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The Climate in the European Union and the Enlarged European Region is a Determinant of the COVID-19 Case Fatality Ratio

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Abstract: Climate could influence the COVID-19 pandemic, but while no evidence has been advanced on the influence of colder climates, some studies have provided data to support a possible heat-related protective factor. The objective is to verify whether areas with a Cold Temperate Climate (TC) have a higher Case Fatality Ratio (CFR) for COVID-19 than areas with a Cold Climate (CC) or with a Mediterranean Climate (MC) in the European Union and the Enlarged European Region. Countries or regions were subdivided into 3 groups according to the Köppen climate classification system: TC (Cfa, Cfb and Cfc in the Köppen system); MC (Csa, Csb); CC (D and E in the Köppen system). The total number of cases and the total number of deaths were detected on 13 August 2020 on the COVID-19 MAP - Johns Hopkins Coronavirus Resource Center-the CFR was thus calculated by area. Living in TC areas is strongly associated with risk of a high Case Fatality Ratio for COVID-19, OR for TC=0.42, IC 95% 0.41-0.43; OR for CC=0.33, IC 95% 0.33-0.35. The results are confirmed in the EU, OR per MC=0.85, CI 95% 0.84-0.87; OR per CC=0.63, IC 95% 0.61-0.65. The study found that the IC in a humid temperate climate is associated with higher CFR with respect to the coldest and warmest temperate climates in Europe. This does not appear to be the only determinant of the pandemic.

Keywords: climate; COVID-19; CFR; enlarged EU; pandemic.

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1. Introduction

It has been hypothesized that the climate could influence the progress of the COVID-19 pandemic. In particular, it has been assumed that the coldest and hottest climates can counter the pandemic. However, apart from some anecdotal considerations [1], no evidence has been
advanced on the influence of colder climates. Studies on the influence of warmer climates have been restricted to analyses relating to changes within single nations [2] and therefore lacking situations of high variability that could confirm the factor independently of specific confounding factors. It has also been found that the lethality of the virus was lower in equatorial areas than in the rest of the world [3], even though in this case, one must consider that fact that there are few equatorial nations and their COVID-19 incidence rate is quite different (countries with no cases are almost all equatorial but they are also isolated islands). The trend in a few nations with high incidence (i.e., Singapore) may have influenced the overall results of the study. Therefore, it is difficult to extend the result to other situations that present extremely high variability for this parameter in countries with similar weather. It is well known that a comparison of the incidence of COVID cases in different countries poses numerous difficulties that are not easily overcome. The number of known cases in a given country could, in fact, be biased by several factors such as (1) accessibility to tests in its health system, (2) reliability of data transmitted to institutional research bodies and international health organizations (with or without intentional manipulation), (3) the country’s demographic profile with more or less extension of ages at risk. A somewhat more reliable factor in assessing virus activity could be the assessment of the Case-Fatality Ratio in different areas. The case Case-Fatality Ratio of COVID is the proportion of deaths from COVID in a given country or area divided by the total amount of people diagnosed with COVID in this country/area in a given period [4]. The Case-Fatality Ratio (CFR) is not directly related to accuracy in identifying cases; in fact, it is based on the cases already identified. It is independent of the incidence rate of the disease in a given population. It may be less biased by errors in communication and a desire to hide the pandemic’s extent because death is counted as declared cases, which are thus somewhat more difficult to conceal. However, the Case-Fatality Ratio can be influenced, albeit indirectly, by the efficiency of the health system because the many diagnostic tests conducted in a particular country could lead to the identification of a greater share of mild cases, which could lower the rate, widening the denominator, regardless of the aggressiveness of the virus. However, this possible bias may be partially disputed if a possible climate-related trend was confirmed in nations with comparable health systems.

The objective of this study is to verify whether areas with a Cold Temperate climate have a higher Case Fatality Ratio for COVID-19 than areas with a cold climate (therefore colder on average) or with a Mediterranean climate (therefore warmer on average) in the European Union and the Enlarged European Region. The specific analysis of the European Union allows the hypothesis to be verified in a context of states with comparable national health systems, while the enlarged European Region allows the hypothesis to be verified in a broader context, which is, therefore, less affected by other possible confounding variables.

2. Materials and Methods

The subdivision of the European Union's climatic regions and the enlarged European area was carried out according to Chen’s classification (2020), which was based on the original scheme by Köppen (1936). Peri-European desert areas were excluded [5, 6]. The regions were divided into 3 groups: Humid Temperate (corresponding to the Cfa, Cfb, and Cfc areas of the Köppen classification); Mediterranean (Csa, Csb areas of the Köppen classification); Cold (areas D and E of the Köppen classification). The total number of cases was detected on 13 August 2020 on the COVID-19 Map-Johns Hopkins Coronavirus Resource Center (detected 2020). The total number of deaths was thus calculated as the Case-Fatality Ratio for the
countries with different climatic areas (Italy and Spain). Although France has only one Region (Midi-Provence-Côte d’Azur) belonging to the Mediterranean area, it was not possible to calculate the differentiated data because no data was provided. The role of climatic zones as a possible determinant was calculated in terms of odds ratio; the 95% confidence limits were calculated using the simplified Miettinen method. A hot, humid climate was considered as a pivot for the other two climates. The comparison with cold climate countries was conducted with and without Russia; in fact, the frequency of cases in this single state is many times greater than that of all the others belonging to the same climate group. Suppose the results of the two evaluations did not agree. In that case, one could, therefore, hypothesize the presence of a specific factor independent of the climate.

3. Results and Discussion

Table 1 shows the European Union regions/countries and of the enlarged European area divided by Humid Temperate (1a), Mediterranean (1, b), and Cold climate. For each nation or Region (in nations with different climate regions such as Spain and Italy), the number of cumulative cases and the number of global deaths for COVID are reported as recorded on 13 August 2020 on the COVID-19 Map - Johns Hopkins Coronavirus Resource Center [7]. The Case-Fatality Ratio obtained by accumulating the data in tables in the different areas is as follows: for the regions with a humid climate, 9.92% in the enlarged European area and 9.90% in the European Union; for regions with a Mediterranean climate, 4.89% in the enlarged European area and 4.43% in the European Union; for regions with a Mediterranean climate, 2.25% (3.60% without Russia) in the enlarged European area and 5.87% in the European Union.

| Region/Country                  | Total Cases | Global Deaths on 13 August 2020 | Case Fatality Ratio |
|---------------------------------|-------------|---------------------------------|---------------------|
| Abruzzo EU                      | 3,516       | 472                             |                     |
| Marche EU                       | 6,976       | 987                             |                     |
| Emilia Romagna EU               | 30,220      | 4,298                           |                     |
| Umbria EU                       | 1,517       | 80                              |                     |
| Toscana EU                      | 10,707      | 1,137                           |                     |
| Piedmonti EU                    | 31,956      | 4,138                           |                     |
| Valle d’Aosta EU               | 1,217       | 146                             |                     |
| Lombardy EU                    | 97,054      | 16,833                          |                     |
| Veneto EU                      | 20,801      | 2,092                           |                     |
| PA Bolzano EU                   | 2,779       | 292                             |                     |
| PA Trento EU                   | 4,998       | 405                             |                     |
| Friuli VG EU                    | 3,461       | 348                             |                     |
| Catalonia EU                    | 89,909      | 5,706                           |                     |
| Aragon EU                       | 19,418      | 991                             |                     |
| Navarra EU                      | 7,713       | 531                             |                     |
| La Rioja EU                     | 4,333       | 366                             |                     |
| Pays Vasco EU                  | 19,009      | 1,553                           |                     |
| Cantabria EU                    | 2,824       | 220                             |                     |
| Asturias EU                     | 2,733       | 334                             |                     |
| France (Provence Not Available) EU | 230,874   | 30,247                          |                     |
| Belgium EU                      | 75,647      | 9,900                           |                     |
| The Netherlands EU              | 61,118      | 6,182                           |                     |
| Luxembourg EU                   | 7,300       | 122                             |                     |
| Germany EU                      | 220,859     | 9,213                           |                     |
| Poland EU                       | 53,676      | 1,830                           |                     |
| Slovakia EU                     | 2,690       | 31                              |                     |
| Czechia UE                      | 19,075      | 391                             |                     |
| Hungary UE                      | 4,768       | 605                             |                     |
### Table 1 b. Case Fatality Ratio in the European and Peri-European Regions with Mediterranean Weather.

| Region /Country | Total Cases | Global Deaths on 13 August 2020 | Case Fatality Ratio |
|----------------|-------------|---------------------------------|---------------------|
| Romania UE     | 65,177      | 2,807                           |                     |
| Bulgaria UE    | 13,893      | 342                             |                     |
| Ireland EU     | 26,838      | 1,174                           |                     |
| Slovenia EU    | 3,641       | 348                             |                     |
| Denmark EU     | 15,070      | 621                             |                     |
| N. Macedonia   | 12,217      | 530                             |                     |
| Montenegro     | 3,813       | 73                              |                     |
| Serbia         | 28,751      | 658                             |                     |
| Bosnia Herzegovina | 14,691 | 553                             |                     |
| Kosovo         | 10,419      | 341                             |                     |
| United Kingdom | 315,581     | 46,791                          |                     |
| San Marino     | 669         | 42                              |                     |
| Andorra        | 977         | 53                              |                     |
| Total EU       | 1,161,767   | 104,742                         | 9.02%               |
| Total          | 1,548,885   | 153,783                         | 9.92%               |

### Table 1 c. Case Fatality Ratio in the European and Peri-European Regions with cold weather.

| Region /Country | Total Cases | Global Deaths on 13 August 2020 | Case Fatality Ratio |
|----------------|-------------|---------------------------------|---------------------|
| Austria EU     | 22,439      | 724                             |                     |
| Finland EU     | 7,642       | 333                             |                     |
| Estonia EU     | 2,164       | 63                              |                     |
| Latvia EU      | 1,303       | 32                              |                     |
| Lithuania EU   | 2,309       | 81                              |                     |
| Total          | 706,469     | 31,342                          | 4.43%               |
Table 2 compares these differences and measures the Association between High Case Fatality Ratio and Humid Temperate Weather in the enlarged European Zone. Living in Humid Temperate Weather regions or countries is strongly associated with a risk of High Case Fatality Ratio for COVID-19, with regard to both inhabitants of the warmest Mediterranean zones (OR=0.42, IC 95% 0.41-0.43) or those living in a cold climate zone (OR=0.33, IC 95% 0.33-0.35 and OR =0.20, IC 95% 0.20-0.21 when Russia is excluded).

Table 3 compares the same differences and measures the Association between High Case Fatality Ratio and Humid Temperate Weather in the European Union. Living in Humid Temperate Weather regions or countries is confirmed as being associated with the risk of a High Case Fatality Ratio for Covid-19, with respect to both inhabitants of the warmest Mediterranean zones (OR=0.85, IC 95% 0.84-0.87) or those living in cold climate zone (OR=0.63, IC 95% 0.61-0.65).

3.1. Discussion.

Ours is the first work that has found a humid temperate climate associated with a higher Case Fatality Ratio with respect to the coldest and warmest temperate climates. This was found both in the enlarged European area and by restricting the number of states/regions considered in the European Union alone. The first evaluation has the advantage of comparing a multiplicity
of different conditions in terms of culture and other possible confounding factors (pollution, greater exposure to travelers, state of health, variables related to the quality of the health system in detecting and transmitting data) [16]; the second evaluation concerns a small number of states with more homogeneous conditions [17]. The fact that both evaluations' results are in agreement, therefore, reinforces the validity of the result. To our knowledge, there are no systematic studies in the literature on possible protection from the risk of mortality associated with cold climates in the Covid pandemic [18,19,20]. Some studies had found a possible protective effect related to heat; in fact, the equatorial countries showed a lower mortality rate out of the total of infected people than the remaining regions and territories located in non-temperate areas of three European nations (France, The Netherlands, and the United Kingdom) had a lower rate of lethality than metropolitan areas in the same nations, in partial independence of age distribution [8, 14]. Moreover, the provinces of 4 Italian regions with the highest temperature in March presented a lower mortality rate from COVID than the other provinces in the same 4 regions [9].

Furthermore, a negative linear relationship was found in Brazil between temperatures and the number of confirmed cases with a curve that flattened at a threshold of 25.8 °C [2, 13, 21]. However, our data only concern the risk of mortality amongst cases and not the risk of disease. Furthermore, in Brazil, there was no data relating to a cold climate. Let's carefully analyze the data in our study. We find that although a humid temperate climate is associated with a high Case Fatality Ratio, other factors are undoubtedly significant. This emerges from the analysis of the states/regions that are strongly discordant from the weather-related trend. Among the nations with a humid temperate climate, for example, the high Case Fatality Ratio of the United Kingdom stands out (14.80 vs 9.92%). Among the cold climate states, there is the case of Sweden (6.9 vs 2.25%). Both nations implemented very limited and delayed lockdown measures.

A similar trend is not observed in Belarus, another country with limited lockdown. However, the data may not be comparable in this case [10]. Some areas with a high metropolitan density show higher CFR trends, for example, the Madrid area. This is possible in relation to greater exposure to the infection, given the greater difficulty of social distancing. Although this trend can be found in several areas with high urban density, it is not always present (for example, in Luxembourg) because probably other factors also come into play. It can also be noted that temperate regions close to the endemic explosion (such as Liguria) still have very high CFRs. This multiplicity of factors at play also highlights this study’s limits; in fact, the current state of knowledge makes it impossible to balance the various potential confounding factors. Another limitation derives from the fact that a country provides the data on the pandemic or at the most by Region, while obviously, the climate does not respond to these limitations. For example, Catalonia has been placed among the humid temperate climates because most of its territory, but not all, have this type of climate. However, the same Region reports an intermediate Case Fatality Ratio (6.9%) compared to those of the two climatic areas even in the European Union, and location in one or the other does not change the results. These considerations cannot be made for France’s southern Region (with a Mediterranean climate) for which no data are available. Suppose our hypothesis has confirmed the interruption of the lockdown in Southern Europe. In that case, it could be followed, with the return of the cold by very problematic autumn [11, 12]. It should also be noted that the second wave in Europe at the end of the summer was characterized by the interest above all of the young people due to the lack of respect for distances in discos and entertainment venues. Therefore, the spread of
the epidemic to weaker bands could coincide with the increase in cold weather, and two risk elements would add up [1, 15, 22].

4. Conclusions

The study found that a humid temperate climate is associated with a higher Case Fatality Ratio concerning the coldest and warmest temperate climates in Europe. Although this does not appear to be the only determinant of the pandemic, it is an element that must be taken into serious consideration for the planning of response strategies.

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Conflicts of Interest

The authors declare no conflict of interest.

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