

# Exploring the Geospatial Relationship Between COVID-19 Positivity and Income in Mixed Urban-Rural Population

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**Abstract.** The COVID-19 pandemic has had a deep influence on American life in general and on the American economy in particular. However, the burden of the pandemic has not been distributed equally among members of a population based on their social-determinants-of-health. The purpose of this study was to investigate whether the median income was associated with COVID-19 total number of tests and positivity rate in Boone County, Missouri during the pandemic. We analyzed the geospatial data using three heat maps showing the Census tract-wise COVID-19 positivity rate, Census tract-wise median income, and Census tract-wise total number of COVID-19 tests to highlight our study findings. Our study results support the hypothesis that individuals with lower median income tend to have a lower total number of COVID-19 tests and higher COVID-19 positivity rates in Boone County, Missouri. The Pearson correlation coefficient between the positivity rate and median income is -0.324.

**Keywords.** COVID-19, geospatial analysis, income disease correlation

## 1. Introduction

The coronavirus disease (COVID-19) is an infectious disease caused by the SARS-CoV2 virus [1]. Since COVID-19's emergence in Wuhan, China in December 2019, it has rapidly spread worldwide. The disease was declared a pandemic on March 11, 2020, by the World Health Organization (WHO) [2]. While many patients recover without the need for any hospitalization or specialized care, COVID-19 is known to severely impact the elderly and those with chronic illnesses and co-morbidities such as diabetes, obesity, and hypertension [2]. The pandemic has caused enormous economic, public health, and social damages [3][4]. Also, it has caused a huge number of challenges to the global public health system as well as the global economy since its emergence until now [5].

According to the U.S. Department of Labor, the unemployment rate reached 14.7% in April 2020 [5]. The COVID-19 pandemic worsens the existing average income inequalities in American society [6][7]. In mid-April 2020, workers and employees at the

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bottom quintile were three times more likely to lose their jobs and be laid off compared to the higher-wage workers and employees [6][7]. Between mid-March and mid-April, the weekly wages of workers at the bottom and top quintiles decreased by 26% and 10%, respectively, compared to 6% and 1% between mid-February and mid-March respectively [6]. In addition, workers and employees aged between 16 and 24 were affected much more than older employees and workers [6]. Between mid-March and mid-April, the Hispanic worker's wages declined by 2-3 percentage points more than other workers [6]. The social distancing following the US state-level emergency declarations led to significant changes in the American people's income during the pandemic [8]. It has been found that wealthier areas significantly decreased mobility compared to the poorer areas [8]. These patterns hold across data sources, mobility measures, and income quintiles [8]. Additionally, previous research has indicated that lower-income communities have lower access to healthcare and higher levels of preexisting health conditions [8].

This effect is a combination of a reduction in working hours (impacting mainly lower-paid workers) and enormous layoffs [6]. It is worth noting that while the COVID-19 mortality rates are very low among young individuals, young workers have been economically stricken harder compared to older workers during the lockdown [6][7][8]. Previous research studies have shown that there are large spatial inequities in COVID-19 testing, confirmed cases, mortality, and positivity rates among U.S. cities [9][10]. It also showed a strong relation between COVID-19 testing, confirmed cases, mortality, and positivity rates with higher neighborhood social vulnerability [9][10]. These differences are reinforced and generated due to the residential discrimination that is linked to structural racism and income inequality [9][10]. In summary, we hypothesized that individuals with lower median income will have lower testing rates and higher positivity rates in a mixed urban-rural population in Boone County, Missouri.

## **2. Methods**

Boone County, Missouri consists of 11 primary cities and towns: Columbia, Ashland, Centralia, Hallsville, Harrisburg, Sturgeon, Hartsburg, Rocheport, McBaine, Huntsdale, and Pierpont; including 40 Census tracts. Boone County is part of the Mid-Missouri geographic region within the Midwestern U.S. and is home to 180,463 residents. We used data from the Cerner Electronic Health Record (EHR) from the University of Missouri Hospital and Clinics in the Mid-Missouri area for individuals who were tested for COVID-19 between March 2020 and December 2021. The data includes the demographic information for 126,900 distinct patients. As well as 236,809 COVID tests, 15,903 which were positive, and 81,809 unique addresses. It also includes the patients' detailed addresses, the testing dates along with the testing locations. Boone County, Missouri has a median household income of \$58,740 and income per capita (individual income) of \$30,340. In 2020, Census Tract 16.02 had the highest median household income of \$104,632 followed by Census Tract 12.01 (\$101,529) and Census Tract 17.02 (\$95,389)<sup>2</sup>.

Geocoding can be defined as the process of transforming a description of a location such as an address or a name of a place to a location on the Earth's surface, e.g., a pair

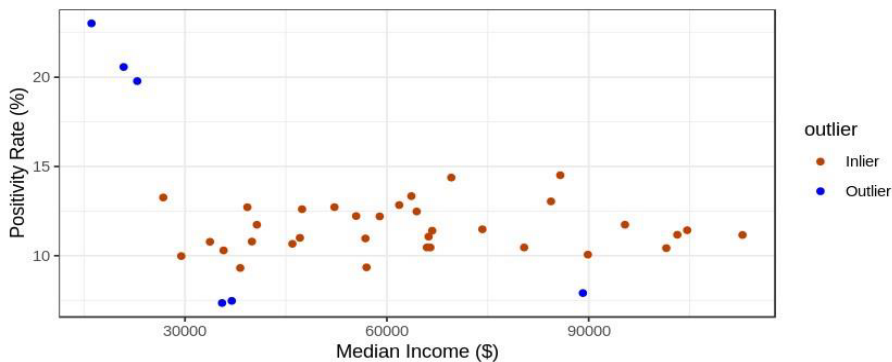
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<sup>2</sup> <https://datausa.io/profile/geo/boone-county-mo>

of coordinates (latitude and longitude). Geocoding allows us to take patients' information and create a map of their locations. We first start by cleaning the data and preparing it for the geocoding process using R and Python. The data went through two main cleansing steps before it was ready for geocoding. The first step focused on cleaning the patients' addresses, while the second step focused on removing the redundancy. Finally, we geocoded the data to get the latitude (lat) and longitude (lon).

### 3. Results

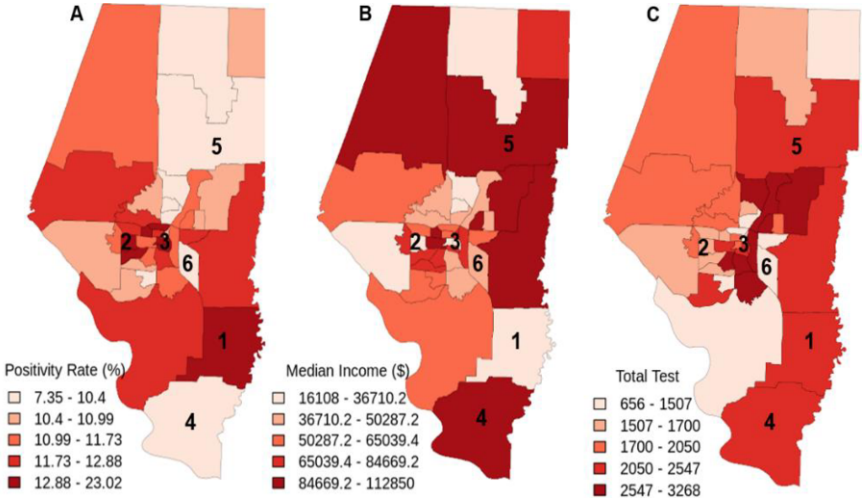
Figure 1 shows the scatter plot of the median income and positivity rate for Boone County, Missouri tracks. We can clearly notice that there are six outlier tracks (blue dots). The three outlier tracks shown on the top of the plot have exceptionally high positivity rates (higher than 19.5%) associated with lower median income. The three outlier tracks shown at the bottom of the plot have exceptionally low positivity rates (lower than 8%) with two tracks in the \$37K/yr and one track within the \$90K/yr areas.



**Figure 1.** Scatter plot for the median income and positivity rate. The plot clearly shows six outlier tracks (blue dots). The top three outlier tracks with exceptionally high positivity rates are associated with lower median income. The bottom three outlier tracks with exceptionally low positivity rates in the \$37K/yr and \$90K/yr areas.

Figure 2 shows three maps of Boone County Missouri, USA. Fig. 2(A) shows the Census tract-wise COVID-19 positivity rate, Fig. 2(B) shows the Census tract-wise median income, and Fig. 2(C) shows the Census tract-wise total number of COVID-19 tests in 2020. The tracks labeled 1–3 represent the highest positivity rates Fig. 2(A). Those three tracks are associated with lower median income Fig. 2(B), and a lower total number of COVID-19 tests Fig. 2(C). On the other hand, the tracks labeled 4–6 represent the lowest positivity rates Fig. 2(A). Those three tracks are associated with higher median income Fig. 2(B), and a higher total number of COVID-19 tests Fig. 2(C).

In summary, the maps clearly show that low-median income tracks labeled 1–3 have higher COVID-19 positivity rates, whereas the high-median income tracks labeled 4–6 are associated with lower COVID-19 positivity rates. Additionally, the Pearson correlation coefficient indicates an inverse relationship between the positivity rate and the median income.



**Figure 2.** Three maps of Boone County Missouri, USA showing (A) Census tract-wise COVID-19 positivity rate, (B) Census tract-wise median income, and (C) Census tract-wise total number of COVID-19 tests in 2020. The maps clearly show that the tracks labeled 1, 2, and 3 have high positivity rates and lower median income, whereas the tracks labeled 4, 5, and 6 have higher median income and lower positivity rates. Tracks 1-6 are the outliers identified in Fig. 1

#### 4. Discussion

The scatter plot in Fig. 1 has six outliers shown in blue dots. The upper three outlier tracks have an exceptionally high positivity rates (higher than 19.5%) associated with lower median income. The bottom three outlier tracks have exceptionally low positivity rates (lower than 8%) with two tracks in the \$37K/yr and one track within the \$90K/yr. First, in Fig. 2(A), we analyzed the positivity rate of the Boone County individuals by Census tract-wise. Fig. 2(A) clearly shows the geographic locations of the tracks with higher COVID-19 positivity rates (labels 1, 2, and 3) compared to the lower positivity rates (labels 4, 5, and 6). Second, in Fig. 2(B), we analyzed the median income of the Boone County individuals by Census tract-wise. We can clearly see from the Fig. 2(B) the geographic locations of the tracks with higher median income (labels 4, 5, and 6) compared to the lower median income (labels 1, 2, and 3). Finally, in Fig. 2(C), we analyzed the total number of COVID-19 tests of the Boone County individuals by Census tract-wise. In Fig. 2(C) the geographic spots where the total number of COVID-19 tests are higher (labels 4, 5, and 6) compared to the spots with a lower number of tests (labels 1, 2, and 3). From the analysis, we can conclude that tracks 1, 2, and 3 have higher positivity rates, lower median income, and a lower total number of tests. On the other hand, tracks 4, 5, and 6 have lower positivity rates, higher median income, and a higher number of total tests. Despite the interesting findings, there are several limitations in our study. First of all, the tests have been known to have the possibility of false positives and false negatives. Second, we do not have information about the individuals who did not test in Boone County or tested at some other clinics and facilities other than the University of Missouri hospital and clinics.

## 5. Conclusions

As COVID-19 is an ongoing source of threat, there will definitely be a continuous need for research studies and analyses to understand its behavior and to monitor the social determinants-of-health, demographic, and equitable distribution of life-saving resources for fighting the virus. From a social-determinants-of-health and geospatial perspective, our study findings support the hypotheses that low-income individuals have lower testing rates and higher positivity rates than high-income individuals in Boone County, Missouri. Therefore, more resources should be allocated to the most vulnerable income to address the COVID pandemic in an equitable manner. As such, our team is conducting additional studies that will include more geospatial analysis and remote sensing based on the zip code addresses and census blocks/tracts of the tested individuals in Boone County to study and define the associations and other features that could be related to the testing, positivity, and death rates for COVID.

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