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Investigating the Effects of Meteorological Parameters on COVID-19: Case Study of New Jersey, United States

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ABSTRACT

This research aims to explore the correlation between meteorological parameters and COVID-19 pandemic in New Jersey, United States. The authors employ extensive correlation analysis including Pearson correlation, Spearman correlation, Kendall’s rank correlation and auto regressive distributed lag (ARDL) to check the effects of meteorological parameters on the COVID new cases of New Jersey. In doing so, PM 2.5, air quality index, temperature (°C), humidity (%), health security index, human development index, and population density are considered as crucial meteorological and non-meteorological factors. This research work used the maximum available data of all variables from 1st March to 7th July 2020. Among the weather indicators, temperature (°C) was found to have a negative correlation, while humidity and air quality highlighted a positive correlation with daily new cases of COVID-19 in New Jersey. The empirical findings illustrated that there is a strong positive association of lagged humidity, air quality, PM 2.5, and previous infections with daily new cases. Similarly, the ARDL findings suggest that air quality, humidity and infections have lagged effects with the COVID-19 spread across New Jersey. The empirical conclusions of this research might serve as a key input to mitigate the rapid spread of COVID-19 across the United States.

1. Introduction

A new type of pneumonia emerged in Wuhan, China at the end of 2019. It was named as coronavirus disease (COVID-19), which officially announced as a global pandemic on 20 February 2020 by World Health Organization (WHO), (Shahzad et al., 2020; Shakoor et al., 2020). This disease symptoms include fever, cough, and acute respiratory disorders like dyspnea, which can lead to pneumonia, acute respiratory syndrome, renal failure, and even death (Hemida and Ba Abduallah, 2020). According to the WHO data, a total of 23 million cases were confirmed with more 808,000 deaths all over the world until 23 August 2020 (WHO, 2020). The deadliest COVID-19 disease increases the risk of infection through the human to human contact (Wang et al. 2020; Chen et al., 2020) and can be able to transmit through the air (Mostafa et al. 2020). The recent literature examined that the contagion of viruses may be affected by several factors such as climatic conditions like temperature and humidity, air pollution, population density, use of masks, and quality of medical care (Iqbal et al., 2020; Kraemer et al., 2020).

Environmental factors influence the transmission rate and survival of epidemiological infectious diseases like coronavirus. Recently, some epidemiological and laboratory research work suggested that the temperature, air quality, and population density are the main outbreak factors for coronavirus disease (Dalziel et al., 2018; Guo et al., 2020; Ma et al., 2020; Tan et al., 2005; Tosepu et al., 2020; Yuan et al., 2006; Xie and Zhu, 2020). In the same line, previous studies reported that the climate and weather conditions affected the spatial distribution and

Abbreviations: COVID-19, Corona Virus Disease 2019; Aqi, Air Quality; US, United States; ARDL, Auto-regressive Distributed Lags; SARS-CoV-2, Corona Virus Disease 2019.

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The meteorological and weather parameters could influence the infection rate and disease spread via various channels. For instance, the temperature level, humidity, or air quality might increase or decrease transmission rate, risk, and survival period of the virus in the air or on surfaces. Hence, the significance and sensitivity analysis of meteorological parameters on coronavirus’s infection rate is essential to ensure the survival and safety of humans (Shahzad et al., 2020; Jahan-giri et al. 2020).

In this regard, it was reported that some meteorological variables (temperature, humidity, and air) involve in contagion and affect the survival of the SARS virus (Yuan et al., 2006). Climate variables can also be a direct cause of biological interactions between SARS-CoV and humans. Such reasons and factors motivate the researcher to consider the related environmental factors as determinants of COVID-19. To this end, our study joins the strand of recent studies Ma et al., (2020); Shi et al., (2020); Sooryanarain and Elankumaran, 2015).

Furthermore, recent studies reported that COVID-19 correlates with extreme temperature and weather conditions (Oliveiros et al., 2020; Wang et al., 2020; Ahmadi et al., 2020). The retrospective studies show that the outbreak of severe acute respiratory syndrome (SARS) in 2003, in Guangdong ended with an increase in temperature (Wallis ve Nerlich, 2005). Temperature and its variations were documented to be effective on the spread of SARS (Tan, 2005). Some clinical examinations suggested that COVID-19 patients are probably similar to those of SARS and MERS (Fareed et al., 2020; Shi et al., 2020; Xie and Zhu (2020) and Chen et al. (2020).

2. Environmental Quality in New Jersey

For the case of the United States, the COVID-19 disease has had high infection and transmission rate since its outbreak across all the states of country. In USA, the situation was very strange and surprising, unlike the neighboring countries (Canada, Mexico) or a few other developed nations. Among the states of the United States, New York, New Jersey, California, Florida and taxes are highly affected with higher transmission rate and fatalities due to COVID-19 spread. Up till July, the New Jersey state has witnessed more than 16000 deaths from COVID-19, while the infections and deaths are continuously increasing. New Jersey’s air continues to be among the most polluted in the US, with a large swath of the state receiving failing grades for smog. North Jersey City ranked as the 10th worst metropolitan area in the US for ozone levels. Centers for Disease Control estimates that 735,000 people lived in New Jersey state who suffer from asthma disease due to smog ingredients that can trigger asthma attacks. According to a report by the American Lung Association, they found 161,461 Pediatric asthma patients, 575,425 Adult asthma patients, 437,827 Chronic obstructive pulmonary disease patients, and 4,993 Lung cancer patients due to the environmental pollution in New Jersey state (New Jersey environment department report). New Jersey’s smog levels were worse in 2016 because of record high temperatures. The state average temperature rises up to 55 degrees was the third warmest since 1895.

New Jersey (38°56’ N to 41°21’ N, 73°54’ W to 75°34’ W) has adverse environmental issues mainly due to economic activities. The implementation of mandatory lockdown in New Jersey to prevent COVID-19 transmission has resulted in a drastic reduction of environmental pollution by 60 percent. New Jersey’s air continues to decline due to older diesel engines on trucks being retired or retrofitted along with the continued closing of coal-fired power plants. New Jersey State and federal government efforts in recent years have been introduced to buy back old high-emission vehicles, impose new restrictions on diesel truck emissions. Still, a considerable amount of air pollution gets blown into New Jersey from coal-burning power plants in the Midwest. The New Jersey administration is looking at rolling back fuel emission standards for cars and small trucks, which environmental advocates say will harm air quality. And it also wants to dismantle the clean power plan that restricts the amount of greenhouse gases that go into the atmosphere and contribute to global warming. Similar executive actions taken by governments worldwide have negative bearings on the economy, but air quality has drastically improved because of these actions (McKibbin and Fernando, 2020).
proxy); Air quality (Aqi) is an index measuring the maturity of air quality measured in percentage; temperature (temp) is measured in degree C; and humidity (humidity) measured as a share of daily temperature. Data of the COVID-19 was collected from European Union database (European union, 2020).

Data on air quality was obtained from United States Environmental Protection Agency database (EPA, 2020). The daily temperature and humidity were obtained from the website of time and data (https://www.timeanddate.com/). Figure 1 shows the tendency of number of confirmed cases and death in USA across time (1st March to 7th July). We observe that the first recorded cases were in the first week of March 2020. The tendency was very weak at the beginning, while in the last week of March 2020 the number of cases recorded increased sharply and exceeds 35000 cases in 11 April 2020. Compared to the number of people affected by the COVID-19 in USA, the number of deaths was low on average at the end of March, however, the number of deaths accelerated in April to reach approximately 5000 cases of death. In extension to empirical analysis, authors further added human development index, health security index, population density and median age as controlling factors. The data for health security index is accessed from center for health security database (https://www.ghsindex.org/), while the human development index data is available at https://globaldatalab.org/shdi/shdi/. Notably, the health security index represents overall health protection and security related rankings, while human development index shows the education and awareness level of population. The population density and median age data is available at the New Jersey government database (https://www.nj.gov/).

Figure 2 shows the daily new cases of COVID-19 in New Jersey state. The trend of daily confirmed cases in New Jersey has the same skeleton as that of the USA given that New Jersey begins to register confirmed cases in the second week of March (15 cases on 10 March 2020 with a temperature of 17°C and 37% of humidity). The maximum number of daily cases confirmed was 78467 on 17 April 2020. Mature indicator of air quality attained an average of 11277.46 people. The biggest number of cases was equal to 78467 on 17 April 2020. Mature indicator of air quality attain an average of 46 aqi and it touch a maximum level of 82 aqi on 24 March 2020. Regarding air quality, with an average of 38, the temperature was in lowest minimum of 1°C and the highest maximum temperature was reached 26°C (air quality and aqi has the same level with the maximum temperature degree).

The Pearson of coefficient correlation is considered for our case in order to measure the degree of linear relationship between two variables. It is known as the best technique of measuring the relationship between variables of interest because it is based on the method of covariance. It gives information about the magnitude of links between the variables and also gives the direction of this association. The computed correlation value should be between -1 and 1, indicating a strong negative correlation or strong positive correlation, respectively.

The formula of the Pearson coefficient correlation is given as follow:

$$r_s = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$  (1)

The equation (1) illustrate the Pearson coefficient correlation estimation formula. This estimated coefficient defines the ratio of the covariance ($\sum (x_i - \bar{x})(y_i - \bar{y})$) by the product of the standard deviations ($\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}$).

Using a monotonic function, the rank correlation coefficient ($r_s$) developed by Spearman controls the correlation between the variables. Due to the non-normality of the data, it is well to uses that correlation.

Figure 1. USA COVID-19 Outlook
Figure 2. Daily New Cases of COVID-19 in New Jersey

Figure 3. Trends in environmental indicators in New Jersey during the study period

Table 1
Descriptive Statistics.

| Variables     | Obs | Mean    | Std.Dev. | Min | Max | p1    | p99    | Skew. | Kurt. |
|---------------|-----|---------|----------|-----|-----|-------|-------|-------|-------|
| COVID-19      | 129 | 1429.519| 1368.317 | 0   | 4391| 0     | 4372  | .725  | 2.085 |
| Air Quality   | 129 | 31.752  | 11.867   | 11  | 74  | 11    | 64    | .606  | 3.362 |
| PM2.5         | 129 | 27.798  | 9.856    | 11  | 61  | 11    | 60    | .964  | 4.092 |
| Temperature   | 129 | 18.806  | 8.417    | 6   | 35  | 7     | 35    | .378  | 1.776 |
| Humidity      | 129 | 41.62   | 20.664   | 11  | 96  | 12    | 92    | .801  | 2.847 |
| Log COVID     | 125 | 6.48    | 8.837    | .693| 8.387| 693   | 8.383 | -1.491| 5.068 |
| Log Air Quality | 129 | 3.386  | .387     | 2.398| 4.304| 2.398 | 4.159 | -.258 | 2.483 |
| Log PM2.5     | 129 | 3.265   | .347     | 2.398| 4.111| 2.398 | 4.094 | -.018 | 2.892 |
| Log Humidity  | 129 | 3.605   | .509     | 2.398| 4.564| 2.485 | 4.522 | -1.163| 2.445 |
| Log Temperature | 129 | 2.829  | .469     | 1.792| 3.555| 1.946 | 3.555 | -.095 | 1.785 |
coefficient in the present analysis (Şahin, 2020). The Spearman’s correlation assesses monotonic associations. If there are no repeated data values, a perfect Spearman correlation of +1 or – 1 take place when each of the variables is a perfect monotone function of the other.

The coefficient can be defined as follows:

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

(2)

In equation (2) Where \( n \) denotes the number of the data; \( d_i \) indicates the difference in the rank of the \( i^{th} \) element of each random series used. The sign of the Spearman correlation indicates the direction of relationship between the independent and the independent variables. If the dependent variable tends to increase when the independent variable increases, then the spearman correlation coefficient is positive. However, if the dependent variable tends to decrease when the independent increases, then the spearman correlation coefficient is negative. If there is no tendency to increase or decrease for the dependent variable when the independent increases, then the spearman correlation coefficient is equal to zero.

Kendall’s rank correlation is a non-parametric test considered as an alternative to Pearson’s correlation (parametric) to evaluate the degree of relationship based on the pairs of observations. The use of Kendall’s rank correlation is to check for the similarities in the ordering of the data when it is ranked by quantities (towards data science, 2020). The other kinds of correlation coefficients use the observations as the basis of the correlation, while the coefficient of Kendall correlation uses pairs of observations and controls the strength of relationship based on the patten on concordance and discordance between the pairs. The value of Kendall rank correlation is given by the following formula:

$$\tau = \frac{n_c - n_d}{\frac{1}{2} n(n-1)}$$

(3)

In equation (3), Where \( n_c \) denotes the number of concordant (ordered in the same way); \( n_d \) indicates the number of discordant (ordered in different way) and \( n \) indicates the number of observations (statistics solutions, 2020). In fact, the estimated correlation coefficient of Kendall is frequently smaller values than those of Spearman and the probability values are more accurate with smaller sample sizes. The main reason for three correlation techniques is just to check if the results are consistent and not spurious.

Lastly, the authors utilize the Auto-regressive Distributed Lag (ARDL) model approach. The main reason to apply the ARDL method is to check the lagged effects of variables. Notably, the ARDL model is employed in two equations as without lag of covariates in equation (1) and with two days lag (t-2) for lag of covaraites. The ARDL method is considered as widely used time-series technique to check the lagged effects of any factors. During the COVID-19 crisis, the researcher’s argued that the 2 to 15 days time for transmission and infection (Ma et al., 2020; Hemida and Ba Abduallah, 2020; Wu et al., 2020). Due to this reason, this study further unveils the temporal lagged effects of studied indicators with COVID-19 spread. The ARDL findings provide robust and consistent results on short time data e.g from 90 to 150 obserberations. In the recent literature, Wu et al., (2020) also employed similar data and empirical strategy.

4. Empirical Results and Discussion

4.1. Empirical results

The results from Pearson correlation tests are reported in Table 2 and show that the correlation between the numbers of confirmed COVID-19 cases and air quality (PM 2.5) is positive and significant (\( r = 0.1797 \)). On the contrary, temperature has highlighted negative effects on COVID-19 new cases. The empirical finding is in line with the recent research works and argue that temperatur might reduce the daily new infections of COVID-19. Such finding is not surprising and in line with the scientific reasons. The empirical findings are in line with the conclusions of Ma et al., (2020); Shi et al., (2020) and Shahzad et al., (2020) for the case of China. The negative finding justifies that COVID-19 virus might be less stable and less active in high temperature areas.

The recent literature has highlighted that under the conditional experiment conditions, the stability of COVID-19 virus is similar to SARS-CoV. Recently, Chan et al., (2011) reported that if temperature ranges from 20 to 25 °C, with humidity of 40%–50%, the SARS-CoV can remain active for up to 4 to 5 days on surfaces. On the contrary, the stability period of SARS-CoV reduce if the temperature and humidity increase. During the studied period the temperature and humidity of New Jersey are increasing, which might be the reason for negative association between temperature and daily new cases. Although the rise in temperature and humidity in New Jersey is due to seasonal fluctuation, while the COVID-19 new cases in New Jersey are also increasing. One more possible explanation for the temperature can be attributed to the immune system of local residents, which is also linked with weather, food and daily routine life of people. The findings of this research are in line with the study of Wu et al., (2020) for the case of panel study on 166 countries. The correlations between air quality index and PM 2.5 are positive. While, the correlation between temperature and COVID-19 is observed negative and statistically significant. However, there is a positive correlation between air quality, humidity and PM 2.5 with COVID-19 new cases.

Table 3 reports the results from Kendall’s rank correlation. The Spearman non-parametric tests. The findings indicate the existence of strong positive correlations between COVID-19 and air quality and between COVID-19 and humidity (rs = 0.0785; \( p < 0.05 \)) and (rs = 0.2741; \( p < 0.05 \)), respectively), while the relationship between COVID-19 and temperature is found to be statistically significant and negative (rs = - 0.3237; \( p < 0.05 \)). The Spearman correlations between air quality index and PM 2.5 and between PM 2.5 and humidity are strongly proved to be positive and statistically significant at a 1% level of significance (rs = 0.7567; \( p < 0.05 \)) and (rs = 0.2612; \( p < 0.05 \)). The Spearman correlation between air quality index (positive) and the temperature is strongly negative and statistically significant at the 5% significance level (rs = - 0.3185; \( p < 0.05 \)). Overall, the Pearson and Spearman correlation findings report consistent estimates. The estimates of air quality are contrary to the claims of Bashir et al., (2020), who reported inverse impacts of air quality and PM 2.5 with daily new cases and mortality rate in California.

Table 4 reports the results from Kendall’s rank correlation. According to these results, we remark that there is practically similar interaction between variables, as mentioned by Spearman rank correlation. In fact, negative significant association are recorded between COVID-19

### Table 2

| Variables | COVID | Air Quality | PM 2.5 | Temperature | Humidity |
|-----------|-------|-------------|--------|-------------|---------|
| COVID     | 1     |             |        |             |         |
| Air Quality | 0.0785* | 1           |        |             |         |
| PM 2.5    | 0.0251 | 0.7567*     | 1      |             |         |
| Temperature | -0.3237* | -0.3185*   | -0.1313 | 1           |         |
| Humidity  | 0.2741* | 0.3596*     | 0.2612* | -0.6955*    | 1       |

Note: * shows significance at the 5% level.
and temperature and the relationship between COVID-19 and humidity is found to be statistically significant and positive. Two strong positive correlations have verified air quality index and PM 2.5 and between air quality index and humidity at mixed significance levels of 1% and 5%, respectively ($\tau = 0.6645$) and ($\tau = 0.2419$). Finally, Kendall’s rank revealed robust positive correlation of air quality, PM 2.5 and humidity with COVID-19 daily new cases at the 5% significant level.

It is important to go through an econometric regression and check for which of the analysis variables can impact the daily COVID-19 new cases. To this end, the analysis considers the ARDL method. The results from the ARDL regressions are reported in Table 5. Based on the ARDL approach, the results suggest that the daily lagged coefficient of COVID-19 affects positively the actual value of the confirmed number of cases affected by the COVID-19. Thus, a 1% increase in the daily lagged value of COVID-19 confirmed number of cases will contribute to increasing the present number of cases with 0.44%. The ARDL model is applied with meteorological and non-meteorological factors as reported in Table 5 and 6. Notably, the researchers employed the ARDL methodology with lag of COVID-19 new cases in equation 1 and with two days lags of covariates. It is important to mention here that due to limited data availability three or more days lags could not be performed in empirical analysis.

Based on the ARDL approach, the results suggest that the daily lagged coefficient of COVID-19 affects positively the actual value of the confirmed number of cases affected by the COVID-19. Thus, a 1% increase in the daily lagged value of COVID-19 confirmed number of cases will contribute to increasing the present number of cases with 0.44%.

Table 5: ARDL Empirics robustness check with Non-meteorological.

| Variables | ARDL (Eq-1) | ARDL (Eq-2) |
|-----------|-------------|-------------|
| Log Air Quality | 2.0844*** | 1.4000 |
| Log Temperature | -2.8457** | -1.8900 |
| Log Humidity | -1.6274 | -1.9100 |
| Human development index | -10.3996 | -0.2600 |
| Health security index | -0.2699* | -0.8400 |
| Population density | - | -8.3350* |
| Median age | 1.92000 | 2.2000 |
| Constant | 0.0087*** | -3.4400 |
| F-Statistic | 3.972** | 3.542*** |
| Adj R-squared | 102.0041** | 0.4100 |
| F-bound test | 3.492*** | -3.3300 |
| t-test | -3.442** | -3.3300 |

Notes: The symbols *, **, and *** denote the significance level at 10%, 5%, and 1% respectively. The ARDL eq-1 is estimated with human development index, and health security index as control variables. While, equation 2 is estimated with population density and median age of people. The bound tests show that model is stable.

COVID-19 cases of 0.22% and 3.39%, according to ARDL results. The estimates mention that temperature has negative association without lag and with two days lag (t-2) on the COVID-19 new cases. One of the important contributions of this study is to unveil the lagged effects of meteorological indicators on the COVID-19 spread in New Jersey. In the recent literature, Zhang et al., (2020) and Wu et al., (2020) also reported lagged effects of air quality and temperature on COVID-19 for their studies on Chinese cities and 166 countries respectively. The findings of lagged effects of temperature, air quality and COVID-19 on daily new cases validate the claims of health scientists regarding the incubation period of SARS-CoV-2. Figure 4 illustrate the cumulative sum control chart (CUSUM), which is used to check the validity of ARDL model. Notably, the CUSUM plot shows the validity of ARDL model.

The results from the ARDL regressions for non-meteorological indicators is reported in Table 6. In Table 6, we included human development index, health security index, population density and median age as robustness controls. According to the findings, air quality and temperature are positive and negative, respectively. The results revealed that a 1°C increase in temperature was associated with a 2.84% reduction in daily new cases. Notably, a 1 percent increase in air pollution reveals that it is associated with an increase of 2.08% in daily new cases.

Table 4: Pairwise correlation analysis (Kendall’s rank correlation).

| Variables | COVID | Air Quality | PM 2.5 | Temperature | Humidity |
|-----------|-------|-------------|--------|-------------|---------|
| COVID     | 0.9981| 0.9721      | -0.0071| 0.6645*     | 0.9633  |
| Air Quality| 0.0648| 0.9721      | 0.6645*| 0.9721      |        |
| PM 2.5    | -0.0071| 0.6645*    | 0.9633| 0.9605      | -0.4990*
| Temperature| -0.2249*| -0.1932*   | -0.0822| 0.9605      |        |
| Humidity  | 0.1703*| 0.2419*     | 0.1774*| -0.4990*    | 0.9823  |

Note: * shows significance at the 5% level.

Figure 4. CUSUM stability model of ARDL findings
Further, a 1% increase in health security index and population density, resulting in a decrease of 0.26% and 8.33% in daily new cases, respectively. Median age each percent increase is associated with an average increase in the number of COVID-19 cases of 5.69%. The findings of non-meteorological indicators allow us to draw the narrative that effective health policies, safety measures, education quality and awareness and age of population might be important variables to reduce such pandemics and diseases crisis. Based on such findings, the authors further argue that United States can reforms policies keep in view the health protection, health safety, education, and age groups of population across different states to reduce the rapid COVID-19 transmission.

4.2. Discussion of Findings

The ARDL results show that only air quality and temperature led to affect the daily number of confirmed cases (COVID-19). In fact, at mixed levels of statistical significance levels (1% and 5%), PM 2.5 (resp. temperature) affects positively (resp. negatively) COVID-19. Notably, the lagged findings validate recent research arguments and state that the incubation period might exist between the previous infections, air quality, humidity, and daily new cases of COVID-19. While shaping the policies and regulations for traveling, the incubation period might be considered necessary (Xie and Zhu 2020). Due to this reason, some countries which regulated the traveling with quarantine and smart lockdown measures have successfully controlled the COVID-19 crisis. Such findings can be regarded as a contribution to literature, and it might help to draw new implications to control disease spread in New Jersey. Thus, the intoxication and weather factors could be considered as determining features of COVID-19.

Overall, the results might be due to the fact that the moisture in the exhaled bioaerosols evaporates quickly in low humid areas, forming droplet nuclei that might remain in the air and surface for longer time. Consequently, it can increase the virus transmission. Similarly, the cold weather or low temperature hinders the natural immunity of humans. The low temperature due to rains or winter decrease the blood supply and thus slow down the provision of immune cells to the nasal mucus (Wu et al., 2020; Shahzad et al., 2020). Overall, the empirical conclusions endorse the findings of Tosepu et al., (2020); and Sahin (2020); Ma et al., (2020); Fareed et al. (2020); Wu et al. (2020); and Chen et al. (2020), and argue that future research can guide about the role of meteorological parameters and COVID-19 disease.

As a final discussion, the three statistical correlations have proved a strong association between the variable COVID-19, air quality index, PM 2.5, and humidity for the New Jersey. In fact, COVID-19 has proved a strong positive correlation with air quality index, PM 2.5 and humidity. This finding can be traduced by the fact that an increase in any one of these weather indicators will affect the number of confirmed cases affected by COVID-19. The findings can provide evidence that air pollution is an important factor in COVID-19 infection. As shown in the literature, air pollution is closely related to other microbes’ respiratory tract infections (Horne et al. 2018; Mehta et al., 2013).

The results found that temperature (negative) and humidity (positive) related to COVID-19. This correlation is compatible with previous studies (SARS) (Tan et al., 2005; Yuan et al. 2006). In addition, the humidity and air quality can also be said to be the environmental driving force of the COVID-19 outbreak in China (Shi et al. 2020). This is due to the fact that COVID-19 is sensitive to heat and makes it difficult to survive, not to mention useful factors for virus transmission, such as high temperature, crowding indoors and poor ventilation on cold days (Bunker et al., 2016).

On the contrary, in our study the temperature shows negative effects with COVID-19, while the daily new cases are still increasing. Such findings enable us to consider that temperature may not be an effective variable in the COVID-19 spread. The rise in temperature level is due to seasonal reasons, and it may not be the only determinant of COVID-19 in New Jersey. Such findings are in contrast with the conclusions of Tosepu et al., (2020) and Ma et al., (2020) for their studies on Indonesia and China. The results of this study are inconsistent with the findings of Ahmadi et al., (2020) for the case of Iran. Their study reported that humidity, temperature and wind are closely associated with COVID-19 new infections across different cities of Iran.

The results obtained are consistent with previous literature stating that short-term exposure to air pollution can increase the spread and infection of the coronavirus (Zhang et al. 2020; Shakoor et al., 2020). According to the results, a good global health safety score in New Jersey has a positive effect on the daily number of cases. Countries differ widely in their capacity to prevent, detect and respond to outbreaks. The New Jersey sample analyzed has strong operational preparedness capacities, suggesting that an effective response to potential health emergencies, including COVID-19, is possible. Capacity building and cooperation between countries is needed to strengthen global preparedness for epidemic control (Randel et al. 2020). This study also includes variables that reflect medical conditions, population aging, and population density to reduce confounding bias. The empirical mention that health safety measures and health security precautions might be effective tool to mitigate COVID-19 spread. On the contrary, the study observes positive effects of median age with daily new infections.

Overall, different US states have different environment and weather conditions. Similarly, the situation of COVID-19 across all US states is different, which is related to environment and climate change via various channels. Hence, the policymakers and health scientists can work on combined and synchronized policies to combat such epidemics and fight against climate change issues. It is important to mention here that the analysis is based on New Jersey as a single state due to limited available data. Environmental conditions and weather factors may not be very different across the 21 counties of state; hence the findings can be considered for New Jersey. However, future research might consider the county-level data of COVID-19 and meteorological parameters with the incorporation of population density, urban population, etc.

It is important to mention here that the current study has a few limitations. One caveat of this research is that the study mainly focused on meteorological parameters and could not consider population density, inter-city movement, and masks in the empirical analysis. In the same line, future research can focus on county-level analysis, city-level analysis, and comparative analysis of different states to provide more useful insights regarding the determinants of COVID-19 spread.

5. Concluding Remarks

The Coronavirus (COVID-19) has become a pandemic, and it rapidly affecting all humans beyond race, religion, and age groups. The rapid death rate due to COVID-19 across several developed countries has become a major challenge for researchers, health scientists, policy-makers etc. In present study meteorological and non-meteorological factors are highlighted as important factors in determining the rapid spread of COVID-19 in New Jersey. This research unveils interesting and mixed outcomes on the correlation between temperature, air quality, PM2.5, humidity and COVID-19 in New Jersey, United States. Overall, we find that air quality, humidity and previous COVID-19 cases might induce further spread in United States. The correlation findings strongly support the literature and argues that air quality, humidity have direct and lagged effects (0 to 2 days) with the COVID-19 spread in New Jersey. The empirical conclusions are supported by rising number of new cases and deaths across different states of United States. Interestingly, the results further suggest that temperature may not be the real determinant of rapid virus spread in New Jersey. This result justifies that humidity, air quality and temperature are important factors regarding the COVID-19 transmission in New Jersey. Overall, the study offers novel findings and argues that New Jersey state might need reformed policies to combat the virus spread. Based on estimates of non-meteorological indicators the authors further argue that United States can reforms policies keep in view the health protection and safety measures, education
quality, and age groups of population across different states to mitigate the rapid COVID-19 transmission. Although, the data and estimates show significant impacts of humidity, and air quality on COVID-19 in United States, this work has still had some limitations. In a study published Monday (May 18) in Science, Rachel Baker, of the University of Princeton (New Jersey), and his colleagues estimate that the climate seems to modulate the rate of transmission of the virus well: like that responsible for the influenza, but also like the coronaviruses involved in winter colds, SARS-CoV-2 appears to be less active when temperatures and humidity rise. However, this climatic sensitivity has little effect. According to the epidemiological modeling of some researchers, the transmission of the virus is primarily guided by the immunity of the population. Despite very different climatic conditions, the modeling does not show any significant difference in epidemic spread.

For instance, there are several factors need to be investigated related to the COVID-19 virus such as virus resistance, population, urban density, mobility, hygiene, use of masks and sanitizers etc. The future research might evolve around COVID-19 and guide us further about the pandemic, its solutions and causes.

Credit author statement

Buhari Dogan: Conceptualization, Data curation, editing. Mehdii Ben Jebli: Methodology, results and discussion. Khurrum Shahzad: Introduction writing, data collection, reviewing. Taimoor Hassan Faroqoq: Figures, revision, suggestions, and, Supervision. Umer Shahzad: Abstract, conclusion, revision, Supervision, and, editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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