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How health capabilities and government restrictions affect the COVID-19 pandemic: Cross-country differences in Europe

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ABSTRACT

The COVID-19 pandemic in the first months of 2020 posed an unprecedented threat to the health of the world’s population. In this longitudinal design study, we elaborated the typology of 27 European countries based on the complete beginnings of the ongoing COVID-19 pandemic based on health indicators and contextual variables. Two-step analysis using factor scores to run a cluster analysis identifying 5 consistent groups of countries. We then analyze the relationship between the GHS predictive index, the restrictions and health care expenditures within countries categorized into 5 clusters. An analysis of the early stages of a pandemic confirmed that in countries where anti-pandemic measures were rapidly and consistently in place, the spread of the virus was suppressed more rapidly and the first wave of pandemics in these countries was incomparably more benign than in countries with later responses and milder restrictive measures.

1. Introduction

On 11 March 2020, when the novel Coronavirus Disease COVID-19 caused by SARS-CoV-2 was established in 115 countries, the WHO declared the spread of the disease a pandemic. Two days later, on 13 March 2020, the WHO identified Europe as the main epicenter of infection with the new type of coronavirus.

The Coronavirus Disease, which is caused by the North Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), raises many unanswered questions posed by researchers in various disciplines and decision makers around the world. Research and scholarly work in medicine, immunology, cell biology, biochemistry, molecular biology, etc. are currently highlighted as the world is looking for an effective solution to deal with the pandemic (note: at the end of March, 255 research papers focusing on COVID-19 were published on the Web of Science). Geographical research also offers considerable potential to elucidate the spatial spread of the Coronavirus Disease (eg Gao et al., 2020). It can also explain the conditional factors and variations in the number of reported cases and deaths in different countries and regions (eg Angel et al., 2020). Many recent scholarly works argue that the potential differentiation of fatality rates reflects different age structures and testing regimes among countries (Caramelo et al., 2020; Dowd et al., 2020; Zhou et al., 2020). Although it is clear that age structure influences the total fatality rate (Dudel et al., 2020; Kashnitsky 2020), none of the research has yet addressed cross-country differences in terms of pandemic “preparedness” and implemented government restrictions.

In Europe, in particular, some countries show significantly higher fatality rates than others. Currently, national governments are using different approaches to slow the spread of COVID-19, and the preparedness of individual countries has been significantly distinct. Moreover, to the best of our knowledge, no study has empirically tested the extent to which the fatality rate is associated with constraints implemented by countries across Europe, and with health security and related capabilities in these countries. A minor exception is Verhagen et al. (2020), who use the example of England and Wales to demonstrate the relationship between health system capacity, mortality, and the demographic characteristics of infected people. This is a specific case study; however, and cross-country analyses within the European countries are lacking. Moreover, the authors did not address government restrictions.

It is generally accepted that preventing a disease is cheaper than treating the disease and its consequences. At the beginning of a pandemic when effective vaccines are not yet available to protect the population from the disease, the main prevention was based on reducing the spread of the virus in the population. The two main implement pandemic strategy to reducing the virus in the population are: (i) suppression strategy (radical marginalization) aimed at minimizing the spread of the virus in a population, and (ii) mitigation strategy aimed at slowing the spread of
the infection in the population rather than minimizing its spread (Baker et al., 2020; Han et al., 2021; Walker et al., 2020). The choice of one strategy or a combination of both not only affects the health outcomes for the population but also has a critical economic impacts (higher restrictions - higher costs).

The main goal of our paper is to develop a typology of European countries on the basis of their initial strategic response to the pandemic, and the consequent health indicators and other epidemiological features, using a longitudinal approach instead of the conventional transverse approach. The results of the typology will be viewed in terms of three intriguing block of the questions, which require urgent answers: Regarding the question of whether pandemic preparedness can be predicted:

a) Can it be shown that, in a cluster of countries with the most severe outbreak, there was lower pandemic preparedness under the GHS and vice versa? Is the GHS index a suitable predictive indicator?

b) How does the level of the GHS Index correlate to the degree of restrictions, and to the quality of health care? Did countries with lower preparedness impose stricter restrictions and vice versa? Additionally, do countries with a lower GHS index also have a lower share of health care spending?

c) Whether government restrictions contribute to reducing the impact of a pandemic.

The paper is structured as follows. The next section reflects literature review concerning spread of infectious diseases and COVID-19. The next section introduces used data and methodology. The subsequent part provides the empirical findings of statistical analyses according to structure of research questions. The final section presents the main conclusions, implications for practice, and potential outlines for future research.

1.1. Literature review

Following the “Spanish Influenza” (caused by an A(H1N1) virus) pandemic of 1918–1919, and the two next influenza pandemics, the “Asian Flu” (1957–1958), caused by an A(H2N2) virus, and the “Hong Kong Flu” (1968), caused by an A(H3N2) virus, broad interest remains in understanding what happened - both to inform current pandemic planning and to advance basic scientific knowledge about how pandemic influenza viruses form and cause disease (Taubenberger & Morens, 2010). Unfortunately, despite huge technological progress and intensive studies of the influenza virus, we are still unable to predict future pandemics.

Since describing the course of SARS-CoV-2, the first 41 admitted hospital patients with laboratory-confirmed 2019-nCoV infection published Lancet already on January 24, 2020 (Huang et al., 2020) and 5 days later next study of 99 patients hospitalized with the disease at Wuhan Jinyintan Hospital (Wuhan hospital for emergency medical treatment) published on January 29, 2020 (Chen et al., 2020), have seen a gradual increase in the number of studies on disease spread and severity. A few days later, a study based on a more massive population sample of 1,099 hospitalized patients with laboratory-confirmed disease COVID-19 was published in the New England Journal of Medicine (Guan et al., 2020).

As far as we know, a real-time geographical analysis of the pandemic of infectious disease COVID-19 has not been published. Nevertheless, we consider it essential to start from the studies and knowledge of previous analyses of the spatial diffusion of infectious diseases, which were based on epidemic-terminated (retrospective) data. Spatial diffusion of infectious disease has, for some time, been of interest to geographers and epidemiologists. Geographic diffusion processes are a scientific field of research that focus on the movement of events, goods, information, ideas, and people through space and time (e.g. Haggett et al., 1977; Sabel et al., 2010). The diffusion rates and patterns depend on the mode of transmission. In respiratory viruses such as influenza, where the virus replicates and is transmitted by air, diffusion is rapid.

To address the spatial spread of infectious diseases, models associated with Peter Haggett’s research are crucial. Such studies include the spread of the choleroid epidemic (Haggett, 1994), modelling temporal and spatial patterns, and research on global epidemics with Cliff, Haggett and Smallman-Raynor (1998). Cliff and Haggett have examined the process of measles and influenza diffusion using the example of Iceland, which has a closed island population (Cliff et al., 1981; Cliff & Haggett, 1992). Probably the first work of its kind to present a spatial analysis of the spread of infectious disease in an epidemiological context is, Atlas of Disease Distributions: Analytical Approaches to Epidemiological Data (Cliff & Haggett, 1992). It records both the spread of AIDS, smallpox or measles, and the risk of radiation. Cliff and Haggett have attempted to link epidemic models with spatial theory to better describe the flow and movement of infectious disease in time and space. Many scientists, including geographers, have been warning of the emergence of new influenza strains that could lead to a global pandemic (e.g Mayer, 2000 or Taubenberger & Morens, 2010).

1.2. Data and methodology

1.2.1. Context

Each European country had a different starting position from the economic, social, or demographic point of view before the start of the COVID-19 pandemic. The onset of the pandemic did not start in Europe all at once. The diffusion of COVID-19 was progressive in European countries. The first European case of COVID-19 was confirmed in France (24 January 2020), the second in Germany (27 January 2020). On 8 April 2020, the decisive day for our analysis, the epidemic had been in European countries an average of 48 days (75 days in France vs. 31 days in Bulgaria). As of 8 April, the number of positive COVID-19 cases in 27 selected European countries amounted to 715,353 - including 59,900 deaths - in a population of 525,361,063. Each country has gone through different epidemiological trajectories.

1.2.2. Data

Our analysis of the ongoing COVID-19 epidemic in selected European countries is based on three data sources derived from electronic records. Primary data on the daily epidemiological situation numbers of confirmed cases and deaths were taken from the Humanitarian Data Exchange (HDX) database (data.humdata.org) attributed on the 8th of April 2020.

Explanatory Data on a country’s risk for epidemics and pandemics was taken from the GHS Index database (ghsindex.org) - a project of the Nuclear Threat Initiative (NTI) and the Johns Hopkins Center for Health Security (JHU) developed with The Economist Intelligence Unit (EIU). Restriction data was taken from the European Border and Coast Guard Agency (Frontex; frontex.europa.eu). Such data reflect a series of restrictions to mitigate the pandemic virus on 27 March 2020 and are based on open source information and operational data (Frontex 2020). Data include information regarding whether a state of emergency was activated or not. Further, we adopted various constraints implemented by national governments, i.e. the extent to which air, land, and sea borders are open, restricted, or closed. It also states to what extent public gatherings are allowed, if schools are open, and the intensity of residential lockdown. These five indicators (Air, Land, Schools, Public gatherings, and Lockdown) were quantified (1 - open/allowed, 2 - restricted, 3 - closed/banned) for use in statistical analyses. Additional data on the age structure and population of individual countries were obtained from the Eurostat Explorer database.

The standardization of data is necessary to compare the health indicators of the population of different regions due to different age structures. Population age structure may explain the remarkable variation in epidemiological characteristics across countries. Within Europe, Italy has one of the largest elderly European populations, with 22.8% of
its population over age 65, compared to 14% and 16% in Ireland and Slovakia respectively. Unfortunately, in the case of the ongoing COVID-19 epidemic, available detailed epidemiological data are still limited, so we must calculate using crude indicators, without adjusting the effect of different age structures. We address this shortcoming by adding a variable proportion of people aged 65 and over to the analysis.

Given that the pandemic did not affect each country on the same day, the transversal indicators relating to a day show very little evidence of the country’s epidemiological situation at that stage of development. The characteristics are not temporally constant during the early period of the outbreak. We see the added value of our approach, which assesses the epidemic in each country by its number of days.

Based on the above data limitations, we used multiple indicators to analyze an unfinished pandemic in different countries, which we then synthesized by a factor analysis method (and, for simplicity in further text, referred to as epidemiological). These include health indicators: incidence rate, case fatality and deaths rates; and contextual variables: the number of days of an ongoing epidemic at the decisive moment of analysis (as of 08 April 2020) and indicators of age structure.

For our analysis, we use the incidence rate due to COVID-19 (IR) on the decisive day, 8 April 2020 (the cumulative number of confirmed cases of COVID-19 occurring in a country population during epidemic period on 8 April 2020, expressed as the cumulative number of reported COVID-19 cases on 8 April 2020 per 100,000 population). It should be stated that the total number of COVID-19 cases is higher than the number of known confirmed (reported) cases. Next we used two types of mortality indicators. Crude death rates due to COVID-19 (CDR) were calculated as total confirmed deaths due to COVID-19 on 8 April 2020, relative to the size of the total population. Case fatality rates of COVID-19 (CFR) were calculated as the ratio between total confirmed deaths due to COVID-19 and confirmed cases due to COVID-19 with three different denominators. These are:

1. Case fatality rate A (CFR-A) with transversal approach - numerator and denominator on the same date (8 April 2020). This is the most common method of calculation, but the most inaccurate.
2. Case fatality rate B (CFR-B) with trajectorial approach - denominator on 26 March 2020. Based on the Wuhan epidemic (Dzúrová, Jarolímk, 2020), we assume a 14-day delay between confirmed cases and deaths.
3. Case fatality rate C (CFR-C) with trajectorial approach - numerator and denominator on twenty days after the first 100 confirmed cases (different day in each country).

If the number of total cases is higher than the number of confirmed cases, then the ratio between deaths and total cases is smaller than the ratio between deaths and confirmed cases. As testing becomes more widespread, case fatality rates may decrease due to an increase in the true denominator.

Complementary variables of our analysis were the number of days from the first confirmed case to 8 April 2020 (DAYS) and the proportion of persons over the age of 65 years (AGE65).

For the analysis of clusters of countries grouped according to pandemic indicators, we consider for each country 3 explanatory variables: predictive risk for the occurrence of infectious diseases (GHS index); indicator of restrictions, and indicator of quality of health care. Explanatory Data on a country’s predictive risk for epidemics and pandemics in outbreaks such as COVID-19 was taken from the GHS Index database (ghsindex.org) - a project of the Nuclear Threat Initiative (NTI) and the Johns Hopkins Center for Health Security (JHU) developed with The Economist Intelligence Unit (EIU).

The country’s strategy in marginalizing or mitigating the virus was assessed based on the restrictions applied. Restriction data was taken from the European Border and Coast Guard Agency (Frontex; frontex.europa.eu). Such data reflect a series of restrictions to mitigate the pandemic virus on 27 March 2020 and are based on open source information and operational data (Frontex 2020). Data include information regarding whether a state of emergency was activated or not. Further, we adopted various constraints implemented by national governments, i.e. the extent to which air, land, and sea borders are open, restricted, or closed. It also states to what extent public gatherings are allowed, if schools are open, and the intensity of residential lockdown. These five indicators (Air, Land, Schools, Public gatherings, and Lockdown) were quantified (1 - open/allowed, 2 - restricted, 3 - closed/banned) for use in statistical analyses.

In the COVID-19 pandemic, the next important explanatory indicator is the expenditure on healthcare. Health expenditure relative to GDP in 2017 was taken from the Eurostat database (ec.europa.eu/eurostat/statistics-explained).

2. Methodology

We constructed a dataset relating to 27 countries. Initially, seven variables underlying epidemiological variation between European countries during the ongoing COVID-19 pandemic (IR, CFR-A, CFR-B, CFR-C, CDR, DAYS and AGE65) was determined using a Factor analysis (with Varimax rotation). Instead of using seven variables, the obtained latent components (with initial eigenvalues above 1) were considered in the cluster analysis. This procedure attempts to identify relatively homogeneous groups of countries (i.e. where the countries within a cluster are similar and differ from the countries in other clusters) based on epidemiological variation through latent components. The Hierarchical Cluster Analysis Method (Method between-groups linkage) created a graphical solution – dendrogram (the dendrogram rescales the actual distances to numbers between 0 and 25, preserving the ratio of the distances between steps). No strict rule for determining the number of clusters after a hierarchical clustering procedure exist; the number of clusters was determined based on expert assessment according to the dendrogram. Subgroup analysis was performed using a Z score. To visualize the results, scatter plots were constructed at the end of the analysis.

All analyses were carried out using the SPSS (SPSS Inc, Chicago, USA) and STATA (Stata Corp, College Station, Texas, USA) statistical packages.

3. Results of the empirical analysis

For our analysis, we used 27 selected European countries. Table 1 documents that these countries have a different trajectory of the COVID-19 pandemic and shows that the later the epidemic started in the country, the faster it spread. Furthermore, four countries (France, Germany, Italy, and Sweden), in which the pandemic began in the second half of January 2020, reached 100 confirmed cases in 36, 34, 23 and 35 days respectively. This differed from Bulgaria and Slovakia, for example, where the epidemic began in the second week of March 2020 and the first hundred cases were reached in just 12 days. The incidence rate varies considerably from country to country, with the highest levels on 08 April 2020 in Spain (316 cases per 100,000 population) and the lowest in Bulgaria and Hungary (below 10 cases per 100,000 population). However, the interpretation of this indicator requires caution as it not only reflects the duration of the epidemic, but also the intensity of testing. The last three columns of Table 1 document the three variants of the case fatality rate calculation, and the fallacy that in countries where the highest incidence was found, the highest fatality rate is also reported.

Fig. 1 documents the position of 27 selected European countries based on pandemic duration and incidence (A) and case fatality rates (B); the number of pandemic durations to 8 April 2020 (on the x-axis, going across) versus the total number of confirmed cases of COVID-19 per 100,000 population and case fatality rate (on the y-axis, going up). The regression line demonstrates positive association in both relations, i.e. the longer the epidemic lasts, the higher the expected
incidence and fatality levels. However, it is important to compare the positions of particular countries in part A and part B of Fig. 1. For example, the position of Switzerland (Figure A) stands out as the second highest incidence rate, but Figure B shows the position of Switzerland coinciding with a cluster of countries with the lowest case fatality rate. An example of the opposite situation is United Kingdom, with a low incidence rate (A) but a high level of case fatality rate (B), which is a very serious reality.

The typology of European countries is based on a two-step analysis comprised of factor analysis to simplify multiple measures of epidemiological characteristics: first by identifying and scoring countries on underlying components of these characteristics, and then using factor scores to run a cluster analysis identifying consistent groups of countries.

Table 2 presents the first step outputs from Factor analysis and shows the explained variance and factor loadings of the three most important factors. The first component explains 36% of the total variance. Factor 1 (x-axis) strongly associated with all three measure of CFR, have loadings around + 0.85. Factor 2 (y-axis) strongly associated with IR and DAYS, have loadings on the y-axis around + 0.95. Three factor scores of these factors were used as inputs variables for the typology by cluster analysis. Fig. 2 shows a hierarchical solution from cluster analysis – dendrogram. The horizontal axis of the dendrogram represents the distance or dissimilarity between Clusters. Countries are represented on the vertical axis. We decided to cut the dendrogram to create five clusters of countries. The Table below the dendrogram shows the list of countries assigned to the five Clusters. Cluster 1 is a grouping of 13 European countries. The most similar countries based on epidemiological characteristics are the Czechia and Lithuania (forming a cluster at very low distances). A further seven countries are gradually joining the two countries in Cluster 1. Subsequently, Bulgaria and Greece are added to Cluster 1. And, in the last step, Finland and Germany are joining Cluster 1. Cluster 2 consists of only two countries, Finland and Germany, which are simultaneously the most similar to each other and different from the other groups. At higher distances they joined to Cluster 1. The group of five countries in Cluster 3 joins the groups of countries in Cluster 1 and Cluster 2 over long distances, with demonstrably different epidemiological characteristics. The remaining seven countries have created two separate Clusters (Cluster 4 and Cluster 5), demonstrating their specific epidemiological characteristics as significantly different from all other European countries.

To describe individual clusters, we used all 6 variables, which we first standardized to convert the variables to the same scale (using the Z-score method). The five clusters, obtained by a cluster analysis of European countries based on epidemiological characteristics, have significant differences according to Z-scores (Fig. 3). The five clusters show the epidemiological characteristics of five clusters. Looking at the Z Score (which represents the distance of a certain variable from the average), we find significant differences between the health indicators of clusters as well as contextual indicators. First, it is necessary to emphasize that the best results of epidemiological indicators evince Cluster 2 (N = 2) and Cluster 3 (N = 5) and differ between themselves only in contextual indicators - the best in dealing with COVID-19 pandemic. On the contrary, the worst course of the pandemic is recorded by countries in Cluster 4 (N = 4) and Cluster 5 (N = 3), worst in dealing with COVID-19 pandemic. In more detail, Germany and Finland (Cluster 2) are characterized by a significantly above-average number of days from onset to 8.4.2020 (DAYS) as well as a high proportion of people aged 65 years

| Country   | Date of the first conf. case | Date of the first 100 conf. cases | Difference in days | N of days from onset to 8.4.2020 | Incidence rate (per 100 th) 8.4.2020 | Estimating case fatality rates of COVID-19 (%) |
|-----------|------------------------------|----------------------------------|--------------------|----------------------------------|--------------------------------------|---------------------------------------------|
| Austria   | 25.2.20                      | 8.3.20                           | 12                 | 43                              | 146.1                                | FR-A = 2.1, FR-B = 4.0, FR-C = 0.8         |
| Belgium   | 4.2.20                       | 6.3.20                           | 31                 | 64                              | 204.3                                | FR-A = 9.6, FR-B = 35.9, FR-C = 2.9        |
| Bulgaria  | 8.3.20                       | 20.3.20                          | 12                 | 31                              | 8.5                                  | FR-A = 4.1, FR-B = 9.1, FR-C = 4.0         |
| Croatia   | 25.2.20                      | 19.3.20                          | 23                 | 43                              | 22.9                                 | FR-A = 1.4, FR-B = 3.8, FR-C = 1.3         |
| Czechia   | 1.3.20                       | 13.3.20                          | 12                 | 38                              | 49.9                                 | FR-A = 1.9, FR-B = 5.1, FR-C = 0.9         |
| Denmark   | 27.2.20                      | 10.3.20                          | 12                 | 41                              | 93.0                                 | FR-A = 4.0, FR-B = 11.6, FR-C = 3.0        |
| Estonia   | 27.2.20                      | 14.3.20                          | 16                 | 41                              | 89.4                                 | FR-A = 2.0, FR-B = 4.5, FR-C = 0.6         |
| Finland   | 29.1.20                      | 13.3.20                          | 44                 | 70                              | 45.1                                 | FR-A = 1.6, FR-B = 4.2, FR-C = 1.2         |
| France    | 24.1.20                      | 29.2.20                          | 36                 | 75                              | 168.5                                | FR-A = 9.6, FR-B = 37.3, FR-C = 1.6        |
| Germany   | 27.1.20                      | 1.3.20                           | 34                 | 72                              | 136.5                                | FR-A = 2.1, FR-B = 5.4, FR-C = 0.3         |
| Greece    | 26.2.20                      | 13.3.20                          | 16                 | 42                              | 17.6                                 | FR-A = 4.4, FR-B = 9.3, FR-C = 3.7         |
| Hungary   | 4.3.20                       | 21.3.20                          | 17                 | 35                              | 9.2                                  | FR-A = 6.5, FR-B = 22.2, FR-C = 6.5        |
| Ireland   | 29.2.20                      | 14.3.20                          | 14                 | 39                              | 123.9                                | FR-A = 3.9, FR-B = 12.9, FR-C = 2.5        |
| Italy     | 31.1.20                      | 23.2.20                          | 23                 | 68                              | 231.0                                | FR-A = 12.7, FR-B = 21.9, FR-C = 6.6       |
| Latvia    | 2.3.20                       | 20.3.20                          | 18                 | 37                              | 30.1                                 | FR-A = 0.4, FR-B = 0.8, FR-C = 0.4         |
| Lithuania | 28.2.20                      | 22.3.20                          | 23                 | 40                              | 32.6                                 | FR-A = 1.6, FR-B = 5.0, FR-C = 1.0         |
| Netherlands| 27.2.20                     | 6.3.20                           | 8                  | 41                              | 118.9                                | FR-A = 10.9, FR-B = 30.3, FR-C = 5.0       |
| Norway    | 26.2.20                      | 6.3.20                           | 9                  | 42                              | 114.2                                | FR-A = 1.7, FR-B = 3.0, FR-C = 0.4         |
| Poland    | 4.3.20                       | 14.3.20                          | 10                 | 35                              | 13.7                                 | FR-A = 3.1, FR-B = 13.0, FR-C = 1.7        |
| Portugal  | 2.3.20                       | 13.3.20                          | 11                 | 37                              | 127.9                                | FR-A = 2.9, FR-B = 10.7, FR-C = 2.2        |
| Romania   | 26.2.20                      | 14.3.20                          | 17                 | 42                              | 24.5                                 | FR-A = 4.6, FR-B = 21.4, FR-C = 3.7        |
| Slovakia  | 6.3.20                       | 18.3.20                          | 12                 | 33                              | 12.5                                 | FR-A = 0.3, FR-B = 0.9, FR-C = 0.2         |
| Slovenia  | 5.3.20                       | 13.3.20                          | 8                  | 34                              | 52.4                                 | FR-A = 3.7, FR-B = 7.1, FR-C = 1.9         |
| Spain     | 5.2.20                       | 2.3.20                           | 30                 | 67                              | 315.8                                | FR-A = 10.0, FR-B = 25.6, FR-C = 5.1       |
| Sweden    | 31.1.20                      | 6.3.20                           | 35                 | 68                              | 82.3                                 | FR-A = 8.2, FR-B = 24.2, FR-C = 1.6        |
| Switzerland| 25.2.20                     | 5.3.20                           | 9                  | 43                              | 272.5                                | FR-A = 3.8, FR-B = 7.6, FR-C = 1.4         |
| United    | 1.2.20                       | 6.3.20                           | 34                 | 67                              | 82.9                                 | FR-A = 11.2, FR-B = 64.6, FR-C = 5.0       |

Data source: Humanitarian Data Exchange, data.humdata.org, own calculation.

Note - Estimating case fatality rates of COVID-19.
FR-A (Fatality rate A) = Deaths cumul. on 8.4.2020 × 100/Confirmed cases cumul. on 8.4.2020.
FR-B (Fatality rate B; 14-days delay) = Deaths cumul. on 8.4.2020 × 100/Confirmed cases cumul. on 26.3.2020.
FR-C (Fatality rate C) = Deaths cumul. twenty days after the first 100 cases x 100/Confirmed cases cumul. twenty days after the first 100 confirm. Cases.
and older (AGE65+), but these countries also have significantly below average health indicators. Further, Cluster 3 is characterized by a slightly above average level of incidence rate, but also by below average fatality rates and by a significantly lower proportion of elderly population (AGE65+). Cluster 1 (N = 13), with the highest frequency shows a slightly above average proportion of the population aged 65 years and older (AGE65+), but most of the remaining epidemiological indicators show slightly below average values. The worst epidemiological impacts of the COVID-19 pandemic are reported by cluster 4 (Italy, Spain, France, Belgium) with significantly above average levels in all health indicators. Cluster 5 (Netherlands and United Kingdom) shows a similarly high level of case fatality; but, compared to the previous cluster, there is a lower proportion of those aged 65+ in these countries - and the incidence rate is also below average. In sum, Fig. 3 shows significant spatial variation of epidemiological features in the contemporary COVID-19 pandemic and raises questions which require an urgent answer. Above all it is necessary to understand why the coronavirus SARS-CoV-2 had different impacts in each different country’s populations.

In the cluster of countries with the highest restrictions (the most numerous cluster 1) there was the highest suppression of the virus - the lowest incidence. Conversely, in the cluster of countries with the lowest restrictions (cluster 5), the lowest testing rate and a high test of positivity rate were also demonstrated.

Therefore, in the next step, we tried to verify whether the overall GHS score is predictive of the readiness to prevent threats from infectious diseases. The GHS index is based on 6 categories, and 34 indicators (Table 3). The six categories comprise prevention, detection and reporting, rapid response, health system, compliance with international norms, and risk environment. We focused on the preparedness of particular countries and health capacity gaps between clusters according to the GHS overall score - which is currently a frequent source of information during the global pandemic (Table 3). Countries with the highest GHS levels should be most prepared for the threat of infectious diseases. The average values of GHS, i.e. preparedness against the threat of infectious diseases by clusters are given in Table 3. We tested the null hypothesis that the average value of the GHS index did not differ...
between clusters. The alternative hypothesis that there are significant differences in the average GHS values of naturalization of countries into clusters was confirmed only in the case of indicator 6.5. Public health vulnerabilities (sign. 0.026).

Surprisingly, the highest GHS scores are reported by cluster 5 (69,2), and cluster 4 (62,8), i.e. countries that have congested health systems and the highest case fatality rates (note: at the time of writing). Conversely, a notable feature of Cluster 2, which includes the least affected countries with relatively low levels of fatality and mortality, is the very high overall GHS index score (67,4). From the data, countries with similar GHS scores follow very different trajectories in terms of pandemic progression. A possible explanation for this situation may provide a deeper understanding of the 5 categories and 34 indicators inside the GHS index (see Table 3). Looking beyond the overall score of the GHS index there is evidence of substantial variation between clusters. The first finding is that Clusters 2 and 3 show better results (compared with Clusters 4 and 5) in the categories “zoonic disease,” “biosecurity,” and “biosafety.” More significant are the better results within the category “rapid response and mitigation of the spread of an epidemic” (emergency preparedness and response planning, risk communication etc.). These countries also achieved a higher score, for example, in the category “overall risk environment and country vulnerability to biological threats,” but it is necessary to emphasize their higher score in “health capacity in hospitals and community care centers.”

Second, surprisingly, a typical feature of Cluster 1, including the moderately affected countries with relatively average health indicators, is its lowest overall score on the GHS index. In other words, European countries within Cluster 1 (with lower preparedness for the threat of infectious diseases) are, against the odds, better able to mitigate the COVID-19 pandemic. Although epidemiological indicators are not optimal (as in Cluster 2), it can be said that these countries are coping well with the pandemic. These countries achieved a higher score, for example, in the indicators “emergency preparedness and response planning,” “emergency response operation,” and “access to communications infrastructure.” Therefore, it cannot be simply stated that the countries in Cluster 1 have a low overall score on the GHS index, as they may exceed the more advanced countries within clusters 4 and 5 in the sub-components of this indicator. This is illustrated, for example, by higher healthcare access in countries within Cluster 1 compared with Belgium, France, Spain, and Italy (Cluster 4). When comparing Cluster 1 and Cluster 5 (Netherlands, Hungary and United Kingdom), the results show that these three countries already significantly outnumber Cluster 1 countries in almost all categories (Prevent, Detect, Respond, Health, Norms, Risk). The exceptions are the indicators “epidemiology workforce” and “data integration between environmental health sectors,” which sound better for countries in Cluster 1. This implies that, although clusters 4 and 5 include above-average economically developed countries, that also have a very high GHS index score, this does not lead to lower fatality rate according to the GHS index in these clusters. Therefore, continuing the analysis and assessment of the level and intensity of implemented government restrictions across Europe is justified, as it may be another substantial factor for spatially different case fatality rate.

To further scrutinize our findings regarding the typology of countries into five clusters and differentiations in preparedness based on the GHS index, we analyze a series of restrictions to slow the spread of the virus. Table 4 presents the quantification of restrictions within clusters. A number of important differences emerge between European countries regarding the implementation of various constraints. The highest intensity of restrictions is in Cluster 1 (Central and Eastern European countries and Norway, Denmark, Sweden). This cluster of countries is characterized by below-average case fatality rates. Even within this cluster, however, there are differences in the intensity of restrictions. Sweden, with a liberal approach to dealing with the pandemic and the free movement of persons, is only partially restricted. Conversely, there are countries in Central and Eastern Europe that have introduced relatively fast restrictions. It is obvious that there are different trajectories leading to low values of fatality and death rates. However, it is necessary to recognize that Sweden’s approach is rather unique in this group of countries. Another important finding is that countries within Cluster 2 and Cluster 3 opted for less intensive restrictions, but also experience the lowest case fatality rates and death rates within Europe. So, generally, this result suggests that increased restrictions probably affected the slower virus spread rate and the subsequent lower fatality rate, but better results can also be achieved with less stringent restrictions. By contrast, Great Britain and the Netherlands (Cluster 5) showed the lowest restrictions (as averaging rate of total restrictions) at the end of March. However, the pandemic feature of these countries was also a significantly above-average case fatality rate (at least at the beginning of April, when this analysis was conducted). An approach by the governments of these countries favored a faster discharge of the population with novel coronavirus, but the capacity of the healthcare system was soon overloaded. A number of important differences, however, emerge.
between restrictions. Looking at partial details, e.g. the lowest average differences are in school closures (which prevail in almost clusters) and within the similar restriction of public gatherings. Conversely, very different approaches exist in the lockdown of people at home. This is particularly severe in cluster 4 (Italy, Spain, etc.), but this is also due to insufficient and overburdened medical capacities (so it is not a prevention, but a reaction).

In the last part of our analysis, we processed a scatter plot showing the relationship between the total score of the GHS index (Fig. 4), the overall intensity of the implemented restrictions (Fig. 5), and health care expenditures as percent of GDP (Fig. 6) within all countries - categorized into 5 clusters. It can be assumed that the countries with the highest level of restrictions chose a marginalization strategy at the beginning of the pandemic, ie the maximum limitation of the spread of the virus in the population. On the contrary, those countries that chose a mitigation strategy, ie a low level of restrictions, aimed at slowing down the passage of infection through the population. On the contrary, those countries that chose a mitigation strategy, ie a low level of restrictions, aimed at slowing down the passage of infection through the population. Fig. 4 presents some cursory evidence that suggests that European countries with a lower ranking within the GHS index may be negatively, and significantly, linked to much higher fatality rates. An example is Clusters 2 and 3 covering the GHS index may be negatively, and significantly, linked to much higher fatality rates.

Second, it is clear that strict restrictions are not the only method of coping with pandemic. An example is Clusters 2 and 3 covering the countries that have best dealt with the pandemic and show the best coping with pandemic. An example is Clusters 2 and 3 covering the countries that have best dealt with the pandemic and show the best

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### Table 3 (continued)

| Cluster | 1 | 2 | 3 | 4 | 5 | ANOVA sig. |
|---------|---|---|---|---|---|------------|
| FINANCING AND ADHERENCE TO NORMS | | | | | | |
| 5.1) IHR reporting compliance and disaster risk reduction | 70.0 | 62.5 | 69.2 | 75.0 | 83.3 | 0.882 |
| 5.2) Cross-border agreements on health emergency response | 100.0 | 100.0 | 96.2 | 100.0 | 100.0 | 0.914 |
| 5.3) International commitments | 99.4 | 98.5 | 98.1 | 100.0 | 97.9 | 0.344 |
| 5.4) JEE and PVS | 5.0 | 6.3 | 7.7 | 12.5 | 8.3 | 0.964 |
| 5.5) Financing | 20.0 | 25.0 | 35.9 | 50.0 | 44.5 | 0.342 |
| 5.6) Commitment to sharing of genetic & biological data | 66.7 | 83.4 | 69.3 | 83.4 | 77.8 | 0.175 |
| 6) OVERALL RISK ENVIRONMENT AND COUNTRY VULNERABILITY TO BIOLOGICAL THREATS | 81.4 | 76.0 | 71.1 | 81.7 | 74.9 | 0.061 |
| 6.1) Political and security risk | 85.7 | 75.9 | 78.0 | 82.2 | 82.1 | 0.122 |
| 6.2) Socio-economic resilience | 90.6 | 83.7 | 82.5 | 99.3 | 87.3 | 0.381 |
| 6.3) Infrastructure adequacy | 86.7 | 83.3 | 71.8 | 87.5 | 77.8 | 0.179 |
| 6.4) Environmental risks | 64.3 | 59.7 | 55.6 | 59.6 | 51.7 | 0.119 |
| 6.5) Public health vulnerabilities | 77.6 | 75.6 | 65.9 | 78.3 | 72.5 | 0.026 |

Data source: The Global Health Security index, www.ghsindex.org, own calculation.

Note: The highest score 100 the best.
countries was not as restrictive, yet their novel coronavirus management was the “best” (compared to other countries). Moreover, these are countries that have been prepared for a potential pandemic (according to the GHS index). Countries’ preparedness is closely associated with health expenditures as a share of GDP (see Figs. 5 and 6). The approach of these countries can be seen as more appropriate, since they did not have to reduce their economy as significantly (due to restrictions) in order to deal with the pandemic and are likely to continue to experience faster socio-economic growth after the pandemic (compared to CEE countries - most of cluster 1).

4. Conclusions and implications

This research has compared and contrasted the health and contextual factors within the COVID-19 pandemic, respectively during the first wave in Europe in real time. It has shed light on different restrictions, strategy and policy decisions to mitigate the spread of the virus and different “preparedness” levels of countries as an important prerequisite for the fight against the COVID-19 pandemic.

Based on factor and cluster analysis, we elaborated five clusters of countries and identified substantial epidemiological differences. There was an intriguing challenge to understand whether The Global Health Security Index can be a predictive indicator of the different initial effects of a pandemic and why the coronavirus SARS-CoV-2 has different impacts in different populations. The presented result of clustering based on health impact indicators on the population of each country in a real-time pandemic is certainly worth discussing from several points of view. We present our short demographic and economic reflections. In summary, the Global Health Security Index had a limited relationship with the impact of the pandemic in each country at the beginning of the pandemic.

In assessing the impact of a pandemic, we are in a situation where, in summary, we are comparing the results of health impacts on an elderly population that is most at risk in the COVID-19 pandemic - generations born in the first half of the last century (birth between the First and Second World War). This birth group of people experienced different conditions that shaped their lives and health and, undoubtedly, their

| Cluster | Mean Restriction | Air | Land | School | Public gatherings | Lockdown |
|---------|-----------------|-----|------|--------|-------------------|----------|
| 1       | 13,62           | 2,77| 2,85 | 2,92   | 3,00              | 2,08     |
| SD      | .870            | .439| .376 | .277   | .000              | .277     |
| 2       | 12,00           | 2,00| 2,00 | 3,00   | 3,00              | 2,00     |
| SD      | 0,000           | 0,000| 0,000| 0,000  | 0,000             | 0,000    |
| 3       | 13,00           | 2,40| 2,60 | 3,00   | 3,00              | 2,00     |
| SD      | 1,000           | .548|.548 | .000   | 0,000             | 0,000    |
| 4       | 13,25           | 2,00| 2,25 | 3,00   | 3,00              | 3,00     |
| SD      | .500            | 0,000| .500| 0,000  | 0,000             | 0,000    |
| 5       | 12,00           | 2,33| 1,67 | 3,00   | 2,67              | 2,33     |
| SD      | 2,000           | .577| 1,528| 0,000  | .577              | .577     |
| Total   | 13,15           | 2,48| 2,52 | 2,96   | 2,96              | 2,22     |
| SD      | 1,099           | .509|.700 | .192   | .192              | .424     |

Data source: Frontex, frontex.europa.eu, own calculation.

Note: 0 = not applicable, 1 = allowed, 2 = restricted, 3 = closed/banned; Overall score “Restriction” as a sum.

Fig. 4. Relationship between GHS index and Restriction index, 27 selected European countries divided into 5 clusters.
Data source: ghsindex.org, and frontex.europa.eu; own calculation.

Notes: GHS index (100 - maximum readiness, 0 - no readiness), Mean: 60,789 - vertical line.
Restriction index (15 – maximum restriction, 5 – minimum restriction); Mean: 13,15 - horizontal line.
Interlaced regression line (R Square = 0,444; Standardized Coefficient Beta = −0,666; Sign. <0,0001).

Fig. 5. Relationship between GHS index and Health expenditure as a percentage of GDP, 27 selected European countries divided into 5 clusters.
Data source: and frontex.europa.eu; own calculation.

Interlaced regression line (R Square = 0,467; Standardized Coefficient Beta = 0,683; Sign. <0,0001).
medical resilience.

In this respect, the results of the analysis indicate that above-average economically developed countries (within cluster 4 and 5) have a very high GHS index score and their readiness should be higher in many ways. This, however, does not lead to better health indicators. It can be concluded here that some of the most economically advanced European countries such as the United Kingdom overestimated their economic advantage, delayed the introduction of vigorous measures till much later, which did not stop the epidemic and led to tragic loss of lives. Conversely, a typical feature of Cluster 2 and 3, including the least affected countries with relatively low levels of fatality and mortality, also reached a very high overall score on the GHS index. Therefore, it can be seen that countries with similar GHS scores follow very different trajectories in terms of pandemic progress. Another important finding is that countries within Cluster 2 and 3 adopted fewer intensive restrictions, but at the same time reached the best health index within Europe.

Further, European countries within cluster 1 (with lower preparedness of the pandemic system) are, against the odds, able to mitigate against the COVID-19 pandemic. However, it is essential to note that these countries do not have an equally high percentage of elderly population (the most vulnerable group within novel coronavirus) compared with the more developed countries. A possible explanation for this effect is not only in demography, but also in the strength and intensity of restrictions that have been implemented by national governments. The highest intensity of restrictions is in Cluster 1 (Central and Eastern European countries and selected Scandinavian countries), which adopted relatively fast and effective restrictions, and these countries are characterized by below-average case fatality rate, the spread of the virus was successfully reduced and the epidemic wave was very mild. However, it is necessary to stress that these are not linear relations and findings on the effects of restriction categories, as well as score of GHS index, must be interpreted with caution. Different approaches to fight COVID-19 can be seen at the selected country level. However, the relationship between the quality of the institutional environment and the degree of restriction should be precisely quantified in future research.

Moreover, early evidence from several settings globally indicates that rigorous public health measures, particularly related to isolation and social distancing, implemented immediately after identifying cases can reduce, significantly contributed to reducing the spread of the virus and reducing the viral load in the population.

Empirical analysis in this paper takes a first step toward understanding the spatially different spread of novel coronavirus and an explanation of the spatial variation of health indicators, including predictors. As with any other paper, however, there are some limitations that should be taken up in future research. There is a number of limitations associated with geographical research into the initial spread of COVID-19, related to differences in both case recording and case detection (testing), there are many people with coronavirus but without confirmed cases. But, for this analysis we had to work with official statistics. Moreover, the number of deaths is based on country-by-country reporting principles. As for restrictions, we recognize that only the restrictions implemented at the end of March entered our analysis. It would be preferable to take into account the dynamic view of the gradual introduction of restrictions in individual countries. Such data was schedule as of April 8, 2020 unavailable.

Furthermore, it is necessary to mention the economic context of the COVID-19 pandemic, which cannot be measured in this article, but is closely related to the subject under investigation. There are always two main strategies: marginalization or mitigation of the virus. National governments face the dilemma of how to protect human health while limiting the economic impact of restrictive measures and must decide when to limit those measures. Protecting human health from infectious diseases such as COVID-19 requires reducing the spread of the virus. The spread of the virus can only be effectively reduced through strict, economically demanding preventive measures. The analysis of the early stages of the pandemic confirmed that in countries where anti-pandemic measures were implemented quickly and consistently, the spread of the virus was suppressed more quickly and the first wave of the pandemic in these countries was incomparably more favourable than in countries with delayed response.

As our paper shows, less economically developed countries in the European context have introduced quickly much stronger restrictive government measures to limit the spread of virus, and the case fatality rates are significantly lower in these countries. However, it is necessary to point out that the economic convergence of these less developed countries in Central and Eastern Europe to the European “core” is limited and the strength of the restrictions could undermine their further economic performance.

Therefore, the future research agenda should be aimed at clarifying the different economic impacts in different countries according to the effectiveness of the intensity of implemented restrictions to the reduction of the virus. In this sense, it can be assumed that strong restrictions in CEE have led to a reduction in the burden on health care facilities and thus to the protection of lives and low overall fatality rates.

But as a result, these countries, which chose the marginalization strategy and protected the health of their populations more effectively by substantially reducing the viral load, may have been much more negatively impacted economically than more advanced countries in Western or Northern Europe. Subsequent developments have shown that during further epidemic waves, some countries changed strategic approaches to the pandemic. In the first wave, the countries that were among the most successful in suppressing the virus did not repeat the timely and vigorous approach of restrictions that had led to the suppression of the virus. An example is the Czechia, which had minimal deaths per covid due to timely and rapid marginalization in the first wave of the pandemic. However, this was followed by an alternation of vigorous loosening of measures with late measures, and as a result of these two more high epidemic waves by the end of 2020.

It can be concluded that the alternation of marginalization and mitigation approaches is related to the formation of high epidemic waves and significantly negative health indicators. One possible explanation for why successful countries in the initial phase of a pandemic did not repeat the success in subsequent phases may be that the
marginalization strategy did not provoke an epidemic wave, and so populations often became convinced that strong restrictions were unnecessary. With the re-emergence of the virus, governments have become more cautious, restrained, often imposing restrictions late and less effectively.

The analysis of the onset of the pandemic showed that immediate and severe restrictions were highly effective in reducing the number of infections at the beginning of the pandemic in European countries and resulted in fewer deaths. Delayed interventions did not push the wave in a short term, and thus were associated with higher numbers of deaths, and higher economic losses can be expected.

One of the latest studies published in the Lancet (published online April 28, 2021) under the title: “SARS-CoV-2 elimination, not mitigation, creates best outcomes for health, the economy, and civil liberties” corresponds to the conclusions and currently complements our analysis. The study showed that milder measures harmed the economy more than severe restrictive measures (lockdowns) (Barton et al., 2021).

**Declaration of competing interest**

None.

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