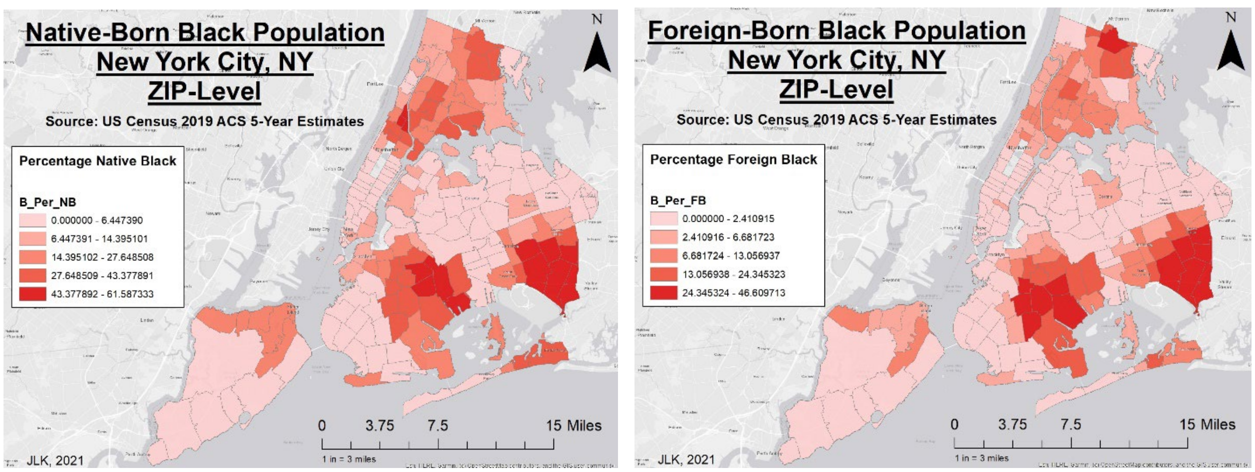

Figure 1. Native & Foreign-Born Black Populations.

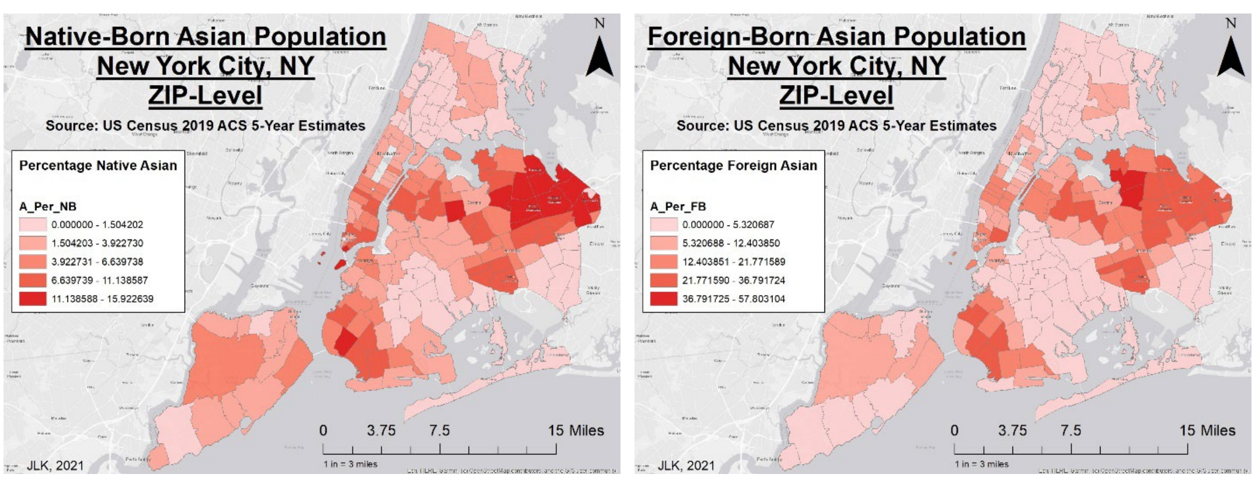

Figure 2. Native & Foreign-Born Asian Populations.

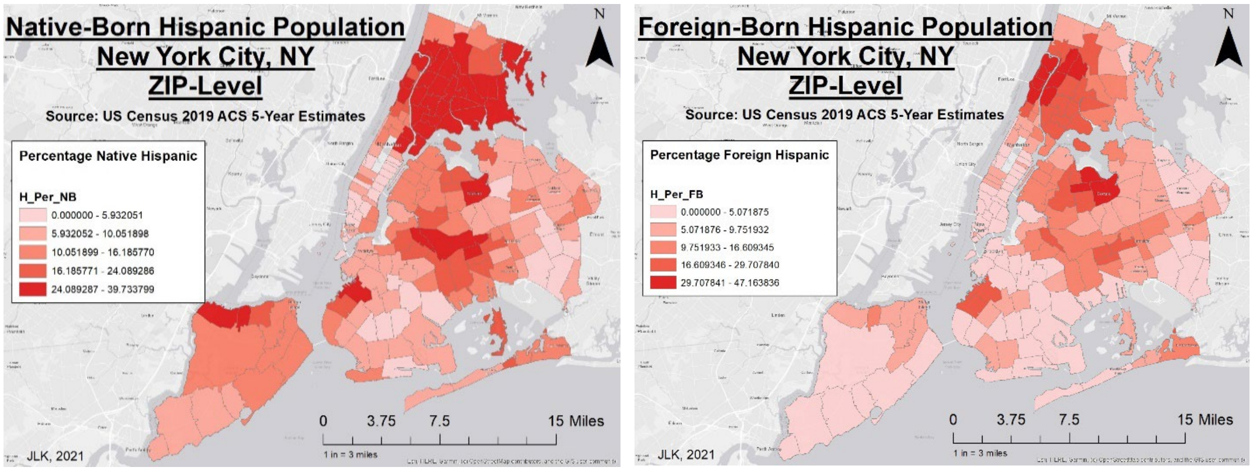

Figure 3. Native & Foreign-Born Hispanic Populations.

Neighborhoods containing high percentages of native & foreign-born black populations – Arverne, Bedford-Stuyvesant, Brighton Heights, Brownsville, Bushwick, Cambria Heights, Canarsie, Castle Hill, East Flatbush, East Harlem, Eastchester, Far Rockaway, Forest Houses, Harlem, Hunts Point, Jamaica, Laurelton, Midwood, East New York, New Brighton, New Lots, Ocean Hill, Queens Village, Richmond Hill, Rockaway Beach, Rosedale, South Bronx, South Jamaica, South Ozone Park, South Richmond Hill, Spring Creek, Springfield Gardens, St. Albans, Stapleton, Starrett City, Tompkinsville, Wakefield, Williamsbridge

Neighborhoods containing high percentages of native & foreign-born Asian populations – Auburndale, Bath Beach, Bay Ridge, Bay Terrace, Bayside, Bayside Hills, Bellerose Manor, Chinatown, Douglaston, Downtown Flushing, Dutch Kills, East Flushing, Elmhurst, Financial District, Flushing, Forest Hills, Glen Oaks, Gravesend, Hunters Point, Koreatown, Linden Hill, Little Neck, Lower East Side, Murray Hill, Oakland Gardens, Rego Park, Sunset Park, Two Bridges

Neighborhoods containing high percentages of native & foreign-born Hispanic populations – Astoria Heights, Bushwick, College Point, Corona, Cypress Hills, East Harlem, Elm Park, Greenwood Heights, Inwood, Jackson Heights, Little Dominican Republic, Mariners Harbor, Most of The Bronx, New Lots, North Corona, Ocean Hill, Ozone Park, Ridgewood, Spanish Harlem, Sunset Park, Washington Heights, Woodhaven, Woodside

In a city so densely populated, primarily by minorities, there are underlying themes of disparity regarding income, employment, access to healthcare, and other fields where inequalities are reported. This study seeks to examine if there were any COVID-19 related minority health disparities present at a ZIP code level in NYC during April – August 2020. If there are such disparities, what are the spatial and socioeconomic factors associated with these disparities to further help understand the underlying factors of minority health disparities?

METHODS

First, it was necessary to obtain demographic data. This study utilized 2019 ACS 5-Year Estimates on all instances, which was obtained from the United States Census Bureau's data site (U.S. Census Bureau, 2020). Using the advanced search option, it was necessary to select all ZIP-Codes in New York State, and to obtain data regarding; Demographic & Housing Estimates, Educational Attainment, Employment Status, Health Care Coverage, Population, Poverty Status, Race, and Transportation. From these eight separate CSV files, it was important to only select NYC attribute data that was necessary for this analysis. Ethnic groups were separated into native-born and foreign-born subgroups because of differences in their respective population groups. Johnson et. al. (2010) found that the epidemiology of HIV infection differs for foreign-born black individuals compared with their native-born counterparts in the Unites States. This study used percentage data where possible, as this would be beneficial when Geographically Weighted Regressions (GWR) are carried out later.

Next, it was important to obtain ZIP-Code level COVID-19 infection and death data from the New York City Department of Health (NYC DOH) (New York City Department of Health, 2020). The GitHub repository was a source of COVID-19 infection and death counts tallied up daily. This study collected the accumulated number of COVID-19 infection and death counts from April 6th until August 16th, 2020. It is necessary to mention that the NYC DOH did not report death statistics until May 18th, 2020.

Following this, it was important to obtain the locations of the Metropolitan Transit Authority (MTA) bus stops and subway stations. The data for the locations of bus stops and subway stations were sourced from CUNY Baruch College's Newman Library (CUNY Baruch, n.d.). Within the five boroughs, there are 14,890 bus stops along with 509 subway stations. Including bus stops and subway stations as exploratory variables was necessary because many NYC residents don't have access to a vehicle, which was also an exploratory variable. Also, the Pew Research Center found that those who are lower-income, black or Hispanic, of immigrant status, or under the age of 50 are especially likely to use public transportation on a regular basis (Anderson, 2016).

After obtaining all attribute data, it was necessary to obtain a shapefile of all five boroughs at a ZIP-Code level. New York City's OpenData site was the source for this (Calgary, n.d.). In all, New York City is comprised of 263 ZIP-Codes. However, certain ZIP-Codes containing no population (i.e., Central Park, LaGuardia Airport) have been omitted from this report. After removing outlying ZIP-Codes with no population, the shapefile contained 196 ZIP-Codes, indicating there are 67 ZIP-Codes that do not contain a permanent population in New York City. After removing the 67 unnecessary ZIP-Codes, it was important to join all attribute data to the ZIP-Code shapefile. Lastly, it was important to calculate the X & Y centroid for each ZIP-Code area, a step necessary for later running GWR. All geospatial processes mentioned so far were carried out in ArcMap 10.7.1. If necessary, raw rates were converted to percentages in the attribute table.

Geographically Weighted Regressions (GWR) will be utilized for this study to analyze the increase in COVID-19 infection and death counts. GWR is a form of linear regression that is used to model spatially varying relationships. Custodio et. al. (2020) found that GWR was the best method to explain the spatial distribution of COVID-19 in São Paulo, Brazil, which also highlighted the spatial aspects of the data simultaneously. The GWR model will be Poisson, offset by the total population per ZIP-Code area. There were 196 observations and 17 covariates used in the model. Default bandwidth and neighborhood settings were used. The Geographically Weighted Regressions will be ran using MGWR 2.2, an open-source GWR package developed by Arizona State University. Model performance was assessed via Adjusted R^2. Any multicollinearity was assessed using the Pearson Correlation coefficient.

RESULTS

Infection

As Table 1 shows, all minority populations apart from the native-born black and Asian populations returned a positive coefficient. Those populations deemed significant by their p-values are native and foreign-born blacks, Asians, and Hispanics. On all instances, the native-born population's coefficient was lower than the foreign-born population's coefficient. The foreign-born populations were also the populations containing the highest overall coefficient values, suggesting they are more likely to test positive for COVID-19 than their native-born counterparts.

Table 1. GWR Coefficients & P-Values, Minority Populations & Infections, ZIP-Code Level

Population	GWR Coefficient	P-Value
Black (Native Born)	-0.006	0.004
Black (Foreign Born)	0.022	0.000
Asian (Native Born)	-0.031	0.003
Asian (Foreign Born)	0.014	0.007
Hispanic (Native Born)	0.001	0.003
Hispanic (Foreign Born)	0.017	0.000

The only native-born group to have a positive coefficient were the Hispanics, with a coefficient value of .001. The native-born Asians had the lowest coefficient witnessed in this study, suggesting they are least likely to test positive for COVID-19. Meanwhile, their foreign-born counterparts saw the second highest overall coefficient for a minority group regarding infection, making them second most likely to test positive. The foreign-born blacks returned the highest overall coefficient for infection, suggesting they are the most likely to test positive for COVID-19.

All themes of disparity apart from the percentage above the age of 62 returned a positive coefficient (Table 2). All themes of disparity were deemed significant by their respective p-values. The three highest overall coefficients regarding themes of disparity and infection are: percent without high school diploma, percent living with a disability, and percent living in poverty, respectively. Their overall coefficients suggest they are the leading underlying themes of disparity regarding COVID-19 and infection. Figure 4 shows the coefficients of these variables at the ZIP-Code level.

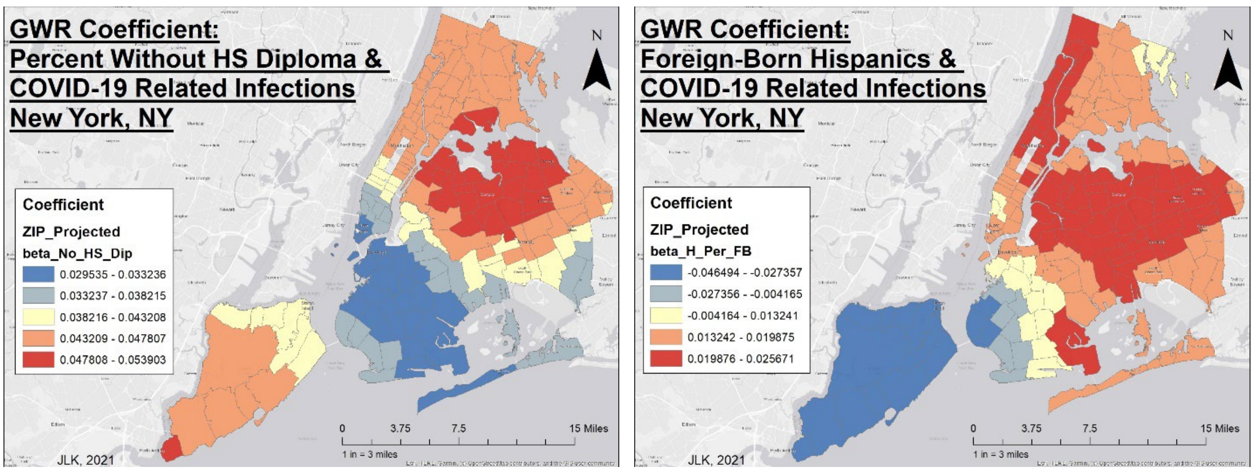

Figure 4. GWR, coefficients of select variables (Education Level & Foreign-Born Hispanics) and related infections.

Table 2. GWR Coefficients & P-Values, Themes of Disparity & Infections, ZIP-Code Level

Disparity Theme	GWR Coefficient	P-Value
% Unemployed	0.004	0.027
% Living on Public Assistance	0.014	0.000
% With No Access to Vehicles	0.003	0.018
MTA Bus Stops & Subway Stations (per 100 Residents)	0.024	0.009
% Living with a Disability	0.035	0.000
% 62+ Years of Age	-0.013	0.032
% Living in Poverty	0.034	0.000
% Without High School Diploma	0.039	0.000
% Uninsured	0.027	0.000

The highest and second-highest overall coefficients regarding foreign-born Asians and COVID-19 infection rates fall in northeast Queens, where they have a strong presence (see Figure 2). The highest and second-highest overall coefficients regarding percent disabled and infection rates fall in eastern Queens, where there is a strong presence of native and foreign-born Asians and blacks (see Figures 1-2). According to Figure 4, the highest and second-highest overall coefficients regarding percent without a high school diploma and infection rates fall in northern Queens and Staten Island, where there is a strong presence of native and foreign-born Hispanics (see Figure 3). Also, according to Figure 4, the highest and second-highest overall coefficients regarding foreign-born Hispanics and infection rates fall in northern Manhattan, the northwest portion of The Bronx, and all of Queens, where this minority group holds large percentages of the overall population (see Figure 3).

Death

All minority populations apart from the native-born Hispanic population returned a positive coefficient. Those populations deemed significant by their p-values are native and foreign-born blacks and Hispanics; neither native nor foreign-born Asians were deemed significant. The native-born black population returned the highest overall coefficient for death, suggesting they are the minority group most likely to pass away due to COVID-19. The foreign-born Hispanic population returned the second highest overall coefficient for death, suggesting they are the minority group second most likely to pass away due to COVID-19. The foreign-born black population is the third most likely to pass away due to COVID-19, with the native-born Hispanic population being the least likely to pass away due to COVID-19, since they have the lowest overall coefficient regarding death. Both Asian populations had p-values far above 0.05, so their results are insignificant regarding death. Table 3 reports these results.

Table 3. GWR P-Values, Minority Populations & Deaths, ZIP-Code Level

Population	GWR Coefficient	P-Value
Black (Native Born)	0.033	0.000
Black (Foreign Born)	0.014	0.045
Asian (Native Born)	0.007	*
Asian (Foreign Born)	0.022	*
Hispanic (Native Born)	-0.045	0.025
Hispanic (Foreign Born)	0.017	0.014

*P-Value > 0.05, Insignificant

All themes of disparity returned a positive coefficient. Those themes deemed significant by their p-values are percent unemployed, percent living on public assistance, access to MTA stops & stations, percent living with a disability, percent above the age of 62, percent living in poverty, and percent uninsured. The three highest overall coefficients regarding themes of disparity and death are: percent living with a disability, percent living in poverty, and percent of population age 62 plus, respectively. Their overall coefficients suggest they are the leading underlying themes of disparity regarding COVID-19 and death. Table 4 reports all coefficients of these variables.

Table 4. GWR P-Values, Themes of Disparity & Deaths, ZIP-Code Level

Disparity Theme	GWR Coefficient	P-Value
% Unemployed	0.060	0.013
% Living on Public Assistance	0.025	0.012
% With No Access to Vehicles*	0.019	*
MTA Bus Stops & Subway Stations (per 100 Residents)	0.013	0.011
% Living with a Disability	0.114	0.03
% 62+ Years of Age	0.090	0.004
% Living in Poverty	0.098	0.039
% Without High School Diploma*	0.037	*
% Uninsured	0.088	0.000

*P-Value > 0.05, Insignificant

The highest and second-highest overall coefficients regarding percent in poverty and COIVD-19 death rates fall in northern Manhattan, most of The Bronx, and northern Queens, where all minority populations are present in high percentages (see Figures 1-3, 6). There is a strong presence of native and foreign-born blacks and Hispanics on the Rockaway Peninsula, in southern Brooklyn & Queens, and in the northern and eastern portions of Staten Island (See Figures 1 and 3). The highest and second-highest overall coefficients regarding native-born blacks and death rates fall on the Rockaway Peninsula, in Southern Queens, extending into central & northern Queens, as well as the northeast portion of The Bronx (see Figure 5). There is a strong presence of native-born blacks on the Rockaway Peninsula and in southern Queens (see Figure 1). The highest and second-highest overall coefficients regarding percent disabled and death rates fall on and in the Rockaway Peninsula, South Brooklyn, southern and central Queens, the western portion of Staten Island, and the lower and middle portions of Manhattan (see Figure 6). Also, the highest and second-highest overall coefficients regarding population age 62 plus and death rates fall in The Bronx and Manhattan, and in northwest Queens and Brooklyn (see Figure 5). There is a strong presence of all minority groups in these areas of the city (See Figures 1-3).

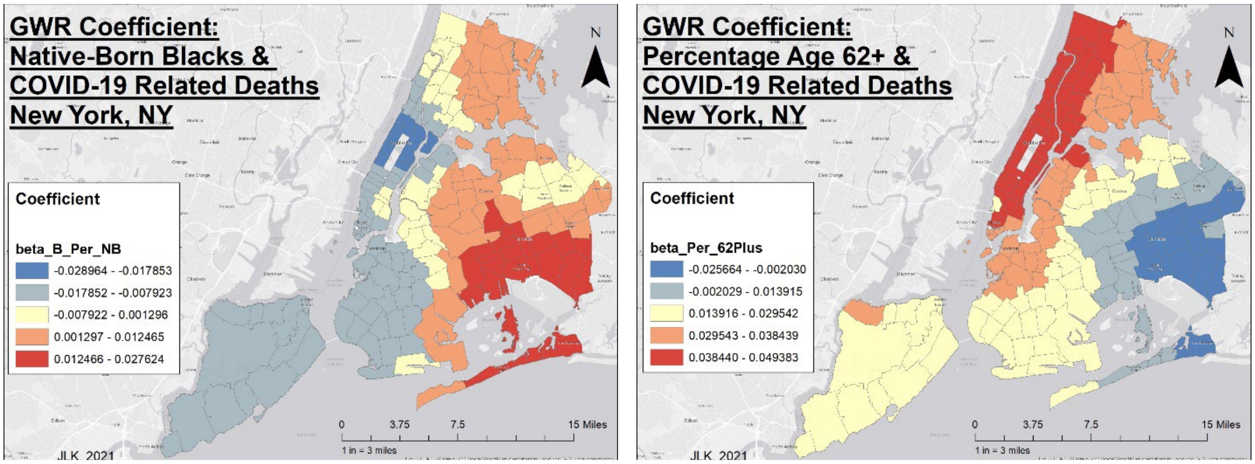

Figure 5. GWR, coefficients of select variables (Native-born blacks & Age over 62) and related deaths.

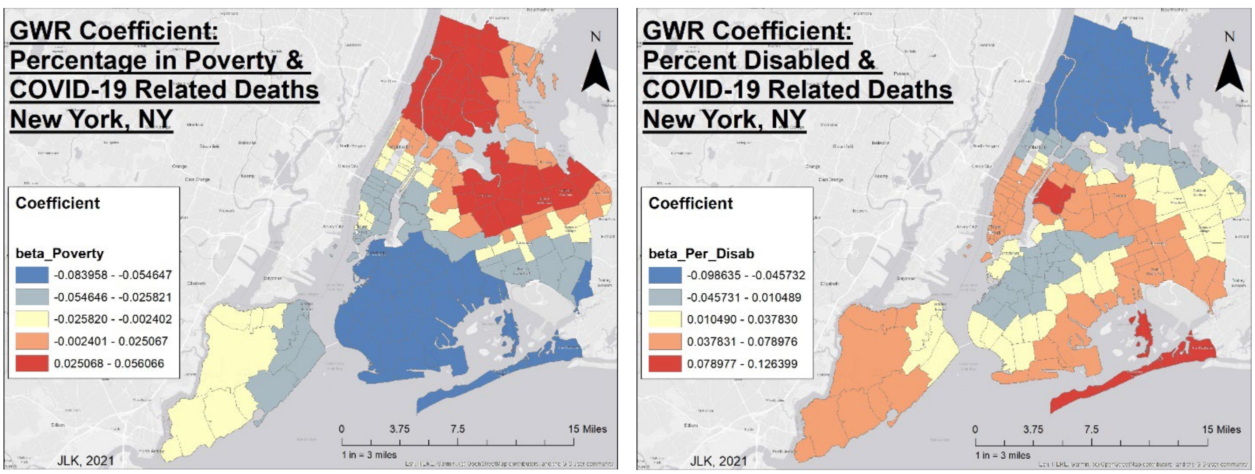

Figure 6. GWR, coefficients of Disability & Poverty and related deaths.

DISCUSSION

The main objective of this study was to examine if a relationship exists between various socio-economic factors and COVID-19 infection and death rates amongst the minority populations of NYC. Other minority populations do exist in NYC, but this study only focused on the three most predominant minority populations. A limitation of this is that the US Census Bureau places other ethnic/racial groups into two categories: "Other Race" or "Two or More Races". This makes analysis impossible for these minority groups, as many ethnic and racial groups are unfortunately aggregated into two large, yet indistinct groups, making their population figures unclear.

A possible limitation of the GWR model is the presence of multicollinearity, a phenomenon of one or more explanatory variables being redundant. This leads to an overcounting type of bias and, in turn, provides an ultimately unreliable or unstable model. As stated previously, any multicollinearity was assessed using the Pearson Correlation coefficient, which helps to check the collinearity of independent variables. As a Poisson GWR model was used in this analysis, there is an assumption that the data will follow a Poisson distribution. However, multicollinearity is a property of the independent variables, implying that it has nothing to do with the type of regression that is being applied. Other possible limitations of using GWR include lack of a unifying approach to estimate local coefficients, incorrect estimates of dispersion of model coefficients, the influence of outliers, weak data, and an assumption violation of homogeneous error variance (LeSage 2004, Wheeler & Páez 2010).

As for the MTA bus stops and subway stations, these themes returned the fifth highest GWR coefficient witnessed in this study regarding themes of disparity and infection. As so many NYC residents rely on public transportation, it is plausible that the utilization of such resources is a vector for the spread of COVID-19. A study found that 34% of urban black residents and 27% of urban Hispanic residents report taking public transit daily or weekly (Anderson, 2016). It is safe to surmise that these minority populations could have been exposed to the virus in this fashion.

CONCLUSION

The SARS-CoV-2 Virus arrived in the United States with a strong presence, and almost immediately became an issue that proved difficult to manage. Infection rates and death counts began to rise rapidly, and local, state, and national government agencies took precautionary measures to stop the spread of Coronavirus. In nearly every instance, the GWR regression coefficient came back positive, except for three variables. Regarding infection, the minority groups with the highest overall coefficients were foreign-born black, foreign-born Hispanic, and foreign-born Asian, respectively. Their native-born counterparts all had coefficients under or just barely above zero. The three highest overall coefficients regarding themes of disparity and infection are: percent without high school diploma, percent living with a disability, and percent living in poverty, respectively. Regarding death, the minority groups with the highest overall coefficients were native-born black, foreign-born Hispanic, and foreign-born black, respectively. While both black populations had a positive coefficient, the native-born Hispanics experienced the lowest overall coefficient witnessed in this study. Both Asian populations were deemed insignificant based on their p-values. The three highest overall coefficients regarding themes of disparity and death are: percent living with a disability, percent living in poverty, and percent of population age 62 plus, respectively. The most vulnerable themes for both infection and death are those living in poverty and those living with a disability. The most vulnerable minority population groups for both infections and deaths would be foreign-born blacks and Hispanics. Figure 7 shows the neighborhoods at highest risk regarding COVID-19.

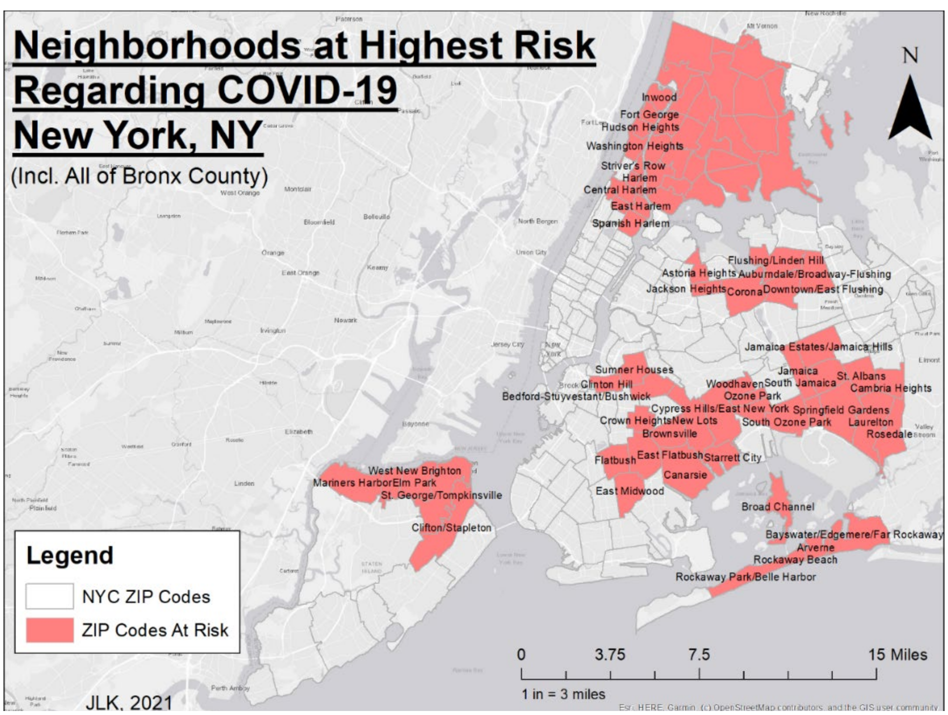

Figure 7. Most Vulnerable Neighborhoods.

So far, the COVID-19 Pandemic is ongoing, which has fortunately been alleviated by the availability of vaccines. This has brought some normality back to the resident's daily lives. This study shows that minority health disparities exist and are further intensified by the pandemic. More importantly, this study addresses culturalization: if a resident of an ethnic group is born domestically or in their home nation, it could lead to constraining probabilities of infection and death. Since this study only considers data before the availability of a vaccine, it will be informative to carry out a study using similar methods to address the role of vaccination rates on outcomes such as infection and COVID-related death rates. More importantly, news outlets have reported the reduction of infection and death rates shortly after the stay-at-home orders were implemented. A formal study is necessary to investigate the role of restrictions on mobility regarding COVID-19 infection and related death rates. These results will not only help researchers to better understand more details related to minority health disparities, but to also support organizations and decision makers to take non-pharmaceutical approaches to minimize minority health disparities within communities.

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