Effects of Climatological Parameters on the Outbreak Spread of COVID-19 in Highly Affected Regions of Spain

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Abstract

The Coronavirus (COVID-19) pandemic is infecting the human population, killing people, and destroying livelihoods. This research sought to explore the associations of daily average temperature (AT) and air quality (PM 2.5) with the daily new cases of COVID-19 in the top four regions of Spain (Castilla y Leon, Castilla-La Mancha, Catalonia, and Madrid). We apply Pearson correlation, Spearman correlation, Kendall's rank correlation, and panel regressions to quantify the overall co-movement between temperature, air quality, and daily cases of COVID-19 from February to 17th April 2020. Overall empirical results show that temperature and air quality exert pressure to increase new COVID-19 infections. Our findings are contrary to the earlier studies, which show a significant impact of temperature in reducing the COVID-19 spread. The conclusions of this work can serve as an input to mitigate the rapid spread of COVID-19 in Spain and reform policies accordingly.

1. Introduction

A novel coronavirus disease (COVID-19) epidemic was first reported in Wuhan (China), in December 2019, which spread quickly around China and the government called it a new type of COVID-19 caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Anderson et al., 2020; Wu et al., 2020; Li et al., 2020). The coronavirus is being transmitted through human-to-human by touching, coughing, and sneezing etc with rapid speed (Wang et al., 2020a). The COVID-19 spread throughout the world from Wuhan city in just few weeks, raising a global attention and being highlighted as pandemic (Chen et al., 2020; Lu et al., 2020; Phan et al., 2020; Xu et al., 2020). Common signs and symptoms of covid-19 reported as fever, cough, having difficulty during breathing, and lung pneumonia detected by X-rays (Holshue et al., 2020; Gorbalenya, 2020; Perlman, 2020). According to the exports, the average incubation might be 5 to 6 days, with the maximum prolonged incubation period of 14 days. According to the reports of World Health Organization (WHO), there are more than 2 million people infected, with 1,39,000 plus fatalities until 17th April 2020 (WHO, 2020).

According to the existing research, the viruses can be transmitted through several ways including the weather and climate conditions (temperature, rain, air quality, pollutant emissions and humidity etc.), and populated areas. (Wang et al., 2020b). Hence, for a better understanding about the nexus between climatology factors and transmission of COVID-19 is critical factor to combat against the spread of COVID-19 in several countries. While the health experts are expected that the cold and humid regions will fasten the COVID-19 outbreak, but it is yet not clear whether the warmer areas will respond to the control of the epidemic in the world. The recent studies have mentioned that among climatology indicators the temperature and humidity are highly associated with the COVID-19 pandemic (Tosepu et al. 2020; Wang et al., 2020b). According to the findings of Massachusetts Institute of Technology (MIT), the COVID-19 outbreak frequently accrues in areas with low annual average temperatures, around 37 to 63°F (~3-17°C). The research conducted at MIT[1], indicated that countries having an average temperature above about

64°F (~18°C) might have less than 6 percent COVID-19 cases. However, COVID-19 presents similar patterns in terms of spread rate as compared to the global spread of the Spanish Flu pandemic in 1919, (which affected hundreds of millions of people) and an outbreak of 2002-2003, severe Acute Respiratory Syndrome (SARS) (3.5% for COVID-19 and 11% for SARS).

Tan, (2005) documented that temperature variation significantly influenced the SARS outbreak. Recently, studies of several researchers have mentioned that there exists a strong association between average daily temperature, humidity, and COVID-19 outbreak in China. The studies documented that warm and humid regions of China have lower spread of COVID-19 as compared to Wuhan (Wang et al., 2020b). Moreover, other researchers from Spain and Finland, found that 95% of infections globally have so far occurred at temperatures between 28 to 50°F (~2-10°C), and in dry climates (Araujo and Naimi, 2020). A study on influenza disease resulted that low temperature and relative humidity increases the chances of disease outbreak in Korea, a significant positive association was observed for diurnal temperature range (DTR) (Park et al., 2019). In the same line, the recent studies have reported that COVID-19 outbreak is highly correlated with meteorological and weather factors e.g. rain, humidity, heat etc., (Oliveiros et al., 2020; Wang et al., 2020b). In a general sense, the climatology factors can also be a direct cause of biological interactions between COVID-19 into humans, because the similar factors (temperature variation, air quality, and humidity) were found to be associated with the SARS virus (Yuan et al., 2006). Therefore, we assume that the climate change and weather conditions might also contribute to the spread of COVID-19.

Spain is located in southwestern Europe, with the capital city of Madrid, situated in the middle of Spain. The first case of COVID-19 in Spain was recorded on 31st January 2020, and it is the second country with the highest COVID-19 cases (190,839) as of 17th April 2020 (Spain Government Department of Health, 2020). Figure 1 illustrates the overall COVID-19 outlook in Spain, mentioning that the country witnessed 9222 cases and 849 deaths in a single day (1st April 2020). The four most top regions of COVID-19 cases are Madrid (51,993), Catalonia (38,316), Castilla-La Mancha (15,997), and Castilla y Leon contained (14,903), respectively, until 17th April 2020 (Figure 2).

The increase in the number of cases took place quite quickly due to its temperature and air quality. Previously, it was suggested that viruses could be transmitted by several factors, including climatic conditions (such as temperature, air quality, and humidity) and population density (Dalziel et al., 2018). The extreme weather conditions that accompany long-term climate variations may also contribute to the spread of the West Nile virus in the United States and Europe (Epstein, 2001). The average temperature of Spain is around 57°F (~14°C) year-round (Figure 3 shows the different regions of Spain). Previous study results showed that the solar flux of ionizing radiation creates non-metrical viruses, e.g., SARS and MERS, by long term variation of solar flux (Qu and Wickramasinghe, 2017). However, COVID-19 or infectious diseases can be inactivated by high solar radiation and prevents an outbreak (Gupta et al., 2015; Qu and Wickramasinghe, 2017). The results of Qu and Wickramasinghe (2017) suggested that a double peak in the sunspot cycle causes pandemics in colder areas like Spain and other European countries. Recent studies on COVID-19 situation in China and Iran suggested that the temperature

fluctuation and humidity are important variables in determining the COVID-19 outbreak and mortality rate (Yueling et al., 2020; Mohsen et al., 2020). Research on climate change and COVID-19 is still limited, and this research will contribute to an effort to prevent COVID-19 disease.

To the best of author's knowledge, this is probably the first work to explore the association between climatology parameters with COVID-19 for the case of Spain. In this study, we analyzed how the COVID-19 outbreak correlates with climatology parameters (temperature and air quality). The temperature and air quality data are based on information between 29th February to 17th April 2020, in Spain, the duration of fast and peak outbreak of COVID-19 pandemic. However, the parameters were subjected from four highly affected regions of Spain (Madrid, Catalonia, Castilla-La Mancha, and Castilla y Leon), which can result in infection prevalence and are more in the exposure to COVID-19 identified. The prime objective of this work is to explore the association between Corona Virus Disease 2019 (COVID-19) outbreak and weather parameters in top four affected regions of Spain.

[1] This is reported by Massachusetts Institute of Technology on 19th March. The research evolves on COVID-19 with new information day be day.

2. Data And Methods

2.1 Study area and Data Specification

In this study, we collected daily data of the top four regions of Spain in COVID-19 infections. These regions include Castilla y Leon, Castilla-La Mancha, Catalonia, and Madrid, while the time of data ranges from February to 17th April 2020. According to World Bank records, Spain has a population of almost 47 million, with a population growth rate of 0.3% per year. The main reason behind selecting Spain is due to the fact that Spain is currently at world 2nd most infected country[2] in the world with 196, 586 confirmed cases, 77,000 plus recoveries, and 20,639 total deaths. The meteorological data, including daily average temperature (AT) and daily PM 2.5 (a proxy of air quality) of each region, were retrieved from World Air Quality organization (<https://aqicn.org>). However, the data for daily COVID new cases is accessed from the EL PAÍS: the global newspaper[3] of Spain. The daily data consists of COVID-19 new confirmed cases, the average temperature in degree Celsius (°C), and real-time air quality as PM 2.5.

Figure 2(a,b, c and d) shows the COVID daily news cases in Madrid, Catalonia, Castilla-La Mancha, and Castilla y Leon, respectively. From Figure 2 (a and b), we observe that Madrid and Catalonia are the most affected regions of Spain, followed by Castilla-La Mancha and Castilla y Leon. Similarly, from Figure 3 (a, b, c and d), we note that the highest fluctuation of daily temperature is recorded in Catalonia, Castilla-La Mancha, and Madrid. Because of normality issues, all three variables are transformed into a natural logarithm. Table 1 shows the descriptive statistics of variables with and without log transformation. The summary statistics display that data is average, and there are no outliers in the panel data.

2.2 Estimation Strategy

For empirical analysis, we use the step by step approach. For instance, first, we checked the normality by descriptive analysis. In the 2nd step, we perform a detailed correlation analysis to check the co-movement between temperature, air quality, and COVID-19 news cases of Spain. Following the recent study by Tosepu et al. (2020), we apply the Spearman correlation technique. We further use the Pearson correlation and Kendall's rank correlation methods to examine the robustness of our correlation findings. After performing the correlation analysis between our primary variables of interest, we utilize the panel regression to check if temperature and air quality exert pressure on COVID incidents of Spain. In doing so, we use panel regression, quantile regression, Pooled OLS (robust Driscoll and Kraay standard errors), and fixed effects methods. The panel regression methods are employed on our baseline model given as;

$$Covid = f(Temp, Air) \quad (i)$$

$$\ln Covid_{i,t} = \alpha_0 + \beta_1 Temp_{i,t} + \beta_2 Air_{i,t} + \varepsilon_{i,t} \quad (ii)$$

In equation (ii), the variables are used with log transformation. Where $Temp_{i,t}$ mentions the impact of daily average temperature $Air_{i,t}$ illustrates the effect of air quality and $\varepsilon_{i,t}$ shows the error term.

[2] The figures are provided as of 20th April 2020. Spain is recording daily new cases of 2000 average.

[3] <https://elpais.com/> reports all kinds of health and other indicators data in Spain.

3. Empirical Results And Discussion

3.1 Main Findings

Table 2 presents the coefficients of Pearson correlation for all possible pairs of our variables of interest. Correlation between all three variables is positive and significant, but weak. Values of coefficients are 0.192 (PM2.5 and temperature), 0.234 (COVID-19 and PM2.5) and 0.21 (temperature and COVID-19) respectively, implying that all variables tend to vary in the same direction together.

Table 3 presents results from Spearman's rank correlation among all pairs of variables. Except the coefficient of PM2.5 with temperature, the other two values are not only positive and significant, but also similar to those obtained from Pearson correlation analysis. It's 0.18 for COVID-19 and PM2.5 while 0.19 for COVID-19 and temperature.

Table 4 presents yet another correlation analysis i.e., Kendall's rank correlation. Resulting coefficients are similar to those obtained from Spearman's rank correlation coefficients. Both of these approaches use ranked data in order to determine the strength and direction of the association. PM2.5 and temperature

exhibit insignificant relationship while other two pairs show significant positive relationship. Kendal's coefficient is advantageous as compared to others when sample size is small. Similar results from all three approaches confirm the positive relationship between temperature, PM2.5 and COVID-19.

Table 5 below presents the results from competing regression models. We have employed four regression models for analysis: panel regression, quantile regression, pooled OLS and fixed effects regression model. Coefficients of air quality (PM2.5) are positive and close in values for all models except the fixed effects model. Each one percent increase in PM2.5 results in an increase of 0.63%, 0.67% and 0.64% increase in COVID-19 cases, according to panel regression, quantile regression and pooled OLS respectively.

Coefficients of the temperature are positive and significant in case of all competing models, suggesting a decisive role of temperature in COVID-19 infections. Showing similar pattern as of PM2.5, panel regression, quantile regression and pooled OLS provide similar coefficients for temperature, close in value, whereas fixed effects model presents a bit different story. Each one percent increase in average temperature is associated with an increase of 1.79%, 1.68% and 1.80% rise in number of COVID-19 cases on average, according to panel regression, quantile regression and pooled OLS results. In case of fixed effects model, each one percent increase in temperature results in 2.95% increase in COVID-19 infections.

3.2 Discussion of findings

Our results are consistent with the recent studies suggesting that bad air quality leads to an increase in the number of new COVID-19 infections (Park et al., 2019). Temperature is associated with the daily new COVID-19 infections but sadly, in way that is not helpful to slow down the spread of this disease, quite opposite to the expectations of many experts and some earlier studies (Tosepu et al. 2020; Wang et al., 2020b). A rise in temperature leads to an increase in the new COVID-19 infections on average, as indicated by the results of our correlation and regression analysis. Similar values obtained from multiple models add to the robustness of our results.

These findings may be limited in application to a European country (Spain) due to its unique climate, social setup and a number of other factors related to healthcare facilities. Nevertheless, the result provide a valuable perspective in climate-infectious-diseases-control studies. Since the outbreak of COVID-19 is still out of appropriate control in Spain at the moment, the data related to new infections and climate factors is in the process of formation. Additional studies at the end of this outbreak will be more helpful to understand the role played by the climate factors in COVID-19 spread or control.

4. Concluding Remarks

This is probably the first article to investigate the correlations between average temperature, air quality, and COVID-19 in Spain population. The study utilizes correlation and panel regression methods to investigate the association between temperature, air quality, and COVID-19 across four regions of Spain with high infections. The empirics conclude that weather might be a significant factor in determining the

incidence rate of COVID-19 in Spain. The empirical findings find that average temperature and air quality significantly raise the COVID new cases in all regions of Spain. The results of this work can assist the policymakers in suppressing COVID-19 disease in Spain for humanity saving efforts.

Abbreviations

COVID-19: Corona Virus Disease 2019; AT:Daily average temperature; PM 2.5:Air quality indicator

Declarations

Declaration of Interest

The authors declare that they have no known competing for financial interests or personal relationships that could have appeared to influence the work reported in this paper. No funding was received for this research work. The datasets used during the current study are available from the website and are available on request.

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Tables

Table 1: Descriptive Statistics

Variables	Obs	Mean	S.Dev	Min	Max	p1	p99	Skew.	Kurt.
Covid-19	196	618.41	648.04	0	3419	0	2616	1.416	4.957
PM2.5	196	39.235	17.925	5	88	6	81	-.196	2.402
Temp	196	15.439	2.628	6	22	7	21	-.547	3.711
LnCovid	196	5.412	2.038	0	8.137	.693	7.869	-1.101	3.063
LnTemp	196	2.72	.19	1.792	3.091	1.946	3.045	-1.434	6.974
LnPM2.5	196	3.51	.647	1.609	4.477	1.792	4.394	-1.25	3.671
Note: Descriptive statistics are shown with and without log transformation.									

Table 2: Pairwise correlation analysis (Pearson correlation)

Variables	LnCovid	LnPM2.5	LnTemp
LnCovid	1.000		
LnTemp	0.234*	1.000	
LnPM2.5	0.210*	0.192*	1.000
Note:* shows significance at the 5% level.			

Table 3: Pairwise correlation analysis (Spearman Correlation)

	LnCovid	LnPM2.5	LnTemp
LnCovid	1		
LnPM2.5	0.1877*** (0.0093)	1	
LnTemp	0.1901*** (0.0084)	0.1152 0.1125	1
Note: Parenthesis shows the p-value. * denotes significance at 1% level.			

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

	lncovid	LnPM2.5	LnTemp
LnCovid	0.9967 1		
LnPM2.5	0.1281** 0.1297** (0.0085)	0.9782 1	
LnTemp	0.1243** 0.1318** (0.0101)	0.0766 0.0819 (0.1132)	0.8934 1
Note: Parenthesis shows the p-value.			

Table 5: Panel Regression Empirics

es	Panel OLS	Quantile regression	Pooled OLS	Fixed effects
LnPM2.5	0.6389*** [2.800]	0.6746** [2.590]	0.6401** [2.86]	0.4489 [3.40]
LnTemp	1.798** [2.370]	1.6864* [1.950]	1.801* [2.26]	2.955*** [3.860]
Constant	-1.725** [-0.840]	-1.044** [-0.440]	-1.731*** [-0.820]	-4.204* [-1.830]
R ²	0.1714	0.0294	0.0891	0.0873
Observations	196	196	196	196

The symbols *, **, and *** denote the significance level at 10%, 5%, and 1%, respectively. t-statistics of the corresponding coefficients are added in brackets.

Figures

Figure 1

Spain COVID-19 Outlook

Figure 2

A: Daily New Cases of COVID-19 in Madrid B: Daily New Cases of COVID-19 in Catalonia C: Daily New Cases of COVID-19 in Castilla-La Mancha D: Daily New Cases of COVID-19 in Castilla y Leon

Figure 3

A: Temperature variation in Madrid B: Temperature variation in Catalonia C: Temperature variation in Castilla-La Mancha D: Temperature variation in Castilla y Leon

Supplementary Files

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