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Geographic disparities in COVID-19 infections and deaths: The role of transportation

Darrell J. Gaskin a,*, Hossein Zare b, Benjo A. Delarmente c

a Johns Hopkins Bloomberg School of Public Health, William C. and Nancy F. Richardson Professor in Health Policy, Department of Health Policy and Management, Director of the Johns Hopkins Center for Health Disparities Solutions, 624 North Broadway, Hampton House, Suite #441, Baltimore, MD, 21205, United States
b Johns Hopkins Bloomberg School of Public Health, Assistant Scientist, Department of Health Policy and Management, Johns Hopkins Center for Health Disparities Solutions, Adjunct Associate Professor, University of Maryland Global Campus, Health Services Management, 624 North Broadway, Hampton House, Room #337, Baltimore, MD, 21205, United States
c Johns Hopkins Bloomberg School of Public Health, Department of Health Policy and Management, 525 North Wolf Street, Room #626, Baltimore, MD, 21205, United States

1. Introduction

The impact of the COVID-19 pandemic has varied substantially by geography (NYT, 2020). The nation first saw cases and deaths on the West Coast, specifically in San Francisco and the Seattle metropolitan areas, WA (Holshue et al., 2020). However, the pandemic quickly exploded in the Northeast where the New York metropolitan area became the epicenter of the disease. This persisted for a few months as Governors from Virginia to Massachusetts struggled to guide their states to flatten the infection and hospitalization curves and minimize the number of deaths. At the same time, other areas of the country seemed to be unaffected by COVID-19 with relatively few cases and deaths despite being major population centers. With the exception of pockets of outbreaks, large areas of some states were seemingly untouched by COVID-19. Even within states with large outbreaks, the number of cases and deaths were not evenly distributed across the state. For example, downstate New York was hit much harder that upstate New York (Thomas, 2020). Other major cities, like New Orleans, Chicago and Detroit stood out like outliers in their respective regions.

To prevent the introduction and spread of COVID-19 in the United States, the US Government issued a series of travel arrival restrictions (DHS, 2020a). Travelers from selected countries were subject to enhanced arrival protocols. Specifically, travelers from these countries were screened for symptoms of COVID-19. These travelers were restricted to landing at selected airports where enhanced public health measures were in place to identify travelers who exhibited overt signs of illness. In addition, carriers were instructed to report ill travelers to appropriate public health officials for evaluation. On January 17, 2020, travelers from Wuhan, China were subjected to enhanced health screening at three US airports: San Francisco (SFO), New York (JFK) and Los Angeles (LAX). On February 2, 2020, this travel restriction was expanded to include all flights carrying persons who have recently traveled from or were otherwise present in the People’s Republic of China (CDC, 2020a). These travelers were only allowed to land at one of the eleven airports designated by the Department of Homeland Security where enhanced public health services and protocols were being
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states. Most counties have governmental units, whose powers and functions vary from state to state (Census, 2020). County governments have powers and functions that vary from state to state (Census, 2020). There are 3,141 counties in the 50 States and the District of Columbia. On average a county has 104,000 population which varies by urban, suburban and rural areas. In some urban counties in populous states like California, New York and Texas have millions of residents. However, in these same states, there are rural counties with fewer than 25,000 residents. About 89% of counties have some kind of airport, but if we consider major airports only 25% of counties are near a large or mid-size airport.

This study used publicly available data from the Johns Hopkins University (JHU) database (JHU, 2020). This data set provides the daily numbers of confirmed COVID-19 cases and deaths at the county level since January 21, 2020, which is the first day for which COVID-19 data is available from the JHU database. To understand the association between transportation and COVID-19 exposure we merged JHU’s data with the Bureau of Transportation Statistics’ Airports database (BTS, 2020), Amtrak Station database (BTS, 2020), Census-2018 commuter data, and the American Community Survey-2018 (Census, 2018). The Airports database is a geographic point database of official operational aerodromes in the United States and U.S. Territories that includes the county in which each aerodrome is located (ACS, 2020).

In addition to restricting where travelers could enter the country, the US Government issued several Presidential proclamations restricting who could enter the country (CDC, 2020c). However, these proclamations had a number of exceptions including US citizens, permanent residents, and persons related to US citizens. These persons could only enter the country at one of selected 15 airports (Lake, 2020). While these airports were supposed to screen travelers, many travelers entered the country without being screened (Kanno-Youngs, 2020).

These two travel restriction policies meant to prevent the introduction and spread of COVID-19 are probably responsible for the geographic disparities in COVID-19 cases and deaths. The policies may have effectively identified and isolated travelers with symptoms, but they also funneled asymptomatic carriers of the COVID-19 to selected airports; and then allowed these asymptomatic travelers to travel to other airports via connecting flights. This funnelling of symptomatic and asymptomatic travelers exposed persons who work at these airports to COVID-19. Unfortunately, airport workers were not provided personal protective equipment and the airports were not routine sanitize for possible contamination. This lack of precaution may have increased the risk of community spread of COVID-19 among residents who lived near these airports.

Consequently, early in the pandemic, persons who were in close proximity to major airports would be at greater risk of infection and mortality. To explore this hypothesis, this study estimates the associations between the proximity to airports and train stations, and the reliance on public transportation to the number of COVID-19 cases and deaths. We hypothesize that because the virus spreads to communities in part through air travelers and related transportation systems, communities closest to transportation hubs will be affected first. Also, these communities will have more cases and deaths during the first phase of the pandemic.

2. Data and methods

2.1. Data and sample size

This is a county level analysis that includes 3,132 counties in the US. In the United States, counties are the primary local legal division in most states. Most counties have governmental units, whose powers and functions vary from state to state (Census, 2020). County governments are typically responsible for locally-based public services including education, police, fire, zoning and public health. There are 3,141 counties and county equivalents in the 50 States and the District of Columbia. On average a county has 104,000 population which varies by urban, suburban and rural areas. In some urban counties in populous states like California, New York and Texas have millions of residents. However, in these same states, there are rural counties with fewer than 25,000 residents. About 89% of counties have some kind of airport, but if we consider major airports only 25% of counties are near a large or mid-size airport.

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2.1.1. Variable measurement

The study has two main dependent variables: The number of confirmed COVID-19 1) cases and 2) deaths at the county level between January 21, 2020 and August 18, 2020 in the US.

2.1.2. Independent variables

The first set of main independent variables includes distance to the nearest airport, airport volume, number of airports, number of train stations, and use of public transportation at the county level. We also included a dummy variable to identify counties which either contain or are within 25 miles from any of the 13 major airports where incoming international travel was directed. We used the latitudinal and longitudinal geographic points of airports and counties and computed the distance between the centroid of each county and the nearest airport in miles. We then created a categorical variable to classify each county as being located within 25 miles, between 25 and 50 miles, and greater than 50 miles away. We used the number of passengers for each airport in 2019 to categorize them into no volume (no airport), middle volume (1–1.07 million passengers), and high volume (1.07 million –39.9 million passengers) airports. To measure the availability of air and rail transportation, we counted the number of airports and Amtrak intercity train stations in each county (BTS, 2020). Finally, to measure the accessibility of other forms of transportation, we included county-level data on the commute traveling time and the percentage of people who drive alone, carpooled, used public transportation, walked, and any other forms of transportation.

We also used data on the racial composition in terms of percentages of White Non-Hispanic (WNH), Black NH, Hawaiian NH, Asian NH, Native American NH and Hispanic in each county to control for racial disparities in outcomes as reported in many recent publications (Aldridge et al., 2020; Tai et al., 2020; Rodriguez-Díaz et al., 2020).

To control for population and population density, we included the county’s population, the number of people per square kilometer, and the average number of people in each household. We also control for the age distribution of population at the county level. Finally, we controlled for the percentage of poverty at the county level.

2.2. Statistical analysis

We used descriptive, bivariate, and multivariate analyses to address the associations between COVID-19 cases and death rates and proximity to and size of airports, train stations, and public transportation.

For the main analysis we ran two sets of negative binomial regressions (NBREG) (STATA, 2018) to determine the associations between COVID-19 cases and death rates and proximity to and size of airports, train stations, and public transportation. Negative binomial regression models use the number of occurrences (counts) of an event
when the event has extra-Poisson variation, to measure number of cases and deaths that accumulated over time (STATA, 2018). In the negative binomial regression, the measure of effect is reported as incidence rate ratios which is the ratio of the number of incident events of the expressed category to the number of incident events in the base category and represents the impact of an independent variable in terms of a percentage change.

In our main models we controlled for racial/ethnic composition, population, population density, household density, and poverty status at the county level. Errors were clustered at the state level.

We also ran two sets of Cox regressions to explore the time dimension of the relationship between COVID-19 outcomes and transportation. The Cox regression is a series of comparisons of those subjects who fail to those subjects at risk of failing (STATA, 2020). In the Cox regression, the measure of effect is the hazard ratio which represents the risk of failure (i.e., the risk or probability of the event of interest occurring) for observations that survive to a certain time point. The Cox regression model requires that covariates satisfy the proportional hazards assumption, i.e., that the effect of a covariate and the ratio of hazards between two participants is constant across time. Graphically, Figs. 1 and 2 imply that our data satisfies this assumption because the survival curves have similar shapes and do not cross across time (Basu et al., 2004; Hess, 1995). In this analysis we used the Cox regression to estimate the effect of a county’s proximity to an airport and the likelihood of getting its first case. Survival in this context implies that a county has yet to receive its first case or death (i.e., the events of interest).

In these regressions, we define failure time to be the number of days since January 21, 2020 to either the first case or first death depending on the dependent variable in the model. We similarly control for racial/ethnic composition, population and household density, and poverty status and cluster errors at the state level. Counties without any cases were censored. We used Stata (version 15) for data management and analysis.

2.3. Sensitivity analysis

We conducted three sensitivity analyses. First, to ensure that our findings are not just the results of the outbreaks in New York and California, we re-ran the analyses excluding these two major states. The findings were very similar to the original models (See appendices A and B.).

In the second sensitivity analysis we used distance and volume as continuous variables. We found that counties further from an airport or with a lower volume of air travelers had fewer cases and deaths. (See appendix C.)

For the final sensitivity analysis, we ran the original model and censored the data at 113 days (i.e., the midpoint) to learn how associations between COVID-19 cases and death rates and proximity to airports, trains stations, and public transportation changed between the first and the second waves of the outbreak. (See appendices D.)

3. Results

3.1. Cases and deaths

COVID-19 cases and deaths were higher for counties which are closer to an airport. In addition, the numbers of COVID-19 cases and deaths increased as the volume of passengers increased (See Table 1). The numbers of deaths and cases were positively correlated with the number of airports, number of train stations, the percentage of adults using public transportation, and the length of commuting time (See Table 2).

We estimated negative binomial regression models to assess the spatial impact of proximity, size and use of the airports, trains, and buses on the extent of the COVID-19 outbreak and report incidence rate ratios. The number of COVID-19 cases and deaths increased with proximity to an airport. Counties closest to an airport (i.e., within 25 miles) had 1.392 (CI: 1.185–1.636) times the rate of COVID-19 cases compared to counties that were more than 50 miles from an airport during the first 215 days of the pandemic. Counties within 25 miles of an airport had 1.545 (CI: 1.234–1.934) times the rate of COVID-19 death compared to counties that were more than 50 miles from an airport during the study period. The volume of passengers coming through an airport was associated with the numbers of COVID-19 cases and deaths. Counties with medium volume airports had 1.284 (CI: 1.058–1.557) times the rate of

![Fig. 1. Survival Curves of First COVID-19 Case and First COVID-19 Death relative to Distance to Major Airports.](image-url)
COVID-19 cases and counties with high volume airports had 0.449 (CI: 0.249–0.809) times the rate of COVID-19 cases and 0.366 (CI: 0.177–0.754) times the rate of COVID-19 deaths compared to the counties that had no airport.

Using public transportation and driving alone to work were associated with higher rates of COVID-19 cases and deaths. A one percentage point increase in the county percentage of adults using public transportation is associated with an increase of 1.057 (CI: 1.019–1.095) times the rate of COVID-19 cases and 1.096 (CI: 1.048–1.147) times the rate of COVID-19 deaths relative to working from home. The percentage of county residents driving to work was associated higher rates of COVID cases (IRR = 1.030 CI: 1.024–1.036) and deaths (IRR = 1.033 CI: 1.025–1.041), respectively (See Table 3).

We estimated a Cox regression to determine how the transportation system was associated with how quickly the COVID-19 virus moved. We calculated the time until the first case and the time until the first death in the county (See Fig. 1). Counties within 25 miles of an airport had a 70.1 percent greater risk of having a COVID-19 case and 33.7 percent greater risk of having a COVID-19 death when compared to counties over 50 miles from an airport. The risk of having COVID cases was greater for counties with a high volume airport compared to counties with no airport. The number of airports increased the hazard of having a COVID-19 death. The proportion of residents using public transportation increased the risk of cases and deaths while carpooling and walking to work decreased the risk of cases.

To better illustrate the impact of the proximity to an airport and the volume of passengers using the airport we graphed the survival curves for these variables. At 56 days, 67.4% of counties within 25 miles of the airport did not have a COVID-19 case, compared to 88.6% of counties between 25 and 50 miles of an airport, and 91.9% of counties greater than 50 miles of an airport. At 126 days, these percentages fell to 1.1%, 5.7% and 65.1%, respectively (See Fig. 1, panel A).

At 70 days, 69.8% of counties within 25 miles of an airport did not have a COVID-19 death, compared to 89.1% of counties between 25 and 50 miles of an airport, and 91.7% of counties greater than 50 miles of an airport. At 126 days, these percentages declined to 27.5%, 49.6%, and 65.1%, respectively. (See Fig. 1, panel A). We see a similar pattern for COVID-19 deaths (See Fig. 1, panel B).

### Table 1
Distribution of COVID-19 cases and deaths by proximity to the airport and volume of passengers travel to the airport.

| Distance to airport | Number of COVID-19 Cases (in county) | Number of COVID-19 Deaths (in county) |
|---------------------|--------------------------------------|--------------------------------------|
|                     | N        | Mean (SD) | N        | Mean (SD) |
| < 25 Miles          | 1124     | 3684 (13,129) | 1124     | 124 (780) |
| 25-50 Miles         | 1281     | 799 (4381)   | 1281     | 19 (107)  |
| > 50 Miles          | 727      | 469 (267)    | 727      | 11 (47)   |

| Volume of passengers | Number of COVID-19 Cases (in county) | Number of COVID-19 Deaths (in county) |
|----------------------|--------------------------------------|--------------------------------------|
| No volume            | 2548                                 | 681 (1940)                           |
| Medium volume        | 529                                  | 3310 (5477)                          |
| High volume          | 55                                   | 36711 (49245)                        |

### Table 2
Associations of COVID-19 cases and death rates and proximity to airports, trains stations and public transportation.

| Number of Airport and Train Stations | Number of COVID-19 Cases in County | Number of COVID-19 Deaths in County |
|--------------------------------------|------------------------------------|-------------------------------------|
| Num. of Airport at County            | 0.320***                           | 0.128***                           |
| Num. of Train Station at County      | 0.450***                           | 0.208***                           |
| Commute                              |                                    |                                    |
| Drove alone                          | 0.018                              | –0.027                             |
| Carpoled                             | 0.016                              | –0.024                             |
| Public trans                         | 0.368***                           | 0.466***                           |
| Walked                               | 0.044***                           | 0.109***                           |
| Other                                | 0.088***                           | 0.078***                           |
| work from home                       | 0.060***                           | 0.039                              |
| Commute Traveling time               | 0.123***                           | 0.089***                           |
| County population                    | 0.837***                           | 0.196***                           |
| Population Density                   | 0.151***                           | 0.452***                           |

**Sources:** JHU-COVID-19 Data (2020 August 21), Airport and Amtrak Station Data (2019) and ACS Data (2018).
Table 3

Associations of COVID-19 cases and death rates and proximity to airports, trains stations and public transportation.

| Table 3 |
| --- |
| **Number of COVID-19 Cases in County** |
| **Number of COVID-19 Deaths in County** |
| **Time to First COVID-19 Case in County** |
| **Time to First COVID-19 Death in County** |
| IRR | CI-95 | IRR | CI-95 | HR | CI-95 | HR | CI-95 |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Distance to airport: Ref: >50 miles |
| 25-50 Miles to airport |
| 25-500 Miles to airport |
| Num. of airport |
| Volume of Airport: Ref: No volume |
| Medium volume |
| High volume |
| Num. of train stations |
| Being in counties or nearby counties with major 13 airports |
| Being an international airport |
| Commute: Ref: Work from home |
| Drove alone |
| Carpoled |
| Public trans |
| Walked |
| Other |
| Commute Traveling time |
| County Population |
| Total county population (/1000) |
| Population density (/100) |
| N |
| 3132 | 3132 | 3084 | 3084 |

*p < 0.05, **p < 0.01, ***p < 0.001.

Sources: JHU-COVID-19 Data (Updated August 21, 2020), Airport and Amtrak Station Data (2019), ACS Data (2018)

Notes:
1) All models have been controlled by race/ethnicity groups, population density, number of people at household, age categories and percent of poverty.
2) We have clustered errors by state to capture states policies and interventions.
3) We have clustered errors by state to capture states policies and interventions.
4) All models have been controlled by race/ethnicity groups, population density, number of people at household, age categories and percent of poverty.

The estimated associations of transportation system factors and COVID-19 outcomes were robust and independent of other community level factors. Our analysis shows that COVID-19 outcomes were related to other community level factors such as racial composition, household size and population density. We found that a percentage point increase in residents who are Non-Hispanic Native Americans is associated with 1.021 (CI:1.005–1.037) times higher the rate of COVID-19 cases. Similarly, a percentage point increase in residents who are Black Non-Hispanic and Hispanic is associated with 1.037 (CI:1.021–1.053) times higher the rate of COVID-19 cases. A one-person increase in household size is associated with an increase of 2.538 (CI:3.307–3.854) times the rate of COVID-19 cases and 2.535 (CI:2.371–2.707) times the rate of COVID-19 deaths relative to working from home. Population density in the community is not found to be associated with the number of cases but is positively associated with the time to the first COVID-19 case and death.

3.2. Impact of other factors

The estimated associations of transportation system factors and COVID-19 outcomes were robust and independent of other community level factors. Our analysis shows that COVID-19 outcomes were related to other community level factors such as racial composition, household size and population density. We found that a percentage point increase in residents who are Non-Hispanic Native Americans is associated with 1.021 (CI:1.005–1.037) times higher the rate of COVID-19 cases. Similarly, a percentage point increase in residents who are Black Non-Hispanic and Hispanic is associated with 1.037 (CI:1.021–1.053) times higher the rate of COVID-19 cases, respectively. Household size is a major predictor. A one-person increase in household size is associated with an increase of 2.538 (CI:3.307–3.854) times the rate of COVID-19 cases and 2.535 (CI:2.371–2.707) times the rate of COVID-19 deaths relative to working from home. Population density in the community is not found to be associated with the number of cases but is positively associated with the time to the first COVID-19 case and death. (See Table 4).

3.3. Limitations

This study has a few limitations. One, it is subject to the ecological fallacy. There could be some confounding factors correlated with airports and transportation systems and the number of COVID-19 cases and deaths. We attempt to control for known demographic and economic
We have clustered errors by state to capture states policies and interventions.

Our findings are consistent with recent research by Zhang and colleagues. They showed that frequencies of air flights and high-speed train services out of Wuhan, China were positively associated with the number of COVID-19 cases in the destination cities. They also found that the distances of cities near major airports. Our results imply that public health resources for screening, detection, and containment should be initially concentrated in communities around airports of international entry in the early stages of a pandemic. Furthermore, it may also be worthwhile to consider redirecting incoming international air travel to a small number of airports in the country that are farther from population centers and in lower population density areas. Examples would include the use of London Gatwick (LGT) instead of London Heathrow (LHR) in the United Kingdom or the use of Tokyo-Narita (NRT) instead of Tokyo-Haneda (HND) airports in Japan.

Our findings are consistent with recent research by Zhang and colleagues. They showed that frequencies of air flights and high-speed train services out of Wuhan, China were positively associated with the number of COVID-19 cases in the destination cities. They also found that the distance of a city from Wuhan is negatively associated with number of COVID-19 cases in the destination cities. They also found that the distances of cities near major airports. Our results imply that public health resources for screening, detection, and containment should be initially concentrated in communities around airports of international entry in the early stages of a pandemic. Furthermore, it may also be worthwhile to consider redirecting incoming international air travel to a small number of airports in the country that are farther from population centers and in lower population density areas. Examples would include the use of London Gatwick (LGT) instead of London Heathrow (LHR) in the United Kingdom or the use of Tokyo-Narita (NRT) instead of Tokyo-Haneda (HND) airports in Japan.

Factors in our models that are associated with the disease. The numbers of COVID-19 cases and deaths are most likely undercounted. Testing in most counties was limited to those who had symptoms and presented in a healthcare facility. There may be many undetected cases in counties which would affect our count of cases and measure of time to the first case. However, this is probably not correlated with proximity to or size of the airport. Future research should look at patient-level clinical data to determine the association between air travel and COVID-19 cases and deaths.

### 4. Discussion

Proximity to an airport was an important risk factor to COVID-19 infections and death. While efforts to restrict travel were meant to prevent the introduction and spread of the virus, this study suggests that it may have amplified the risks for persons who live near airports. Previous efforts to identify travelers with symptoms and the inability to identify asymptomatic travelers may have heightened the risk for residents of cities near major airports. Our results imply that public health resources for screening, detection, and containment should be initially concentrated in communities around airports of international entry in the early stages of a pandemic. Furthermore, it may also be worthwhile to consider redirecting incoming international air travel to a small number of airports in the country that are farther from population centers and in lower population density areas. Examples would include the use of London Gatwick (LGT) instead of London Heathrow (LHR) in the United Kingdom or the use of Tokyo-Narita (NRT) instead of Tokyo-Haneda (HND) airports in Japan.

As international travel begins to resume, some countries (Lieberman, 2020; TheNational, 2020) have required passengers to show a negative COVID-19 test that was performed recently, usually in the past 72 h, prior to admission at their ports of entry. Other countries have started offering COVID-19 testing upon arrival at the airport (Lieberman, 2020). Some airlines have responded (Craig, 2020; Lieberman, 2020) by requiring passengers to present a recent negative COVID-19 test prior to boarding their aircraft. Which strategy is most effective in preventing the entry and spread of COVID-19 remains to be seen. Given the demonstrated role of airports in the spread of COVID-19, strategies such as these may prove to be crucial in the prevention of COVID-19 transmission. Developing standards when caring for and transporting patients with suspected or confirmed infection with SARS-CoV-2 (AMPA, 2020), and specific training for the air ambulance aircrew (Martin, 2020) are other strategies to be considered. Using these strategies in domestic airports may also be worth considering especially for larger countries who wish to contain outbreaks in certain domestic regions.

While the International Air Transport Association (IATA) has released guidelines on the criteria for the use of COVID-19 testing in the air travel process (IATA, 2020), these are primarily non-binding recommendations. Apart from the logistics of screening, testing, and follow-up of passengers, another key issue is the costs involved in testing. The IATA has supported the World Health Organization’s (WHO) recommendation that governments bear the cost for mandatory testing or offer tests at cost price for voluntary testing. Whether
5. Conclusions

Using descriptive, bivariate, and multivariate analyses, we explored the associations between COVID-19 cases and death rates and proximity to and size of airports, train stations, and public transportation. This study highlights the need for robust policies and procedures to detect infected travelers and conduct effective contact tracing to prevent the spread of the future waves of the COVID-19. Otherwise, transportation workers and residents of communities near airports and transportation hubs will be at risk for future outbreaks. Future studies should look at patient level data to assess this association between air travelers, transportation employees and exposure the COVID-19.

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CRediT authorship contribution statement

Darrell J. Gaskin: Conceptualization, Funding acquisition, Methodology, Validation, Writing - original draft, Writing - review & editing.

Hossein Zare: Conceptualization, Data curation, Formal analysis, Methodology, Software, Validation, Writing - original draft, Writing - review & editing.

Benjo A. Delarmente: Methodology, Validation, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The Author(s) declare(s) that there is no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2020.12.001.

Appendix A. Associations of COVID-19 cases and death rates and proximity to airports, trains stations and public transportation (Excluding New York and California)

| Volume of Airport Ref: No volume | Number of COVID-19 Cases in County | Number of COVID-19 Deaths in County | Time to First COVID-19 Case in County | Time to First COVID-19 Death in County |
|----------------------------------|-----------------------------------|-----------------------------------|------------------------------------|--------------------------------------|
| Medium volume                    | IRR CI-95                          | IRR CI-95                          | HR CI-95                           | HR CI-95                             |
| High volume                      | 1.215*** [1.005-1.469]             | 1.233 [0.904-1.681]               | 1.354** [1.109-1.654]              | 1.083 [0.842-1.393]                 |
| Num. of train stations           | 1.096 [0.960-1.252]                | 1.266** [1.059-1.512]             | 1.335*** [1.174-1.518]             | 1.235** [1.067-1.429]               |
| Being in counties or nearby counties with major 13 Airports | 0.537** [0.339-0.851] | 0.467** [0.248-0.877] | 1.336 [0.637-2.603] | 0.860 [0.384-1.924] |
| Being an international airport  | 1.108 [0.905-1.357]                | 1.128 [0.875-1.454]               | 1.516*** [1.203-1.911]             | 1.487** [1.171-1.889]               |

(continued on next page)
Negative Binomial Regression

|                          | Number of COVID-19 Cases in County | Number of COVID-19 Deaths in County | Cox Regression |
|--------------------------|-------------------------------------|-------------------------------------|----------------|
|                          | IRR       | CI-95     | IRR       | CI-95     | HR       | CI-95     | HR       | CI-95     |
| Walked                  | 0.899***  | [0.864]   | 0.890***  | [0.852]   | 0.962**  | [0.936]   | 0.938**  | [0.902]   |
|                         | [0.935]   |           | [0.930]   |           | [0.988]  |           | [0.976]  |           |
| Other                   | 1.113***  | [1.049]   | 1.052     | [0.976]   | 1.018    | [0.973]   | 1.013    | [0.968]   |
|                         | [1.180]   |           | [1.134]   |           | [1.065]  |           | [1.060]  |           |
| Commute Traveling time  | 0.996     | [0.977]   | 1.018     | [0.991]   | 1.021**  | [1.007]   | 1.012    | [0.998]   |
|                         | [1.015]   |           | [1.045]   |           | [1.036]  |           | [1.026]  |           |
| County Population       |          |           |          |           |          |           |          |           |
| Total county population (/1000) | 1.004*** | [1.003]   | 1.005***  | [1.003]   | 1.002*** | [1.001]   | 1.001*** | [1.001]   |
|                         | [1.006]   |           | [1.006]   |           | [1.002]  |           | [1.001]  |           |
| Population density (/100) | 0.998***  | [0.997]   | 0.997***  | [0.996]   | 1.001*** | [1.001]   | 1.001*** | [1.001]   |
|                         | [0.999]   |           | [0.998]   |           | [1.002]  |           | [1.002]  |           |

*p < 0.05, **p < 0.01, ***p < 0.001.

Sources: JHU-COVID-19 Data (Updated August 21, 2020), Airport and Amtrak Station Data (2019), ACS Data (2018)

Notes:
1) All models have been controlled by race/ethnicity groups, population density, number of people at household, age categories and percent of poverty.
2) We have clustered errors by state to capture states policies and interventions.
3) New York and California excluded from the analysis.

Appendix B. Survival Curves of First COVID-19 Case and First COVID-19 Death relative to Distance to Major Airports and Volume of Airports (Excluding New York and California)
Appendix C. Associations of COVID-19 cases and death rates and proximity to airports, trains stations and public transportation

|                          | Negative Binomial Regression | Cox Regression |
|--------------------------|------------------------------|---------------|
|                          | Number of COVID-19 Cases in County | Number of COVID-19 Deaths in County | Time to First COVID-19 Cases in County | Time to First COVID-19 Death in County |
|                          | IRR   | CI-95    | IRR   | CI-95    | HR   | CI-95    | HR   | CI-95    |
| Distance to airport in miles | 0.998*** [0.998]- [0.999] | 0.998*** [0.996]- [0.999] | 0.997*** [0.996]- [0.998] | 0.999*** [0.998]- [0.999] |
| Number of airport         | 1.029*** [1.016]- [1.043] | 1.034** [1.013]- [1.056] | 1.014 [0.994]- [1.034] | 1.036*** [1.024]- [1.049] |
| Size of airport (volume passenger/1,000,000) | 0.994 [0.975]- [1.014] | 0.983 [0.962]- [1.005] | 0.981 [0.952]- [1.011] | 0.988 [0.949]- [1.028] |
| Num. of train stations    | 0.967 [0.844]- [1.109] | 1.017 [0.797]- [1.299] | 1.058 [0.794]- [1.179] | 0.996 [0.944]- [1.051] |
| Being in counties or nearby counties with major 13 Airports | 0.521* [0.307]- [0.884] | 0.592 [0.275]- [1.275] | 1.252 [0.623]- [2.515] | 1.073 [0.640]- [1.801] |
| Being an international airport | 1.207 [0.948]- [1.536] | 1.176 [0.890]- [1.554] | 2.066*** [1.637]- [2.607] | 1.631*** [1.264]- [2.105] |
| Commute Ref: Work from home | 1.031*** [1.026]- [1.037] | 1.035*** [1.027]- [1.042] | 1.013*** [1.008]- [1.018] | 1.009*** [1.005]- [1.013] |
| Drove alone               | 1.005 [0.985]- [1.025] | 0.979 [0.948]- [1.010] | 0.986 [0.971]- [1.003] | 0.988 [0.972]- [1.004] |
| Carpoled                  | 1.058* [1.011]- [1.107] | 1.107*** [1.049]- [1.132] | 1.086*** [1.041]- [1.136] | 1.108*** [1.081]- [1.169] |
| Public trans              | 0.902*** [0.870]- [0.935] | 0.897*** [0.858]- [0.938] | 0.972 [0.943]- [1.002] | 0.935*** [0.899]- [0.973] |
| Walked                    | 1.108*** [1.047]- [1.172] | 1.051 [0.973]- [1.135] | 1.019 [0.975]- [1.065] | 1.015 [0.970]- [1.062] |
| Other                     | 0.994 [0.976]- [1.012] | 1.011 [0.987]- [1.036] | 1.016* [1.002]- [1.030] | 1.009 [0.985]- [1.023] |
| Commute Traveling time    | 1.003*** [1.002]- [1.005] | 1.004*** [1.002]- [1.005] | 1.001*** [1.001]- [1.002] | 1.001*** [1.000]- [1.001] |
| County Population Total county population (/1000) | 0.999 [0.998]- [1.001] | 0.998 [0.997]- [1.000] | 1.456 [0.985]- [1.256] | 0.358* [0.135]- [0.954] |
| Population density (/100) | 1.779** [1.246]- [2.542] | 1.456 [0.985]- [2.152] | (continued on next page) |

*p < 0.05, **p < 0.01, ***p < 0.001.

Sources: JHU-COVID-19 Data (Updated August 21, 2020), Airport and Amtrak Station Data (2019), ACS Data (2018)

Notes:
1) All models have been controlled by race/ethnicity groups, population density, number of people at household, age categories and percent of poverty.
2) We have clustered errors by state to capture states policies and interventions.

Appendix D. Associations of COVID-19 cases and death rates and proximity to airports, trains stations and public transportation in day 113

|                          | Negative Binomial Regression |
|--------------------------|------------------------------|
|                          | Number of COVID-19 Cases in County | Number of COVID-19 Deaths in County |
|                          | IRR   | CI-95    | IRR   | CI-95    |
| Distance to airport Ref: >50 miles | 1.416** [1.108]- [1.810] | 1.657*** [1.273]- [2.156] |
| 25- Miles to airport     | 1.210 [0.994]- [1.472] | 1.210 [0.985]- [1.486] |
| 25-50 Miles to airport   | 0.991 [0.957]- [1.025] | 0.981 [0.943]- [1.021] |
| Volume of Airport Ref: No volume | 1.779** [1.246]- [2.542] | 1.456 [0.985]- [2.152] |
| Medium volume            | 0.562 [0.261]- [1.208] | 0.358* [0.135]- [0.954] |
| High volume              | (continued on next page) |
## Negative Binomial Regression

|                                | Number of COVID-19 Cases in County | Number of COVID-19 Deaths in County |
|--------------------------------|-----------------------------------|-------------------------------------|
|                                | IRR                  | CI-95                | IRR                  | CI-95                |
| Num. of train stations         | 0.985                | [0.783]-[1.239]      | 1.050                | [0.740]-[1.491]      |
| Being in counties or nearby counties with major 13 Airports | 0.477                | [0.223]-[1.020]      | 0.462                | [0.165]-[1.290]      |
| Being an international airport | 1.197                | [0.852]-[1.683]      | 1.354                | [0.902]-[2.032]      |
| Commute                        |                      |                      |                      |
| Drove alone                    | 1.024***             | [1.016]-[1.033]      | 1.029***             | [1.019]-[1.040]      |
| Carooled                       | 1.020                | [0.979]-[1.063]      | 0.986                | [0.943]-[1.032]      |
| Public trans                   | 1.155***             | [1.063]-[1.255]      | 1.144**              | [1.043]-[1.255]      |
| Walked                         | 0.917**              | [0.869]-[0.969]      | 0.952                | [0.892]-[1.016]      |
| Other                          | 1.011                | [0.925]-[1.105]      | 1.051                | [0.948]-[1.165]      |
| Commute Traveling time         | 0.994                | [0.968]-[1.022]      | 1.005                | [0.970]-[1.043]      |
| County Population              |                      |                      |                      |
| Total county population (/1000)| 1.003***             | [1.002]-[1.005]      | 1.004***             | [1.002]-[1.006]      |
| Population density (/100)      | 0.998                | [0.996]-[1.000]      | 0.997*               | [0.995]-[1.000]      |

*p < 0.05, **p < 0.01, ***p < 0.001.

**Sources:** JHU-COVID-19 Data (Updated May 5, 2020), Airport and Amtrak Station Data (2019), ACS Data (2018)

**Notes:**
1) All models have been controlled by race/ethnicity groups, population, population density, number of people at household, age categories and percent of poverty.
2) We have clustered errors by state to capture states policies and interventions.

### Appendix E. Associations of COVID-19 Cases and Death and Distance to Airport

Note 1: Outliers have excluded for the graph.
Appendix F. Associations of COVID-19 Cases and Death Rates and Distance to Airport

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