Analele Universităţii din Oradea, Seria Geografie **XXXII**, no. **1/2022**, pp. **1-15**
ISSN **1221-1273**, E-ISSN **2065-3409** DOI **10.30892/auog.321101-875**

SPATIAL PATTERNS AND DRIVERS IN THE EVOLUTION OF COVID-19 PANDEMIC IN ROMANIA (MARCH 2020-JUNE 2021)

Ionel MUNTELE*
”Alexandru Ioan Cuza” University of Iași, Faculty of Geography and Geology, 20A Carol I Av., 700305, Iași, Romania;
Romanian Academy, Iași Branch, Geographic Research Center, 5 Carol I Av., 700307, Iași, Romania;
e-mail: imuntele@yahoo.fr; imuntele@yahoo.fr

Citation: Muntele, I. (2022). Spatial Patterns and Drivers in the Evolution of Covid-19 Pandemic in Romania (March 2020-June 2020). *Analele Universităţii din Oradea, Seria Geografie, 32*(1), 1-15. https://doi.org/10.30892/auog.321101-875

Abstract: The manifestation of the Covid-19 pandemic raised great interest due to the speed with which it spread globally and by outlining specific diffusion patterns. Romania faced off early on the rise in the number of infections, initially, as in other European countries, extremely localized but later expanded nationwide. The analysis of the available information regarding the evolution of the number of infections and deaths caused, over a sufficiently extended period (March 2020-June 2021) allowed the identification of several spatial patterns. Their regional coherence indicates a series of correlations with socio-economic factors, validated by PCA (principal component analysis). The importance of economic development, in connection with the degree of urbanization, employment and labour mobility or population density thus explains the incidence of the number of cases at a level higher than the national average. In the case of death caused by Covid-19, the quality of the health infrastructure played an important role, the counties with a higher level of endowment being less affected. At the same time, the share of the elderly population, in association with the less populated rural area, was not positively correlated with the number of cases or deaths. Lower population interaction, weaker exposure to international mobility has created the premises for a specific pattern of evolution in these areas.

Key words: Covid-19, pandemic waves, regional patterns, disparities, factorial analysis, Romania.

* * * * * *

INTRODUCTION

In an insecure world, increasingly complex and predisposed to unpredictable, unwanted and unavoidable manifestations, the Covid-19 pandemic triggered in a still obscure context is just one of the “black swans” that take human society out of rhythm, through what N.N. Taleb called the “very unlikely impact” (Taleb, 2018). The onset of a pandemic is only a matter of time, a probability among many others, and the way in which the governments have reacted only confirm their untimely nature, which does not necessarily take into account the level of development but is dependent on globalization. From this point of view, Romania, a state located in Eastern Europe,

* Corresponding author

could not be outside the pandemic circuit given its strongest relations at the continental level (mass emigration to countries like Italy or Spain, strongly affected by the “first wave”) or transit position to/from the former Soviet Union and the Middle East. Thus, when the WHO declared Covid-19 a global pandemic, on 11.03.2020, Romania already registered 47 cases, of which 18 newly confirmed, only two weeks after the first case confirmed in Gorj County (southwest of the country) as contact of a person from Italy. After only 11 days, the first deaths caused by the new virus were registered, the country thus entering the wake of a dynamic that seemed to get out of control, since March 16 the state of emergency was declared. Subsequent developments have allowed a slight relaxation in the summer of 2020 for the second wave to hit hard in autumn, as in the rest of Europe, imposing restrictive measures targeting the most affected areas. Thus, the epidemic was calmed in the first months of 2021, the measures taken being overcome by the third wave that hit especially the eastern states of the continent, at the same time with the start of the vaccination campaign. Although immunization has not progressed at a rapid pace, as would have been desired, partly due to the reluctance of part of the population, partly due to the lack of determination in the application of immunization measures targeting vulnerable groups, this spring has brought a drastic reduction in both the number of illnesses and deaths caused.

The possibility of a ”four wave” is invoked in the political environment, the evolution so far indicating a certain seasonal cyclicality in the manifestation of the pandemic, permanently modified by the genetic mutations of the virus (Audi, et al., 2020; Liu, et al., 2021). During all this time, various variables have been invoked to explain the spread, often specific to the virus, whether we are talking about population structure (advanced aging of the European population for example), the degree of population concentration (urbanization, density) or of particularities of the public health infrastructure. The impact of the restrictive measures adopted, differing from one state to another, although they had a definite role, does not indicate the primacy of a certain pattern, whether we refer to the excessive constraining model from the country where it started the pandemic or more relaxed models like the Swedish one.

LITTERATURE REVIEW

The pandemic triggered by the Covid-19 diffusion generated a wide illustrated scientific interest a wide scientific interest. The approximately 1,220,000 specific entries resulting from a simple Google Scholar search (as of July 1, 2021) illustrate it. The variety of approaches, from the strictly epidemiological to the sociological, economic or psychological ones, makes it difficult to review all the results presented. The swiftness wherewith the scientific world reacted is closely linked to access to information, even if often contradictory, but also to the desire to help identify solutions able to limit the effects of the pandemic.

The purpose of this approach, to test the existence of regional models of diffusion and manifestation of the pandemic in Romania, limits the bibliographic analysis to those works that approached the phenomenon from a spatial perspective.

From the perspective of the spatial diffusion of the pandemic, multidimensional studies have highlighted the fact that there are no fundamental parameters. Bontempi et al (2020 consider that the geographical diversity of contagion diffusion patterns requires the analysis of complex outcomes, te spread of the pandemic being caused by a multiplicity of environmental, economic and social factors (Bontempi, Vergalli, & Squazzoni, 2020). Just like other pandemics, such as the one caused by AIDS, some authors consider that there is a spill over (wildlife-livestock-patient 0) and an international spread, from one country to another and from city to city, imposing an international cooperation and institutional coordination to limit the effects (Wu, 2021). Social distance and quarantine may be needed in the immediate aftermath of an outbreak. The observation from the study that the spread of the recent pandemics follows the same pattern in different regions of the world is not without interest, being a function of population size, the epidemiological model having a fractal structure generated by strong connections between large metropolitan areas (Abbasi, et al., 2020). The importance of population mobility was studied even in the Romanian case where, at least in the first phase of diffusion, it was closely related to the circular migration for work to Western European countries (Hâncean, Perc, & Lerner, 2020).

Factors associated with Covid-19 diffusion have been extensively analysed, both from the perspective of the multiplication of infection cases and death caused. Although the quality of available information is contestable, there has been some temporal overlap in the magnitude of the pandemic, depending on the ability and effectiveness of public health policies (Jinjarak, Ahmed, & Nair, 2021). The close correlations between economic, social and cultural factors are frequently invoked (Mogi & Spijker, 2021), associated with population density. The latter factor imposes very strict measures of social distancing. It is difficult to notice a general model of factor analysis, the specific studies being limited by the access to information, by their correctness. Differences between states, derived from the different way in which the information is collected and reported, have generated more attention to studies at national or regional level. Since the beginning of the pandemic, there have been studies that have tried to systematize the factors (drivers) involved in its development: pace, global interconnectedness, health sector capacity, state capacity, immediacy which risk cascaded from the health system to economy, societal polarization and fragmentation (Collins, Florin, & Renn, 2020). This is how the indicated solutions for limiting the risk appeared, through investments in resilience, the attention paid to key nodes in the system and immediate action in the initial outbreaks. There were also frequent studies that took into account in the first phase of the spread of the pandemic geographical factors such as climate (temperature, precipitation) or the incidence of pathogens (malaria) along with the incidence of BCG vaccination, without being able to establish strong correlations (Kubota, Shiono, Kusumoto, & Fujinamal, 2020).

Large-scale studies, conducted at the continental level, have captured strong spatial disparities. The heterogeneous impact, both at national and regional level or between cities was explained by factors such as the aging population, the frequency of comorbidities, on the background of quality of life (health and income). Thus, an attempt was made to understand channels through which the pandemic spread and to emphasize the regional socioeconomic dimension (Amdaoud, Arcuri, & Levratto, 2021). Studying 125 regions in the European Union, the cited paper established the existence of strong correlations with gross domestic product, unemployment, quality of medical infrastructure (number of physicians, hospital beds etc.). There were also strong correlations with the presence of events with mass participation or with social trust. The analysis of the specific situation in some states highlighted the importance of isolating the vulnerable population (those over 65 or with comorbidities), targeting this category through the measures taken can ensure the partial preservation.

Of particular interest was the balance between the two risks, epidemic and socio-economic. The economic impact of implementing isolation measures has been strong enough, from an ecological perspective, rather beneficial, reducing energy consumption (Werth, Gravino, & Prevedello, 2021). The search for an optimal equilibrium, by analysing the specific situation in China, the United States, Brazil or Europe, attests to the importance of geographical distribution, considered fundamental in imposing social distance (Abbasi, et al., 2020). In this regard, analysing the situation of measures taken in the European Union in the spring of 2020, the need for a complex intervention package was invoked, including home isolation of cases, household quarantine, school closure, (Vokó & Pitter, 2020). An attempt was also made to analyse the correlation between the severity of the pandemic and governments handling (Imtyaz, Haleem, & Javaid, 2020). Thus, the importance of mass testing and lockdown measures or the imposition of spacing norms was invoked. And in the case of Romania, studies were carried out that tried to observe the effect of control measures (Dascălu, 2020). In this way it was concluded that the fast implementation of control measures successfully averted a surge in the number of Covid-19 cases. The importance of the initial government response was important in the management of the pandemic crisis. Romania had to manage in March 2020, a massive flow of returning citizens who went abroad (over 250,000 this month alone). The same study also indicates the importance of socio-cultural factors in controlling the epidemic, although these are difficult to analyse. Studies indicating the resurgence of cultural tensions (ethnic, racial) attest to their importance (Crețan & Light, 2020) on the situation of the Roma community in Romania or Shulz, et al. (2020) on the situation of African-American communities in Detroit, in both cases being invoked stronger exposure to the effects of the pandemic). Such studies are important becauze they brought into question health equity, a key factor in the spread of the pandemic and its effects, including access to the vaccine, starting in late 2020.

Based on the considerations presented in the introduction and the conclusions of the analyzed studies, this approach propose an analysis of the evolution of Covid-19 infections and fatal cases over a sufficiently long period of time to allow the delimitation of regional patterns in a medium-sized country such as Romania. The study period, March 2020-June 2021, captures the three epidemic waves established and mainfested globally, including in Romania (Solis, Franco-Paredes, Henao-Martinez, Krsak, & Zimmer, 2020; Fisayo & Tsukagoshi, 2021; Graichen, 2021; Taboada, et al., 2021).

The main hypothesis of the study starts from the observation of the evolution of the Covid-19 infection. This evidence is explained by the existence of favourable or restrictive factors, whose incidence is not unitary in spatial profile. In a synthetic formulation, he study tries to test the hypothesis that the pandemic diffusion patterns and drivers were dependent on Romania's particularities from the perspective of the level of development, population distribution and quality of medical infrastructure.

MATERIALS AND METHODS

To test the hypothesis, information was collected from several well-known sources ((Worldometers, March 2020-June 2021; Coronavirus COVID-19, Romania, March 2020-June 2021; National Institute of Statistics, March 2020-June 2021). Based on these sources, several series of processed data were created, regarding the incidence of Covid-19 infections and the evolution of the number of deaths due to them, as follows:

a) A global database, having as source Worldometers, the information being summed at continental level, related to 100,000 inhabitants. These data are used to establish which was the particularities of Romania in the study period, presenting a contextual interest;
b) A comparative database on the evolution of mortality between January 2015 and April 2021, following the manifestation of a surplus due to the pandemic between March 2020 and April 2021. The information has synthesized at regional level, on the three major historical divisions of the country (Moldavia, Wallachia and Transylvania) to capture the occurrence of some disparities;
c) A database at national level, having as basic source Covid-19, Romania. The data were collected at county level and statistically processed in the form of dynamic typologies that established the manifestation of distinct profiles during the analysed period (March 2020-June 2021). This descriptive analysis serves to substantiate the factor analysis. The data were reported differently, per 100,000 inhabitants in case of infections and per 1,000,000 inhabitants in case of deaths.
d) A factorial data base regarding 12 variables, two of them being taken into account as dependent variables and the other as explanatory variables as follows:
    - the incidence of the number of cases of Covid-19 between March 2020 and June 2021, expressed per 100,000 inhabitants (CS);
    - the incidence of deaths caused by Covid-19 between March 2020 and June 2021, expressed as a percentage of the total number of cases (DCS);
    - the number of physicians, reported per 100,000 inhabitants, in 2019, the last year for which the INS provides data (PHS);
    - the number of average medical staff, reported per 100,000 inhabitants, in 2019 (NRS);
    - the number of hospital beds, reported per 100, 000 inhabitants, in 2019 (HB);

- the gross domestic product in 2020, expressed in lei per capita (GDP);
- the degree of urbanization in 2020, expressed as a percentage of total resident population (URB);
- the density of the resident population in 2020, expressed in inhabitants per km^2 (DNS);
- the mobility of the population (arrivals and departures with residence, including international migration), in 2019, expressed as a percentage of the total population (MOB);
- the share of the elderly population (over 65 years) in the total population, in 2020, expressed as a percentage of the total population (AGP);
- the share of the population with secondary and higher education in the total population over 15 years, according to the 2011 census, expressed as a percentage (SHE). The mentioned census is the last one carried out in Romania;
- the share of the employed population from the active population in 2020, expressed as a percentage (EMP).

All these statistical series, collected from the official databases of INS (National Institute of Statistics, March 2020-June 2021; 2011 Census) were subsequently standardized according to the extreme values. Z-score was used for standardization, obtaining comparable values for each variable, between 0 and 1.

Methodologically, the descriptive typological analysis used AHC model (agglomerative hierarchical clustering), available in Xlstat, the 2015 version produced by Addinsoft. The Euclidean distance and the Ward method were used to separate the classes, aiming that the dispersion of the intra-class values is clearly lower than that between the classes. For both typologies (evolution of the number of cases, respectively evolution of the number of deaths), 6 classes were retained, at a dispersion of intra-class values (within class) of 33.78%, respectively 26.76%. Respecting these criteria, the classes obtained are distinguished by homogeneity and specific profile.

The factorial analyses were performed on the 12 standardized variables, opting for the PCA variant (main component analysis) proposed by the same Xlstat program. The use of the Pearson correlation coefficient, the Chi-square significance test, a p-value lower than 0.0001 and regression coefficients (R^2) as high as possible, ensures the validity of model. The first PCA had as a dependent variable the number of cases of Covid-19 (CS), registered between March 2020 and June 2021 at county level, compared to 100,000 inhabitants. In this analysis, the number of deaths caused was not taken into account, the 10 explanatory variables (PHS, NRS, HB, GDP, URB, DNS, MOB, AGP, SHE, EMP) being selected to illustrate both social and economic or spatial features. No physical-geographical variables were introduced because the climatic differences are relatively small in Romania. Environmental variables such as the degree of pollution or indicators related to the quality of the environment could not be integrated into the model, lacking the information on the study scale used. The second PCA had as a dependent variable the number of deaths caused by Covid-19 (DCS), reported per 1,000,000 inhabitants, including in the list of explanatory variables, the incidence of Covid-19 infections. In order to detect as accurately as possible the relationships between the variables, the statistical program mentioned also operated a Varimax rotation.

The results of the two PCA were processed to obtain graphic and cartographic materials using Adobe Illustrator CS 12.

RESULTS AND DISCUSSIONS

A first analysis presents the global context in which the pandemic took place. The calculation of the quarterly incidence of the number of cases and death caused by Covid-19, based on data from sources mentioned in the previous chapter, shows that Romania has closely followed the trends in Europe (Table 1).

Table 1. Dynamics of the COVID-19 cases and induced deceases between January 2020 and June 2021 (Data source: Worldometers (Worldometers, March 2020-June 2021); Coronavirus COVID-19, Romania (https://covid19.geo-spatial.org, consulted between Mars 2020 and June 2021)

	Cases per 100,000 inhabitants						Deceases per 100,000 inhabitants					
	01-03 2020	04-06 2020	07-09 2020	10-12 2020	01-03 2021	04-06 2021	01-03 2020	04-06 2020	07-09 2020	10-12 2020	01-03 2021	04-06 2021
ROMANIA	**13**	**129**	**530**	**2624**	**1672**	**631**	**2**	**7**	**17**	**67**	**30**	**41**
Europe	66	261	359	2528	2149	1106	12	13	5	44	28	25
Asia	4	47	183	218	172	597	0.3	1	3	3	1	8
Oceania	14	9	52	41	21	54	0.2	0.1	2	0.3	0.2	0.3
Africa	1	31	82	99	112	101	0.1	1	2	2	2	2
South America	5	506	1294	1207	1844	2656	1	27	40	26	37	80
North America	41	537	1040	2594	2182	788	6	24	27	37	30	18
WORLD	**12**	**127**	**309**	**649**	**595**	**694**	**2**	**5**	**7**	**11**	**8**	**14**

The first wave of infections in spring 2020 was significantly lower than the European average, similar to most Eastern European countries, which can be explained both by the firmness of the limitation measures in March 2020 and by lower testing (Sulyok, Ferenci, & Walker, 2020; Mogi & Spijker, 2021). Since the summer of 2020, however, like many neighbouring countries, Romania has entered a phase of accelerating infections, far exceeding the European average incidence, including in terms of deaths. The increase in October-December, constituting the peak of the pandemic, followed the European average but with a much higher mortality rate, determined by the overload of medical infrastructure but also by the ambiguity of limitation measures, generated by the insistence of the deployment at any cost of the planned electoral program. Subsequently, in the first half of 2021, the situation gradually improved, the third wave of infections, manifested in March-April, being much diminished. The same did not happen with the deaths, which remained at a higher level than the European average, which can be explained by the accumulation of a critical mass of serious cases in the intensive care units in early spring. The excess mortality in Romania can be explained by the poor resilience of the public health system (Popic & Moise, 2021).

Compared to the global average incidence, like Europe as a whole, Romania presented by the spring of 2021 much higher values comparable to those in North America. Compared to Asia, the source of the pandemic, the differences are related to the amplitude of infections, the trends being relatively similar, except for the last months (April-June 2021) in which there was a rapid spread of the delta variant. The southern continents (South America, Oceania, partly and Africa) show a certain reversal of trends, with obvious peaks during the cold southern season (Smit, et al., 2020).

However, from the perspective of death caused, Romania is among the most affected states in the world, on July 1, 2021 being on the 23rd place with 1791 cases per 1,000,000 inhabitants, most affected states being located in Eastern Europe and Latin America. Over mortality due to Covid-19 infection, including cases caused by reduced addressability and poor functioning of health services, was even higher, in 2020 the general mortality of the population being 13.5% higher than the average for 2015-2019, a trend maintained in the first five months of this year (Table 2).

Excess mortality is widespread, mainly in urban areas and is only partially explained by the incidence of Covid-19. The much higher level than other European states shows the deficiencies of Compared to the global average incidence, like Europe as a whole, Romania presented by the spring of 2021 much higher values, comparable to those in North America. The public health system in Romania, being highlighted in some studies (Bogos, et al., 2021). Despite all the limitations imposed by the correctness of the information, the regional disparities are explicable. The lower excess mortality in the south and east of the country reflects the preponderance of the rural population and the higher incidence of deaths caused by Covid-19 in Moldavia may be related to the lower level of development. This evidence is also in line with the results of studies on the evolution of life expectancy at birth in Romania, which indicated a slower growth of this indicator in less developed regions (Muntele, Istrate, Bănică, & Horea-Şerban, 2020). It is assumed that this excess mortality will also lead to a temporary decrease in life expectancy.

Table 2. Evolution of mortality between 2015-2019, in 2020 and in the first five months of 2021, by area of residence and by historical regions
(Data source: Coronavirus COVID-19 on Romania (https://covid19.geo-spatial.org, consulted between Mars 2020 and June 2021); Database Tempo-Online (National Institute of Statistics, March 2020-June 2021); Buletinul statistic lunar al județelor (National Institute of Statistics, March 2020-June 2021))

	The difference between the number of deaths in 2020 and the average for 2015-2019 (%)			Idem for january-may 2021	Covid deaths related to excess mortality (%)	
	Total	Urban	Rural	Total	2020	2021(jan-mai)
ROMANIA	**13.5**	**18.6**	**8.9**	**19.0**	**46.6**	**63.0**
Transylvania	15.1	18.6	11.4	22.7	51.0	63.5
Wallachia	13.3	18.2	8.5	18.0	40.6	57.3
Moldavia	11.6	19.9	6.9	15.7	52.6	65.8

Typology of the evolution of Covid-19 cases and associated deaths

These disparities are even better revealed at regional level by the typology of the evolution of Covid-19 cases and deaths caused by it, according to the territorial database at county level. The existence of a regional profile and a diffusion correlated with the level of economic development is evident both in terms of the evolution of cases and deaths.

The first typology is marked by the relative spatial cohesion of the classes, with a profile similar to the national average, in which the first wave is less expressed and the next two are more clearly marked. The first four classes form a distinct group with values of incidence of cases below average for most of the study period, the last two being distinguished by the virulence of the infections during waves 2 and 3 (Figure 1).

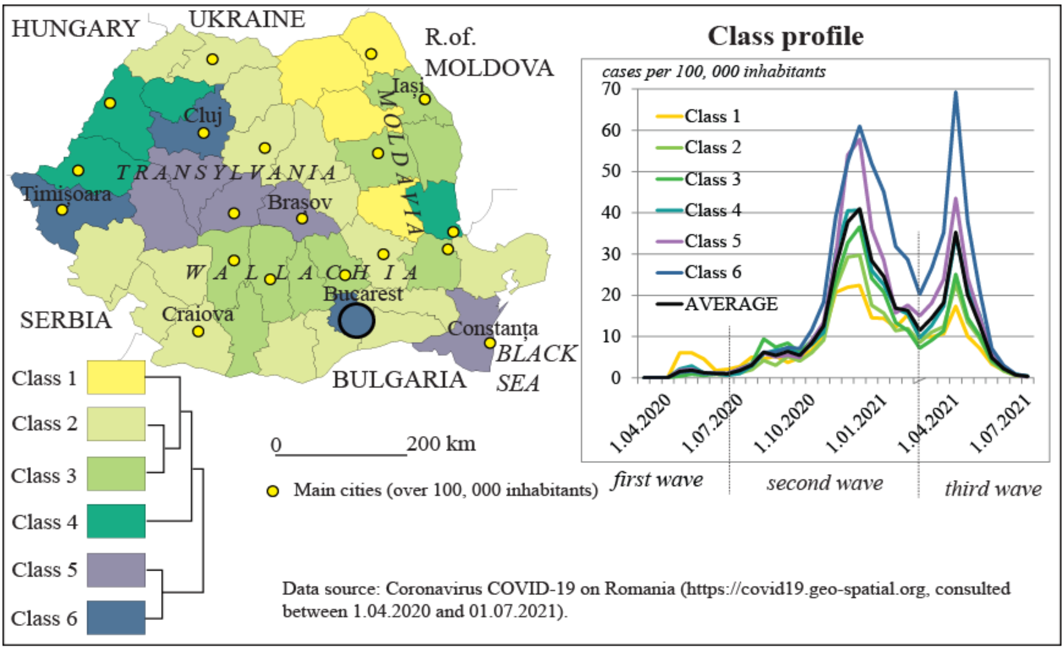

Figure 1. The typology of the evolution of Covid-19 cases in the perioad March 2020-June 2021

Class 1 is the only one in which the first wave is clearly highlighted by a rapid increase in cases in the spring of 2020, simultaneously with the most affected areas in Europe (northern Italy, Spain). It includes the northwest and southwest of Moldavia, with Suceava county in the foreground, in which the epidemiological crisis manifested itself strongly in April-May 2020, attractng from the media the nickname ”Lombardy” of Romania. The precocity of the virulent manifestation of the infection can be attributed to the circular migration as invoked by certain studies (Lobiuc, Dimian, Gheorghiță, Caliman-Sturdza, & Covasa, 2021), the region being known for its magnitude, to which is added the precariousness of the medical infrastructure. Paradoxically, in Romania, the pandemic first manifested itself in predominantly rural areas such as the one mentioned. As the pandemic progressed, in waves 2 and 3, the virulence was well below the national average, probably limited by harsh measures (quarantine of Suceava and neighbouring communes in the first part of 2020).

Classes 2 and 3 are also distinguished by a lower than average incidence, being located in spatial continuity with class 1. They dominate the south and northeast of the country, the difference between them being given by the episodic rise of cases of infection in the summer of 2020 as regard type 3. In contrast, type 2 has always experienced a certain moderation in the evolution of infections. Located in the central-northern part of Wallachia and in the central part of Moldavia, both relatively densely populated, marked by the circular migration of labour, these areas seem to be known in July-September 2020 a late manifestaton of wave 1, possibly favoured by restricting limitation measures. This phenomenon had a general occurrence but in these areas it was much more accentuated. Class 4 corresponds altogether to the national average, showing more obvious accentuation trends since last autumn. Grouped in the northwest of the country, to which is added Galati County in the eastern part, it completes the circular arch that separates the areas most affected by Covid-19.

Classes 5 and 6 are distinguished by the spectacular increase in Covid-19 cases during waves 2 and 3. It forms three distinct cores: one more spatially extended, comprising southwestern Transylvania and part of Banat regions; another characterizing the capital and the neighbouring county of Ilfov; the last, in the southeast it adds Constanța County. The coincidence with the higher level of development of these areas and with strong urbanization cannot be coincidental as the massive insertion in the circuits of international mobility. Class 6 which effectively groups the most dynamic areas of the country (capital, Cluj and Timiș counties) is distinguished by the exceptional peak of the third wave but also by the steep fall that followed, possibly correlated with more active vaccination in these heavily urbanized and developed areas.

The typology of the evolution of the Covid-19 cases highlights, in conclusion, a certain manifestation of some regional models, explicable by the incidence of some socio-economic factors. These patterns are also manifested from the perspective of the evolution of deaths.

The second typology emphasizes more spectacular oscillations and stronger territorial disparities (Figure 2). Under-registration can be raised, but it also manifested itself in terms of case records. Further, strictly local studies may highlight the importance of the quality of public health infrastructure and the readiness of response to pandemic challenges. The fact that the first class groups only Suceava County, in which the extremely high incidence (compared to the national standards at least) in the first phase of the pandemic is required, can be related to the factor invoked above. It is no coincidence that the extreme case of militarized control and prolonged quarantine of maximum risk areas has been reached to reduce what appeared to be a catastrophe. Although contestable, these measures had positive effects over time, third wave manifesting itself more moderately in this county.

Class 2 extends into the central-western part of the country, to which are added more isolated Bistrița-Năsăud in north and Brăila in the southeast. These are distinguished by the much higher than average recrudescence of deaths caused by Covid-19 during second and third wave. These can be considered, along with Suceava, as the most affected areas. The quality of the health public infrastructure in this case is not necessarily poor, compared to the national average, the explanations that can be provided, along with the partial overlap with the areas that recorded the highest number of infections, rather due to a certain vulnerability created by the specific context, being more urbanized and more developed counties in general, with a high labour mobility.

Class 3 group most of Moldavia and Mureș County, in which the evolution of deaths registered certain precocity, similar to class 1, between May and June 2020 but later evolved rather according to the national average. The spatial homogeneity of this class can be considered representative for Moldavia.

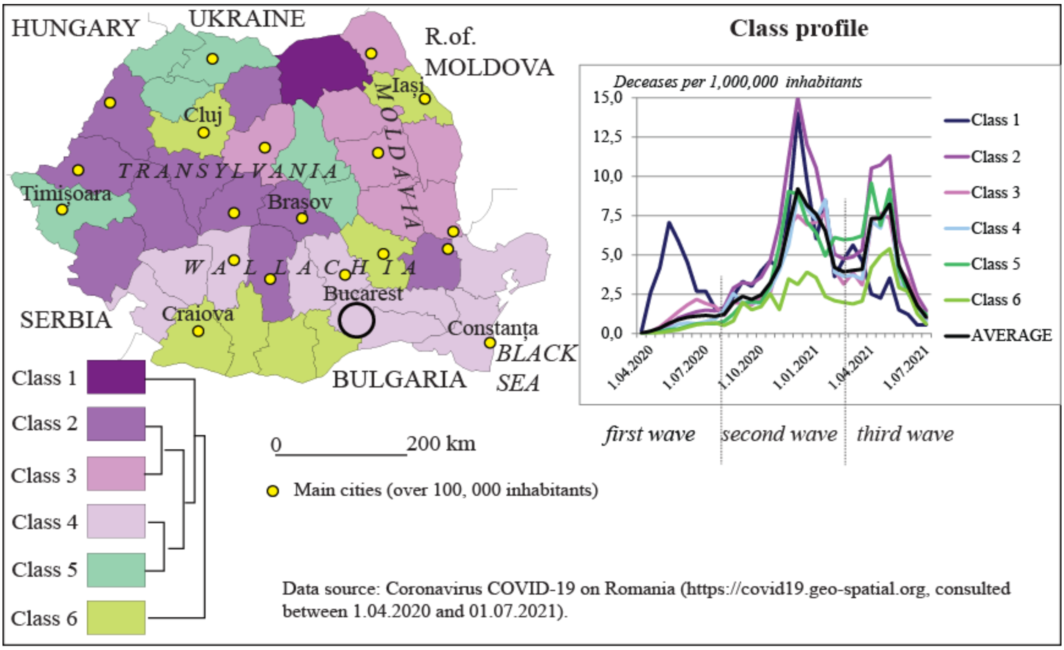

Figure 2. The typology of the evolution of Covid-19 deceases in the period March 2020-June 2021

Class 4, closely follows the national average and is distinguished by the moderation of the second and third waves. The area of expansion, although fragmented, has a certain spatial coherence, covering most of the southern part of the country from Oltenia to Dobruja. It may be considered a southern model, including also the capital, Bucharest.

Class 5, spatially fragmented, includes three rather heterogeneous areas: Timiș County, one of the most developed in the far west; north-western Transylvania, an area strongly marked by circular labour migration to Europe; eastern Transylvania, comprising the two counties with predominantly Hungarian population (Harghita and Covasna), the ethnic factor can be invoked at least in this case by the relative isolation of some communities. The relative increase in deaths, especially during third wave, provides a special profile for this class, constituting somewhat an extension of class 2, together with which it forms the Transylvanian model of evolution.

Class 6 includes a more unitary area, in the extreme south of the country, a predominantly rural area and strongly affected by the aging population, to which is added to the east, with similar features, Buzău County. The counties of Iași and Cluj join through a similar profile, marked by a much lower incidence of deaths caused by Covid-19 even if the number of cases was high. If in the extreme south can be invoked the relative isolation of aging rural population that limited spread of infection, Cluj and Iași counties seem to have responded better to the challenges of the pandemic, being much well equipped from the perspective of medical infrastructure and staff, as university medical centres. The question may arise why Timiș or Bucharest, with similar characteristics, was more strongly affected by fatal cases, but the answer can only be provided by comparative case studies after the pandemic passes.

In conclusion, the typology of the evolution of death cases highlights strong disparities related to the socio-economic specificity and the quality of public health system. The spatial distribution of types is significantly different as a result of the distinct way in which communities have responded to the pandemic challenge.

Factorial analysis of the evolution of Covid-19 cases and associated deaths

In order to test the extent to which the factors related to the socio-economic specificity and the quality of the public health infrastructure, two PCA (principal component analysis) were operated, according to the model set out in the methodology.

The first PCA tries to capture the context in which the expansion of Covid-19 infection took place in territorial profile, having as spatial reference the 41 counties and the city of Bucharest. The dependent variable (CS) is strongly correlated with most of the 10 explanatory variables introduced in the model. Only the NRS variable has a weaker correlation, thus indicating that the insufficiency of the medical assistance staff does not explain the dynamics of the pandemic in the Romanian case. Instead, socio-economic variables such as GDP, SHE, EMP show a close correlation, explaining the virulence with which it manifested itself in second and third pandemic waves in the capital and more developed counties (Timiş, Cluj, Brașov, Sibiu), with a higher employment rate and a higher level of education (Table 3). The correlation with the share of the elderly population is negative, contrary to the conclusions of studies conducted in other countries (Buja, et al., 2020), due to the fact that population aging is more advanced in rural areas, often characterized by a population dispersion that has decreased virus spread. The correlation with the urbanization and population density is also strong enough, thus certifying the importance of the population agglomeration in the diffusion of the studied phenomenon. Among the indicators related to the health infrastructure, the strongest connection is given by the number of physicians, closely related to the others. The elaborated analysis model is validated by a very high value of the coefficient R^2.

Table 3. The correlation matrix between the variables analysed for the evolution of Covid-19 infections, between March 2020 and June 2021

(Data source: Coronavirus COVID-19 on Romania (https://covid19.geo-spatial.org, consulted between Mars 2020 and June 2021); Database Tempo-Online (National Institute of Statistics, March 2020-June 2021); Buletinul statistic lunar al județelor (National Institute of Statistics, March 2020-June 2021))

Variables	CS	PHS	NRS	HB	GDP	URB	DNS	MOB	AGP	SHE	EMP
CS	1	**0.598**	0.286	**0.427**	**0.851**	**0.683**	**0.603**	**0.450**	**-0.439**	**0.842**	**0.776**
PHS		1	**0.783**	**0.793**	**0.694**	**0.635**	**0.388**	0.303	**-0.398**	**0.802**	**0.637**
NRS			1	**0.840**	**0.495**	**0.617**	0.198	0.115	-0.205	**0.565**	**0.441**
HB				1	**0.585**	**0.639**	0.266	0.151	-0.188	**0.652**	**0.543**
GDP					1	**0.723**	**0.510**	0.261	**-0.406**	**0.928**	**0.865**
URB						1	0.189	0.141	-0.302	**0.780**	**0.780**
DNS							1	**0.477**	**-0.448**	**0.553**	0.302
MOB								1	**-0.313**	0.279	0.086
AGP									1	**-0.495**	**-0.464**
SHE										1	**0.883**
EMP											1
Chi-square (observed value): 453.8719; Chi-square (critical value): 73.3115; p-value <0.0001; R^2 =**0.77997**											

The model used can be simplified by creating synthetic indicators, thus grouping the variables according to their specificity (quality of public health infrastructure, level of economic development, population distribution, and population mobility). The redundancy of virtually overlapping variables (such as GDP and SHE or HB and NRS) would be reduced (Figure 3).

The distribution of the counties according to the score of the two separate factorial axes is also interesting. There is a particularly coherent group from a regional point of view, the counties of Moldavia and Transylvania having a specific distribution. The south of the country, an area where it is located and the capital, occupies an intermediate position, interspersed between the two groups indicated. The capital and the neighbouring county of Ilfov are distinguished by their unique position. Equally coherent is the grouping of counties according to certain development indicators or the presence of important urban agglomerations, with a developed medical infrastructure (Iași, Timiș, Cluj, Brașov), relatively close to the capital's position. On the other hand, the poorly developed counties in the south and east of the country, less urbanized and a precarious medical infrastructure are also grouped coherently, as seen in the typological analysis (Teleorman, Călărași, Ialomița, Giurgiu etc.). An analysis of the spatial autocorrelation of the indicators used can certify the existence of regional groupings in which, as a rule, the counties having large cities, with a higher level of development and a complex medical infrastructure behaved differently from neighbouring counties but in continuity with these. They generate a kind of local gradient of epidemic vector diffusion closely related to the interactions induced by population mobility.

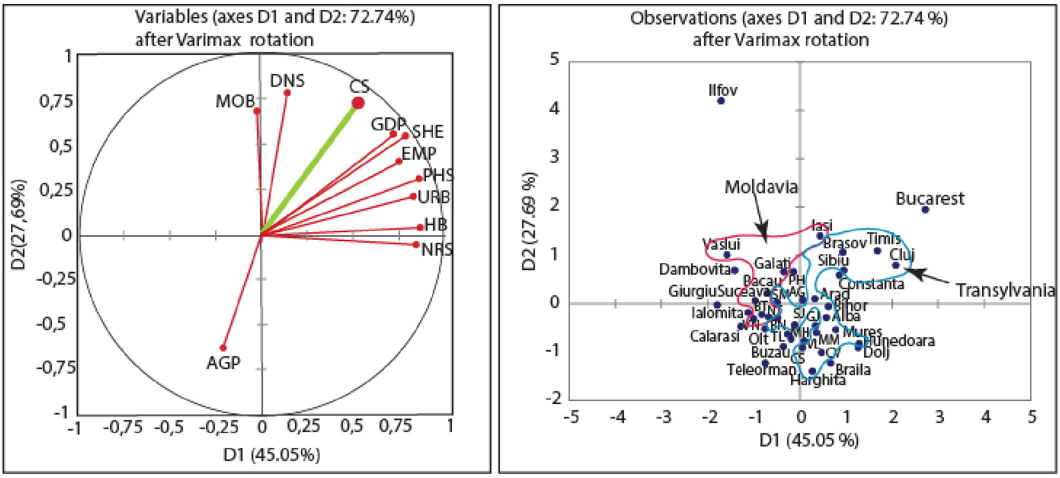

Figure 3. Evolution of Covid-19 cases. Principal component analysis results after Varimax rotation: contribution of factorial axes and the distribution of counties by factor scores

The analysis of the correlation between the deaths due to Covid-19 and the same set of variables, to which is added the number of cases, for the same study period, attests a strong discordance compared to the previous analysis. The relationship between the number of infections and the number of deaths, although strong, is inversely proportional, which can lead to serious reservations about the correctness of the record, both cases and deaths (Table 4, Figure 4).

Of the 10 variables analysed, only 5 show significant values of the correlation, all with negative values, as well as the number of cases. Population density has the highest values and can have a logical explanation, densely populated counties usually have important cities with better medical infrastructure, circumstances in which the level of testing and, implicitly, pandemic control was higher. On the contrary, in sparsely populated counties, usually predominantly rural, even if there was a lower incidence of cases, the death rate was higher due to poor pandemic management and difficulty in accessing specialized services. The other four better correlated variables (PHS, GDP; MOB and SHE) support the same explanations as DNS, expressing strong spatial inequalities. These disparities are likely to be accentuated in the event of a wave 4, given the much higher level of vaccination in large cities (according to (www.vaccinare-covid.gov.ro, 5 July 2021)). The coefficient R^2 has a lower value but can be considered significant enough to ensure an explanatory role to the variables analysed.

Table 4. The correlation matrix between the variables analysed
for the evolution of deaths caused by Covid-19 infections, between March 2020 and June 2021
(Data source: Coronavirus COVID-19 on Romania (https://covid19.geo-spatial.org, consulted between Mars 2020 and June 2021); Database Tempo-Online (National Institute of Statistics, March 2020-June 2021); Buletinul statistic lunar al județelor (National Institute of Statistics, March 2020-June 2021))

Variables	DCS	CS	PHS	NRS	HB	GDP	URB	DNS	MOB	AGP	SHE	EMP
DCS	1	**-0.560**	**-0.385**	-0.014	-0.139	**-0.435**	-0.091	**-0.532**	**-0.385**	0.074	**-0.372**	-0.219
CS		1	**0.598**	0.286	**0.427**	**0.851**	**0.683**	**0.603**	**0.450**	**-0.439**	**0.842**	**0.776**
PHS			1	**0.783**	**0.793**	**0.694**	**0.635**	**0.388**	0.303	**-0.398**	**0.802**	**0.637**
NRS				1	**0.840**	**0.495**	**0.617**	0.198	0.115	-0.205	**0.565**	**0.441**
HB					1	**0.585**	**0.639**	0.266	0.151	-0.188	**0.652**	**0.543**
GDP						1	**0.723**	**0.510**	0.261	**-0.406**	**0.928**	**0.865**
URB							1	0.189	0.141	-0.302	**0.780**	**0.780**
DNS								1	**0.477**	**-0.448**	**0.553**	0.302.
MOB									1	**-0.313**	0.279	0.086
AGP										1	**-0.495**	**-0.464**
SHE											1	0.833
EMP												1
Chi-square (observed value): 491.8204; Chi-square (critical value): 85.9649; p-value <0.0001; R^2 =**0.473246**												

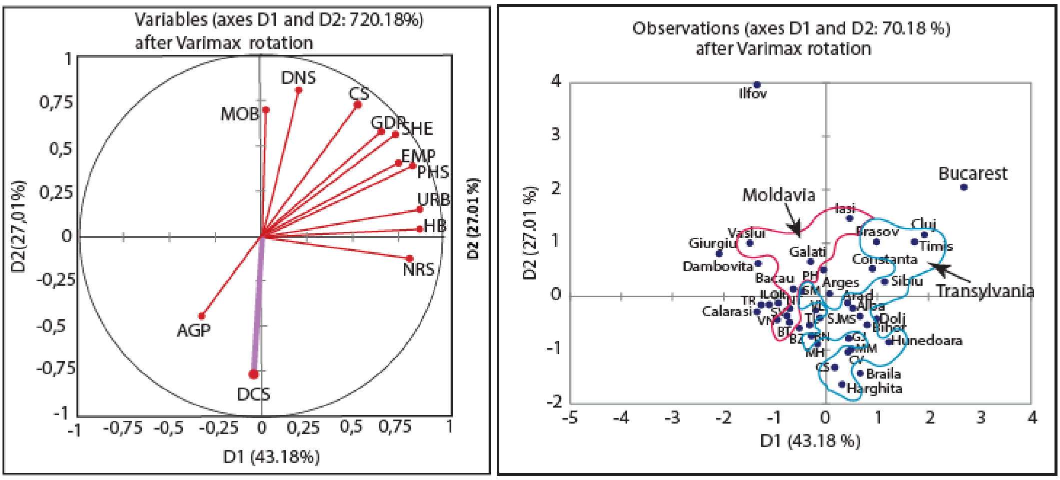

Figure 4. Evolution of deceases caused by Covid-19. Principal component analysis results after Varimax rotation: contribution of factorial axes and the distribution of counties by factor scores

The setting of the variables along the factorial axes is not very different from the analysis of the evolution of cases, the only notable difference being the positioning of the dependent variable. There are small differences in the grouping of variables: EMP is this time almost coincident with PHS, the high level of employment attracting a larger number of doctors; URB and HB are also coincident, in the previous analysis being correlated with PHS and NRS, respectively, explainable by the concentration of hospital units in the cities. These differences certify the somewhat greater dependence of deaths caused by Covid-19 on the level of development of health infrastructure. And in this case, the distribution of counties in the factorial plan distinguishes a grouped arrangement at regional level in Moldavia and Transylvania, the capital and Ilfov County having the same eccentric position. The opposition between the counties with a well-developed health infrastructure and the disadvantaged ones, especially in the south and east of the country, is preserved.

The two principal component analyses certify the manifestation of significant regional disparities in the evolution of the number of Covid-19 cases and of the deaths caused by it. The role of socio-economic factors and the quality of health infrastructure largely validates the study hypothesis.

CONCLUSIONS

Any study on the dynamics of the Covid-19 pandemic and its effects is limited by the quality of the information. The outline of regional models of evolution and the manifestation of some disparities related primarily to the level of development, however, indicate sufficiently clear trends, anchored in the local particularities expressed by the analysed factors. The inaccuracy of the information is rather due to the scale of the phenomenon in terms of the evolution of the number for cases and the absence of a rigorous reporting of deaths caused. The regional amplitude seems to be quite correctly captured by the net detachment of densely populated counties, with a high level of development and stronger mobility, in opposition to the predominantly rural counties, often less populated. The empirical observation of a correlation between agglomeration of the population and the diffusion of pandemic is not a novelty, being part of the natural logic of things. The fact that the information used, with all its limitations, certifies this connection shows that the means available to today's society, even in emerging countries such as Romania, can capture quite faithfully a phenomenon of this magnitude. More debatable is the situation presented by the evolution of death cases, which is in Romania in contradiction with the evolution of infection cases, correlated with strong disparities in the quality of health infrastructure. This discrepancy, which creates an advantage for large hospitals, doubled by poor vaccination in the same disadvantaged areas, is likely to dramatically change the distribution of cases during the inevitable four waves. Official information indicates a very high share of unvaccinated people among those infected after July 1 (82.4%) and all registered deaths were in unvaccinated persons (National Institute of Public Health, July 2021).

The conclusions of the study converge with those expressed in the consulted sources, indicating the manifestation of distinct epidemic waves, whit a specific local development, altogether in line with the trends observed at European level. The observed territorial disparities are sufficiently regionalized to nuance variation in the general pattern of pandemic spread. The explanation of these disparities through principal component analysis certifies the existence of an urban/rural cleavage, depending on the rate of population mobility and the level of socio-economic development. The excess of mortality in the urban environment strengthens this opposition, closely related to the agglomeration of the population. Factors that seem to favour the incidence of the pandemic, such as the aging population, have proved not to have a decisive role in the Romanian case, being a phenomenon present primarily in rural communities, by their more dispersed nature. An interesting result is the certification of the importance of the quality of public health infrastructure. Its concentration in large urban centres has reduced the lethal impact of the pandemic through its superior capacity for intervention, through stricter control. The existence of a private health system, in parallel with public one, ensured a superior availability for the other categories of patients. In contrast, in less developed areas, in many cases hospitals have been blocked to deal with the pandemic. A substantial part of the mortality surplus comes, as it is circulated in the public space, precisely form the impossibility of providing medical care for the chronically ill.

Any conclusions on the pandemic phenomenon generated by Covid-19 can only be preliminary. A complete and correct vision of its development and interference with the socio-economic system can only be issued after eliminating this risk.

REFERENCES

2011 Census. (2011). Retrieved from www.insse.ro

Abbasi, M., Bollini, A., Castillo, J., Deppman, A., Guidio, J., Matuoka, P., . . . Trevisan, L. (2020). Fractal signatures of the COVID-19 spread. *haos, Solitons and Fractals, 140*(1). doi:10.1016/j.chaos.2020.110119

Amdaoud, M., Arcuri, G., & Levratto, N. (2021). Are regions equal in adversity? A spatial analysis of spread and dinamics of COVID-19 in Europe. *The European Journal of Health Economics, 22*(1), 629-642. doi:10.1007/s10198-021-01280-6

Audi, A., Allbrahim, M., Kaddoura, M., Hijazi, G., Yassine, H., & Zaraket, H. (2020). Seasonality of Respiratory Viral Infections: Will COVID-19 Follow Suit? *Frontiers in Public Health, 15*(3). doi:10.3389/fpubh2020.567184

Bogos, K., Kiss, Z., Fronius, A., Temesi, G., Elek, J., Madurka, I., . . . Moldvay, J. (2021). Different Trends in Excess Mortality in a Central European Country Compared to Main European Regionas in the Year of the Covid-19 Pandemic (2020): a Hungarian Analysis. *Pathology & Oncology Research, 27*. doi:10.3389/pore.2021.1609774

Bontempi, E., Vergalli, S., & Squazzoni, F. (2020). Understanding COVID-19 diffusion requires an interdisciplinary, multidimensional approach. *Enviromental Research, 188*. doi:10.1016/j.envres, 2020.109814

Buja, A., Paganini, M., Cocchio, M., Scioni, M., Rebba, V., & Baldo, V. (2020). Demographic and socio-economic factors, and healthcare resource indicators associated with the rapid spread of Covid-19 in Northern Italy: An ecological study. *Plos ONE, 15*(12). doi:10.1371/journal.pone.0244535

Collins, A., Florin, M., & Renn, O. (2020). COVID-19 risk governance: drivers,responses and lessons to be learned. *Journal of Risk Research, 23*(7-8), 1073-1082. doi:10.1080/13559877.2020.1760332

Coronavirus COVID-19, Romania. (March 2020-June 2021). Retrieved from https://covid19.geo-spatial.org

Crețan, R., & Light, D. (2020). COVID-19 in Romania: transnational labour, geopolitics, and the Roma ”outsiders”. *Eurasian Geography and Economics, 61*(4-5), 559-572. doi:10.1080/15387216.2020.1780929

Dascălu, Ș. (2020). The Successes and Failures of the Initial COVID-19. Pandemic Response in Romania. *Front. Public Health, 10*(1). doi:10.3389/fpubh.2020.0034

Fisayo, T., & Tsukagoshi, S. (2021). Three waves of COVID-19 pandemic. *Postgraduate Medical Journal, 97*(1147). doi:10.1136/postgradmedj-2020-138564

Graichen, H. (2021). What is the difference between the first and the second/third wave of Covid-19? German perspective. *Journal of Orthopaedics, 24*((March-April 2021)). doi:10.10106/j.jor.2021.01.011

Hâncean, M., Perc, M., & Lerner, J. (2020). Early spread of COVID-19 in Romania: imported cases from Italy and human-to-human transmission networks. *Royal Society Open Science, 7*(1). doi:10.1098/rsos.200780

https://covid19.geo-spatial.org. (consulted between Mars 2020 and June 2021). Retrieved from https://covid19.geo-spatial.org

Imtyaz, A., Haleem, A., & Javaid, M. (2020). Analysing governmental response to the COVID-19 pandemic. *Journal of Oral Biology and Craniofacial Research, 10*(1), 504-513. doi:10.1016/j.jober.2020.08.005

INS. (n.d.). Retrieved from www.insse.ro

Jinjarak, Y., Ahmed, R., & Nair, S. (2021). Accounting for global COVID-19 diffusion patterns. *European Economist*. Retrieved from https://european.economicblogs.org/

Kubota, Y., Shiono, T., Kusumoto, B., & Fujinamal, J. (2020). Multiple drivers of the COVID-19 spread: The roles of climate, international mobility and region-specific conditions. *PloS ONE, 15*(9). doi:10.1371/journal.pone.0239385

Liu, X., Huang, J., Li, C., Zhao, Y., Wang, D., Huang, Z., & Yang, K. (2021). The role of seasonality in the spread of Covid-19 pandemic. *Environmental Research, 195*(1). doi:10.1016/j.2nvres.2021.110874

Lobiuc, A., Dimian, M., Gheorghiță, R., Caliman-Sturdza, O., & Covasa, M. (2021). Introduction and Characteristics of SARS-CoV-2 in North-East of Romania During the First COVID-19 Outbreak. *Frontiers in Microbiology, 12*. doi:10.3389/fmicb.2021.654417

Mogi, R., & Spijker, J. (2021). The influence of social and ecomomic ties to the spread of COVID-19 in Europe. *Journal of Population Research*. doi:10.1007/s12546-021-09257-1

Muntele, I., Istrate, M., Bănică, A., & Horea-Șerban, R. (2020). Trends in Life Expectancy in Romania betweeen 1990 and 2018. A Territorial Analysis of Its Determinants. *Sustainability, 12*(9). doi:10.3390/su12093802

National Institute of Public Health. (July 2021). *Raport săptămânal (EpiSăptămâna 29, 2021) (Weekly Report 29, 2021)*. Retrieved from www.cnscbt.ro/index.php/analiza-cazuri-confirmate-covid19/2598

National Institute of Statistics. (March 2020-June 2021). *Baza de date Tempo-Online (Tempo-Online Database)*. Retrieved from www.insse.ro

National Institute of Statistics. (March 2020-June 2021). *Buletinul statistic lunar al județelor (The monthly statistical bulletin of the counties)*. Retrieved from www.insse.ro

National Institute of Statistics. (n.d.). *www.insse.ro*. Retrieved from 2011 Census: www.insse.ro

Popic, T., & Moise, A. (2021). Health system resilience in te context of te Covid-19 pandemic: the gap between Eastern and Western Europe. *STG Resilience Papers*. Retrieved from htpps://hdl.handle.net/1814/71699

Shulz, A., Mehdipanah, R., Chatters, L., Reyes, A., Neblett, E., & Israel, B. (2020). Moving Health Education and Behaviour Upstream: Lessons from COVID-19 for Addressing Structural Drivers of Health Inequities. *Health Education & Behavior, 47*(4), 519-524.

Smit, A., Fitchett, J., Engelbrecht, F., Scholes, R., Dzhivhuho, G., & Seijd, N. (2020). Winter is Coming: A Southern Hemisphere Perspective of the Environmental Drivers of SARS-CoV-2 and the Potential Seasonality of COVID-19. *International Journal of Environmental Research and Public Health, 17*(16). doi:10.3390/ijerph17165634

Solis, J., Franco-Paredes, C., Henao-Martinez, A., Krsak, M., & Zimmer, S. (2020). Structural vulnerability in the U.S. Revealed in Three Waves of COVID-19. *The American Journal of Tropical Medicine and Hygiene, 103*(1), 25-27. doi:104269/ajtmh.20-0391

Sulyok, M., Ferenci, T., & Walker, M. (2020). Google Trends Data and Covid-19 in Europe: Correlations and model enhancement are European wide. *Transboundary and Emerging Diseases, 68*(4), 2610-2615. doi:10.1111/tbed.13887

Taboada, M., Gonzalez, M., Alvarez, A., Eiras, M., Costa, J., Alvarez, J., & Seoane-Pillado, T. (2021). First, second and third wave of COVID-19.What have we changed in the ICU management of thes patients? *Journal of Infection, 8*(26). doi:10.1016/j.jinf2021.03.027

Taleb, N. (2018). *Lebăda neagră: impactul foarte puțin probabilului (The Black Swann:The Impact of the Highly Improbable, romanian edition).* Bucharest: Curtea Veche.

Vokó, Z., & Pitter, J. (2020). The effect of social distance measures on COVID-19 epidemics in Europe: an interrupted time series analysis. *GeroScience, 42*(1), 1075-1082. doi:10.1007/s11357-020-00205-0

Werth, A., Gravino, P., & Prevedello, G. (2021). Impact analysis of COVID-19 responses on energy grid dynamics in Europe. *Applied Energy, 281*(1). doi:10.1016/j.apenergy.2020.116045

Worldometers. (March 2020-June 2021). Retrieved from www.worldometers.info

Wu, T. (2021). The socioeconomic and environmental drivers of the COVID-19 pandemic: A review. (R. S. Sciences, Ed.) *Ambio, 50*(1), 822-833. doi:10.1007/s13280-020-01497-4

www.vaccinare-covid.gov.ro. (5 July 2021). Retrieved from www.vaccinare-covid.gov.ro

Submitted:	Revised:	Accepted	Published online
August 16, 2021	February 28, 2022	March 03, 2022	April 13, 2022