

### Spatial Analysis of the COVID-19 Pandemic in Hungary: Changing Epidemic Waves in Time and Space

Uzzoli, Annamaria; Kovács, Sándor Zsolt; Fábián, Attila; Páger, Balázs; Szabó, Tamás

Veröffentlichungsversion / Published Version

Zeitschriftenartikel / journal article

#### Empfohlene Zitierung / Suggested Citation:

Uzzoli, A., Kovács, S. Z., Fábián, A., Páger, B., & Szabó, T. (2021). Spatial Analysis of the COVID-19 Pandemic in Hungary: Changing Epidemic Waves in Time and Space. *Region: the journal of ERSA*, 8(2), 147-165. <https://doi.org/10.18335/region.v8i2.343>

#### Nutzungsbedingungen:

Dieser Text wird unter einer CC BY-NC Lizenz (Namensnennung-Nicht-kommerziell) zur Verfügung gestellt. Nähere Auskünfte zu den CC-Lizenzen finden Sie hier: <https://creativecommons.org/licenses/by-nc/4.0/deed.de>

#### Terms of use:

This document is made available under a CC BY-NC Licence (Attribution-NonCommercial). For more information see: <https://creativecommons.org/licenses/by-nc/4.0>

## Spatial Analysis of the COVID-19 Pandemic in Hungary: Changing Epidemic Waves in Time and Space

Annamária Uzzoli<sup>1</sup>, Sándor Zsolt Kovács<sup>2</sup>, Attila Fábián<sup>3</sup>, Balázs Páger<sup>2</sup>,  
Tamás Szabó<sup>2</sup>

<sup>1</sup> Research Centre for Astronomy and Earth Sciences, Budapest, Hungary

<sup>2</sup> Centre for Economic and Regional Studies, Pécs, Hungary

<sup>3</sup> University of Sopron, Sopron, Hungary

Received: 29 November 2020/Accepted: 24 November 2021

**Abstract.** This paper examines the spatial dynamics and regional distribution of the novel coronavirus epidemic in Hungary in an effort to obtain a deeper understanding of the connection between space and health. The paper also presents comprehensive epidemiologic data on the spatiotemporal spread of the COVID-19 pandemic in terms of the epidemic waves. Following a comparison of the growth rates of infection numbers, the current study explores the geographical dimension of the three pandemic waves. The partial transformation of spatial characteristics during the three epidemic waves is among the most important results found. While geographical hotspots influenced the first wave, newly confirmed coronavirus cases in the second and third waves were due to community-based epidemic spreading. Furthermore, the western-eastern spatial relation and the core-periphery model also affected the regional distribution of new cases and deaths in the initial two waves. However, a new spatial pattern – realised by the northern-southern spatial orientation – appeared during the third wave. The outputs of this paper offer feasible suggestions for evidence-based policymaking in pandemic prevention, mitigation, and preparedness.

### 1 Introduction

The link between human health and environment is not only strong but also multidimensional. Environmental factors affect health in extremely varied and complex ways, both in terms of socio-economic consequences and in terms of spatial significance (Remoundou, Koundouri 2009). The novel coronavirus pandemic has given us a clear understanding of the relationship between space and health. The effects the COVID-19 pandemic have had on society and the economy interconnect in varying ways at every spatial level. Spatial locations, human environments and geographical regions have differing effects on the actual epidemic situation, because social interactions among people have particular relevance in the number of people infected (Wang 2020).

The outbreak of a novel coronavirus pandemic based on the SARS-CoV-2 virus and its disease (COVID-19) occurred at the end of 2019. It spread rapidly and impacted the entire world by the end of February 2020. Combating the COVID-19 was the primary task facing all countries in the past year-and-a-half or more. The spatial scope, spatiotemporal distribution of the epidemic spread, the turning point time, and infection severity all provide policymakers with the essential information needed to create efficient epidemic

prevention plans for future pandemics (Amdaoud et al. 2021). The COVID-19 pandemic triggered health and economic crisis the world over. Current challenges are long-term, and their societal and economic impacts remain unpredictable. The creation of effective solutions requires new approaches that integrate a community-based management strategy.

Pressing issues associated with monitoring and prevention concern everyone, and long-term issues related to the spread of this infection are naturally related to the spatial dimensions of human social interaction (Appiah-Otoo, Kursah 2021). The pandemic continues to surge all around us, which, in turn, requires the constant intervention of the public authorities. In the face of this significant health crisis, governments are multiplying containment measures, including border closures and travel bans, in an effort to decelerate the rapid spatial diffusion of the virus (Bavli et al. 2020).

Many Central and Eastern European (CEE) countries imposed tight restrictions at the very beginning of the first wave of the novel coronavirus in the spring of 2020. As a result, these countries experienced low infection rates and low death rates as the virus ravaged Western European countries (Röst et al. 2020). When the second wave of the virus hit the CEE region, it became apparent that Central and Eastern Europe would not avert the full brunt of the pandemic the second time around. The CEE countries also faced much larger outbreaks over the late summer and early autumn than in the spring of 2020. They managed the first wave of COVID-19 in the first half of 2020 very rapidly, but the governments of CEE countries have been struggling since. Reintroducing restrictions has been politically challenging, particularly after many months of eased restrictions. The third epidemic wave hit all European countries in the spring of 2021, with the CEE countries experiencing the most severe epidemiological situation. The second and the third pandemic waves in Europe had a more severe effect on CEE countries, which had been less affected by the first wave, indicating a change in the spatiality of the pandemic (Kovalcsik et al. 2021).

Unfortunately, Hungary is also part of the ongoing worldwide pandemic. Compared to Western European and the other CEE countries, the first pandemic wave was mild in Hungary, resulting in relatively low numbers of new coronavirus cases (Gombos et al. 2020). During the first wave, Hungary conducted a cross-sectional nationwide survey called H-UNCOVER. The survey revealed a low active infection rate (2.9 out of 10,000 people) and a low prevalence of prior SARS-CoV-2 exposure (68/10,000) (Merkely et al. 2020). However, Hungary experienced its highest number of cases and deaths during the third wave in the spring of 2021. Hungary is also a member of the Visegrad Group, where the spatial heterogeneity in the spread of the COVID-19 pandemic was similar during previous epidemic waves. One key piece of scientific evidence is that the pandemic hit countries and regions differently. The health crisis varied sharply across countries and within regions in the same country (Urbanovics et al. 2021), which is the main reason this paper focuses on the spatial distribution in the spread of the COVID-19 pandemic within Hungary.

## 2 Aims and Methods

The paper reviews spatial features of the three pandemic waves between 4 March 2020 and 11 June 2021 to discover how restrictions and mitigation interventions influenced the spatial distribution of infection in Hungary. This article concentrates solely on the spatial distribution of the pandemic and does not address economic challenges. Moreover, the present study is based on an investigation of Hungarian epidemiological data and does not aim to provide a European or a Central European overview of the pandemic.

The primary aim of this paper is to analyse the spatial features of the 2020 and 2021 COVID-19 pandemic in Hungary. Two main objectives focusing on the empirical analysis of health geography determine the framework of the study:

- Objective 1 is to produce statistical evidence on the spatial characteristics of the epidemic waves. The objective contains a spatial analysis of the new coronavirus cases during the first, the second, and the third waves of the epidemic. It also presents the main spatial characteristics of the three pandemic waves based on their comparison.

- Objective 2 is a regional assessment of policy responses implemented to mitigate social interactions during the three waves of the novel coronavirus pandemic. The analysis contains national, regional, and local measures targeting pandemic containment and the countering of spatial effects.

The secondary scope of the study is to develop a mixed methodology based on both quantitative and qualitative techniques to make a regional assessment of mitigation measures by targeting their spatial relevance.

The emphasis of our analysis is on evaluating the regional distribution of the incidence and prevalence of the COVID-19 disease. The other focus is on analysing the territorial adequacy of policy interventions and the capacity of these interventions to tackle territorially differentiated implications. The crucial questions are the following:

- What part of Hungary has been most affected by the pandemic?
- What is the typical spatial pattern of the pandemic?
- How did the spatial pattern of the pandemic change during the three relevant waves?
- How did territorial or spatial adequacy appear in policy interventions during the three waves of this pandemic?

Methodologically, our examination is a multidimensional approach integrating both quantitative and qualitative techniques.

The quantitative part of the examination is built on secondary, databased statistical analysis. The analysed data are taken from official sources (e.g. Hungarian Central Statistical Office, [koronavirus.gov.hu](https://www.koronavirus.gov.hu)).

Statistical data analysis covers the period between 4 March 2020 and 11 June 2021. The first two confirmed coronavirus cases were announced in Hungary on 4 March 2020, which denotes the start date of the Hungarian epidemic as well as our analysis. Over the more than 16 months of the COVID-19 epidemic in Hungary, the most relevant epidemiological data were announced daily. However, the daily data announcements were officially cancelled on 11 June 2021 and were shifted to include only weekdays.

The majority of epidemiological data was published only at the national level, but some regional level data was also reported. To calculate the proportion of crude epidemiological data per 100,000 inhabitants, we utilized officially published population data from the Hungarian Central Statistical Office ([www.ksh.hu](http://www.ksh.hu)).

Our spatial analysis used some quantitative variables based on epidemiological data. These epidemiological variables have spatial relevance, but they are available at different geographical scales, which means the variables are not synchronised with each other according to spatial examination level. Here is a classification based on their official availability:

**Variables available at the national level** (whole country): these are only available at the national level to describe the total or the daily number of confirmed cases and deaths, e.g. the total number of confirmed cases, the total number of active cases<sup>1</sup>, new daily confirmed cases, the total number of deaths, the total number of recovered cases etc. These variables are only suitable for describing national tendencies and changes in time.

**Variables available at the county level** (NUTS 3): only two are available at the county level and suitable for analysing the regional distribution of the total number of confirmed cases and new daily confirmed cases.

**Variables available at the micro-regional level** (LAU 1): these two variables are available at the local level to evaluate the spatial pattern of epidemic waves, e.g. the total number of confirmed cases and the total number of deaths.

<sup>1</sup>It is based on the total number of confirmed cases without the number of recovered cases and deaths.

Missing detailed spatial data does not allow an in-depth spatial analysis, because officially present epidemiological data such as total confirmed cases are published only at the county level. Available spatial data allow only a certain type of analysis that focuses on reviewing changes in regional patterns regarding the waves, especially at the county level. Two variables, such as the total confirmed cases and the total number of deaths, were announced only once at the micro-regional level at the beginning of June 2021. The examination period of these variables was not officially synchronised: the total number of confirmed cases covers the period between 4 March 2020 and 14 February 2021, while the total number of deaths included the period between 4 March 2020 and 4 March 2021. This explains why we could examine the first two epidemic waves at the micro-regional level, whereas we could only examine the spatial pattern of the third wave at the county level.

Official epidemiological data are analysed according to the three pandemic waves. The beginning and end dates of each wave are based on the changing number of active cases. We decided to use these as key indicators because the variable shows the number of people currently infected within the country. Thus, the long-term changes of this indicator also provide comprehensive information about the increasing or decreasing tendency of the given epidemic wave, while its highest number indicates the peak of the wave.

Our descriptive analysis compares the growth rates of active numbers among the three pandemic waves. It also studies the spatial dimension of the pandemic. There were significant differences among the waves due to the number of active cases – especially between the first wave and the subsequent two waves. Therefore, we chose separated figures to visualise each epidemic wave, which explains why the y-axis of each figure is shown on a different scale. Nevertheless, using separated figures to analyse each wave despite summarising each in only one figure helped us to harmonise the aim of the analysis with the research question, thereby providing a complete picture of the common and spatial characteristics of the COVID-19 pandemic in Hungary.

The present study considers the role of geographical distribution of infections and deaths and assigns a greater role to the territorial divisions of the sub-national levels as units of analysis within the spatial limitations of the study. Therefore, besides descriptive data, we also apply spatial analysis to record the results. Firstly, we examined the relationship between epidemiological data and different socioeconomic indicators using Pearson's correlation coefficient. Secondly, we examined the spatial concentrations of the epidemiological data using Location Quotient (LQ), which indicates the relative distributions or relative concentrations of a subarea to the area as a whole (Pandey et al. 2021). Thirdly, we conducted a cluster analysis of the micro-regions (LAU 1) involving the rate of deaths within COVID-19 infected persons and three socio-economic indicators (annual income per taxpayer, unemployment rate and life expectancy at birth). For clustering micro-regions, we used hierarchical cluster analysis and applied Ward's method, which is based on the size of an error sum-of-squares criterion. To choose the number of clusters, we applied Calinski–Harabasz's and Duda–Hart's criteria (Everitt et al. 2011). Finally, we decided to create eight groups from the micro-regions.

Calculations were prepared in Microsoft Excel and Stata, while maps were created with QGIS 3.12 software.

The content analysis within the qualitative part focuses on reviewing the restrictions ordered by the Hungarian government during the COVID-19 pandemic. The objective is to evaluate the spatial relevance of specific measures. All official documents, such as government decrees, circulars, regulations and other policy documents announced under the state of epidemiological emergencies, are examined. These documents are taken from the following three governmental sources:

**Hungarian Official Gazette** (<http://www.magyarkozlony.hu/>): this source provides the official text of any newly issued piece or amendment to Hungarian legislation. The website is operated by the Central Office for Administrative and Electronic Public Services and is only available in Hungarian.

**Official Governmental Website in English** (<https://abouthungary.hu/>): this source offers news in brief about Hungary, but also contains official speeches and remarks

written in English.

**Official Governmental Website on the pandemic** ([koronavirus.gov.hu](https://koronavirus.gov.hu)): this is the official information website on the pandemic written only in Hungarian, covering news, epidemiological data, brochures, legislation etc., regarding the Hungarian novel coronavirus epidemic.

The contextual framework of our content analysis is constructed on the following relevant questions, which are the specific focus for studying the Official Hungarian Policy Documents on the pandemic:

- How does the given governmental regulation integrate spatial adequacy regarding the epidemic? Does the policy intervention contain territorially or spatially sensitive measures at all?
- Which is the relevant spatial scale in restrictions and measures? Is there a balance between nationally and locally introduced measures?
- How can local competency appear in the restrictive and mitigating measures? Do municipalities have a role in policy responses to the challenges of the pandemic in Hungary?

In response to the fundamental questions of our content analysis, the results are suitable to compare spatial consequences of the restrictions; thus, it is also appropriate to discover the connection between measures and the growth of epidemic waves.

Based on applied quantitative and qualitative methods, the logical structure of our research is as follows:

1. The first step comprises the processing of epidemiological data related to the coronavirus epidemic and investigating territorial patterns of infections in Hungary.
2. The second step covers a comparison of the spatial effects of the first and the second waves of the pandemic.
3. The third step constitutes the evaluation of the policy measures and interventions introduced in the first and the second waves of the pandemic from the perspective of efficiency in providing adequate solutions and integrating spatial aspects.
4. The fourth step encompasses an overview of the connection between the spatial distribution of the pandemic and the spatial adequacy of policy interventions.

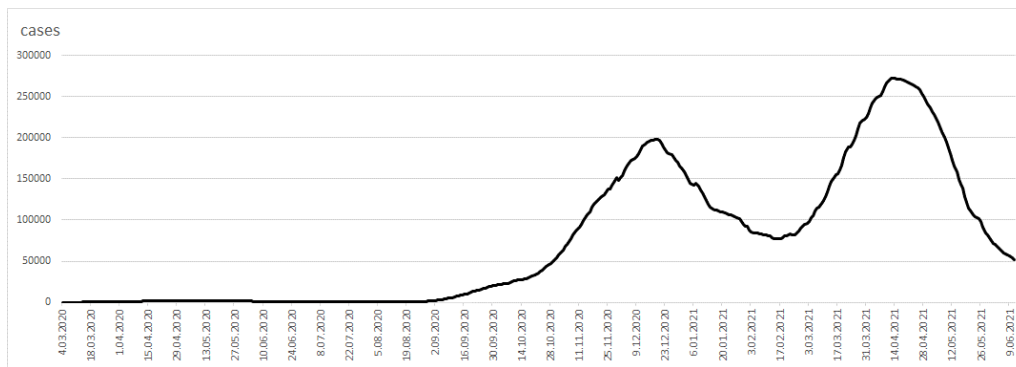
The results and experiences of this research can contribute to successful preparation for and prevention of further pandemic waves as well as inform the mitigation of adverse spatial impacts.

### 3 Results

The structure of this chapter is as follows: Firstly, via a statistical analysis focusing on epidemiological data of the pandemic, we present a comprehensive comparison of the epidemic waves in Hungary. Secondly, we provide a description of our statistical analysis regarding the spatiality of the epidemic waves. Thirdly, we summarise our experiences in analysing the spatial adequacy of the Hungarian restrictions.

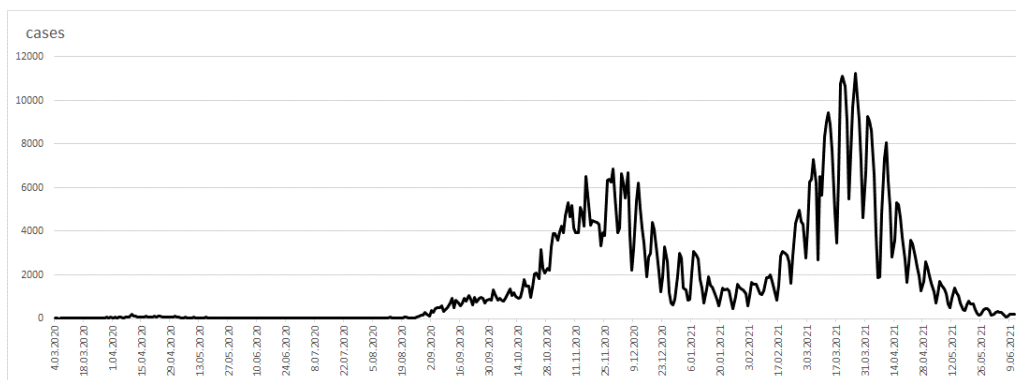
#### 3.1 *The Most Important Characteristics of the Epidemic Waves of the COVID-19 Pandemic in Hungary – ‘Flatten the Curve’ Versus ‘Over the Top’*

The first two confirmed coronavirus cases were announced in Hungary on 4 March 2020. These two known cases were foreign students studying in Hungary. According to the government’s official website ([koronavirus.gov.hu](https://koronavirus.gov.hu)), the first coronavirus-related death happened on 15 March 2020. The first recovered patient left the hospital on 12 March 2020. On 11 March 2020, the Hungarian government declared a state of epidemic emergency



Data source: [koronavirus.gov.hu](https://koronavirus.gov.hu)

Figure 1: Total number of active COVID-19 cases in Hungary (4 March 2020 – 11 June 2020)



Data source: [koronavirus.gov.hu](https://koronavirus.gov.hu)

Figure 2: Daily new confirmed COVID-19 cases in Hungary (4 March 2020 – 11 June 2021)

lasting until 18 June 2020, and the state of emergency was reinstated on 11 November 2020. The second announced state of emergency was extended several times and was valid until the 18 December 2021.

When examining the daily evolution of COVID-19 confirmed active cases, the three waves based on the pace of the spread of the epidemic in Hungary become apparent (Figure 1, Figure 2).

The first epidemic wave (4 March 2020 – 17 July 2020): this period followed the public health strategy of ‘flatten the curve’. The number of active cases was below 2,100, and the number of daily new cases only reached 210. This first wave lasted longer than four months and integrated different phases of the incidences. At the beginning of this period, in the phase of isolated cases, the daily number of new cases exhibited a steady increase. In the phase of group incidences, a partial acceleration of epidemic spread was witnessed after 21 March 2020. The rising number of active cases reached its peak on 4 May 2020 (2055 people). The phase of a continuous decline in the number of active cases started on 5 May 2020, and the daily number of confirmed cases of infections dropped below 50. A steady declining trend generally implied a low number of infected patients per day. The lowest number of active cases was reported on 17 July 2020 (478 people). The new daily cases generally remained below 10 throughout the middle of summer, which was similar to the initial phase of the first wave. A slight increase in the daily number of new cases linked to regional or institutional hotspots was detected from the end of July. These new cases were easy to isolate.

The second epidemic wave (18 July 2020 – 16 February 2021): this period could

be described by the term ‘over the top’, meaning that the number of daily new cases and active cases as well as deaths were significantly higher than in the first wave of the Hungarian COVID-19 epidemic. A phase of stagnating numbers of active and daily new cases began in the middle of June, while a slight increase began at the end of July, which is why we detect it as the boundary between the first and the second waves of the epidemic. Furthermore, a breakout in the number of daily new cases, which tripled from the previous day, occurred on 26 August 2020. Moreover, the number of weekly new cases displayed a nearly five-time difference during this period. The highest number of daily new cases occurred on 29 November 2020. That day saw 6,868 daily new cases, which was 33 times greater than the highest number of daily new first wave cases (210) reached on 10 April 2020. The sharply rising number of active cases from the beginning of September peaked on 17 December 2020 with 86,954 cases. Following this day, a continuous, slightly decreasing tendency started in the second epidemic wave. This second wave lasted longer than six months, but it could not reach the lows in the number of active or daily cases recorded in the first wave. The main reason behind this lack of bottoming is the beginning of the third epidemic wave, which erupted on 17 February 2021.

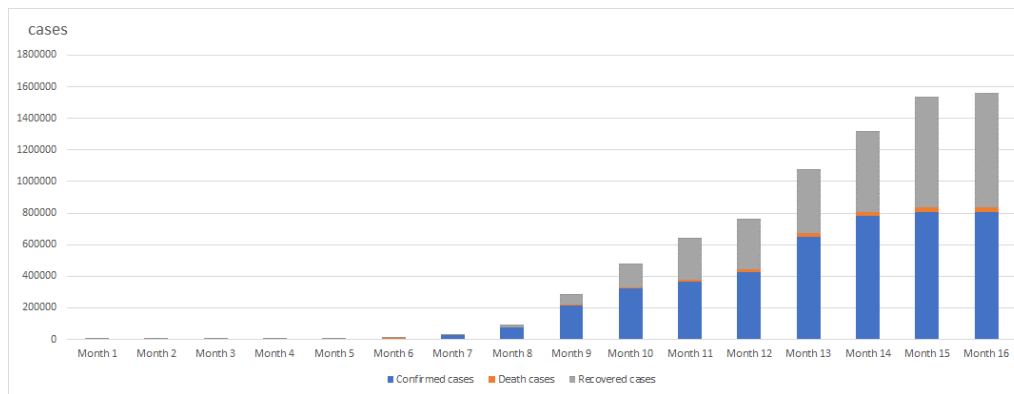
The third epidemic wave (17 February 2021 – 16 May 2021): during this period, the term ‘over the top’ refers to the number of daily new cases and active cases as well as deaths, which were the highest ever in the Hungarian COVID-19 epidemic thus far. All the examined epidemiological data peaks were tilted, and the three-month period of this epidemic wave proved the most challenging. Over 90% of all confirmed cases in Hungary during the third epidemic wave were caused by the Alpha variant of the SARS-CoV-2 virus.

The highest number of active confirmed cases, 272,066, was recorded on 14 April 2021, marking the peak of the third wave. The phase of intensive increase in this phase lasted from 17 February 2021 to 18 April 2021. The highest number of daily new cases during this period, 11,265, occurred on 26 March 2021. The moderate decreasing phase of the third wave started on 19 April 2021. The wave persisted well into June as the number of active cases remained over 50,000. The number of daily new confirmed cases fell below 1,000 in the middle of May. By the middle of June, daily new cases averaged 150-200. Though the third wave extended beyond three months, the Government Special Operational Body announced the measures in place at the beginning of June.

The relatively quick exit from the third wave compared to the other two waves has been attributed to the progressive vaccination program in Hungary. The government published its vaccination strategy at the end of 2020 and based its national plan on a detailed list that prioritised citizens according to vulnerability (based on age, occupation, or chronic illnesses). Healthcare worker vaccinations started at the end of 2020, while older people began receiving vaccines at the end of February 2021. Mass vaccination started at the beginning of April 2021. By 22 April 2021, 3.5 million Hungarians had received the first dose of the Covid vaccine. A month later, on 23 May 2021, 5 million had been registered as having received the first shot.

Besides vaccination, the other significant difference between the epidemic waves is in the number of PCR tests. The number of PCR tests has changed over time, which can significantly affect the number of cases detected. Test numbers remained low during the first wave due to the lack of testing capacity, which resulted in a very low number of daily new confirmed cases. The official coronavirus figures seemed reliable regarding a high number of tests during the second wave because there was a 30-40 times larger difference in new daily cases between the first two epidemic waves. There were on average 3,000-7,000 PCR tests per day during the spring of 2020. During the autumn of 2020, the number of tests rose to 10,000-12,000 on average. By the peak of the second wave, it was more than 20,000. The rate of positive tests varied between 8% and 24%. However, at the peak of the third wave, over 30,000 PCR tests were administered per day. Of these, at least 30 % were positive. The number of PCR tests declined in unison with the decreasing phase of the third wave, flattening out at 1,000-2,000 tests per day with a 1-2% positive test result ratio. On 11 June 2021, the total confirmed number of people infected with SARS-CoV-2 in Hungary stood at 806,790, and active COVID-19 cases amounted to 52,272. There were 5,567 people in compulsory home quarantine. The total number of





Data source: [koronavirus.gov.hu](https://koronavirus.gov.hu)

Figure 3: Total number of confirmed COVID-19 cases, deaths and recovered patients in Hungary per month (4 March 2020 – 11 June 2021)

recovered patients was 724,614, while deaths numbered 29,904. Hungary ranked among European countries with the highest ratio of COVID-19 deaths per million inhabitants. The mortality rate for the novel coronavirus reached 3.7 % of the total infection rate by the middle of June 2021, which was higher than the European average. More than 80% of deaths occurred in people over 65. Eight per cent of all inhabitants in Hungary were registered as confirmed COVID-19 cases.

According to the official government website, 25% of daily new confirmed cases at the beginning of September 2020 were in the 20-29 age group ([koronavirus.gov.hu](https://koronavirus.gov.hu)). By contrast, at the beginning of November, the average age of those who contracted the virus was 45. Out of every 100,000 residents, 1,540 Covid-19 patients were in the 20-29 age group, 1,331 in the 30-39 age group, 1,632 in the 40-49 age group, and 1,473 in the 50-59 age group. 1,589 patients were aged 60-79, and 1,408 were older than 80 ([koronavirus.gov.hu](https://koronavirus.gov.hu)). Unfortunately, there was no further information on the mean age of daily new confirmed cases after the September 2020 announcement; data are not available yet.

The total number of confirmed cases significantly increased from the beginning of the second wave (Figure 3). In the first half of October 2020, the number of daily deaths was less than 50, and daily new confirmed cases already exceeded 1,000 at this time. The continuous increasing tendency in the number of deaths began from the beginning of November. Daily deaths hovered around the hundred mark. During the second wave, the number of deaths per day remained below 200, but peaked at 311 deaths in the third wave. On the other hand, the total number of recovered patients slowly followed the number of new daily cases, implying an increase in complicated cases requiring hospitalisation or longer recovery periods. The number of hospitalised patients on ventilators continuously increased from the middle of the second wave and peaked during the third wave. The highest number of hospitalised patients was 12,553 on 30 March 2021, while the greatest number of patients on ventilators hit 1,529 on the same day. Healthcare capacity became overloaded during the second wave, while Hungary's healthcare system reached the point of exhaustion in the middle of the third wave.

In sum, the most relevant differences among the three pandemic waves in Hungary are realised in the following features. Firstly, the number of daily new cases and active confirmed cases in the second and third waves were generally 30-50 times higher than in the first wave. Secondly, the typical figure of the epidemic curve was flattened in the first wave; steep in the second wave, and a wide plateau in the third wave. Thirdly, the epidemic curve reached a bottom at the end of the first wave, but not in the second wave because the third wave, based on the spatial spreading of the Alpha variant of the SARS-CoV-2 virus, erupted quickly. Fourthly, at the beginning of the second wave, social interactions among the younger generation exacerbated the epidemic wave, giving rise to an ascending phase. This resulted in a mean age of confirmed cases that was significantly

lower at the beginning of the second wave. Still, it steadily increased in parallel with the spatial spreading of the epidemic curve. Finally, hospitalised patients needing ventilators reached a peak during the third wave, resulting in an overloaded healthcare system.

### 3.2 *Spatial Distribution of the Epidemic Waves of the COVID-19 Pandemic in Hungary – Local Hotspots versus National Chain of Infections*

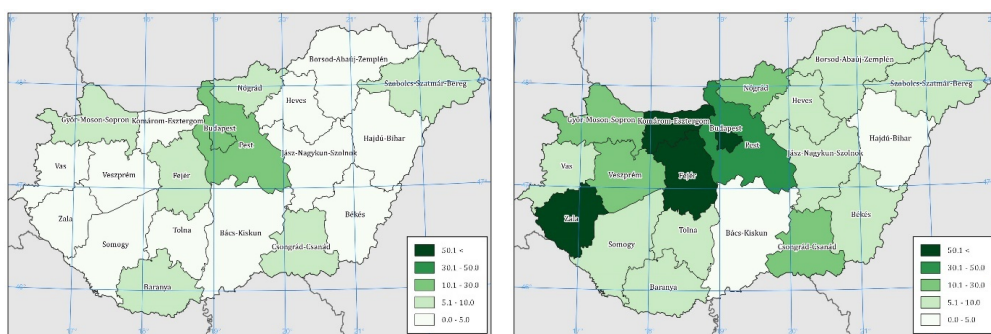
The spatial distribution of the COVID-19 pandemic partially transformed during the three epidemic waves in Hungary. On the one hand, the geographical centres of the infections were Budapest and Pest County, with the highest numbers of total confirmed and daily new cases in the waves. Home to 31% of the Hungarian population, the dense population of the capital city (Budapest) and its surroundings (Pest County) played a decisive role in case numbers. On the other hand, there were significant spatial inequalities among different parts of the country according to the number of confirmed cases per 100,000 inhabitants.

According to regular official spatial data published at the county level in Hungary (NUTS 3 level), the spatial pattern differed in the waves.

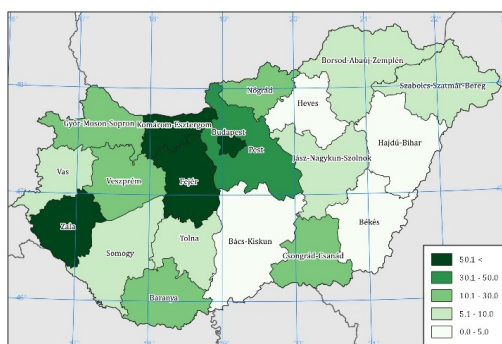
The county-level distribution of new confirmed COVID-19 cases in Hungary revealed a spatial concentration in the capital city (Budapest) and its surroundings (Pest county) in the first wave and pointed to a western-eastern division of the country (Figure 4). According to the total number of confirmed cases per 100,000 inhabitants, the eastern half of Hungary (with the exception of Csongrád-Csanád County) was less affected, based on the lower number of infections. From the final days of April 2020, an increasing number of new confirmed cases were detected predominantly in the western counties – Fejér, Komárom-Esztergom, Veszprém, and Zala counties – where infections affected larger institutions (hospitals, nursing homes). Institutional hotspots – e.g., those based on the increasing number of infections in nursing homes or hospitals – significantly influenced the geographical concentration of new cases per week. This growing tendency for new and active cases led to a peak at the beginning of May, resulting in a typical spatial pattern of COVID-19 diseases within the country based on a western-eastern division. From the beginning of July, the daily number of new infections increased in the eastern part of the country, specifically in Borsod-Abaúj-Zemplén, Csongrád-Csanád, and Hajdú-Bihar counties. The spatial conclusions of the first wave reveal that the north-western part of the country was severely affected in contrast to the southern and eastern parts of Hungary. This north-western part is more economically developed than the rest of the country (with the exception of Budapest and its immediate surroundings).

The spatial distribution of new confirmed coronavirus cases during the second wave demonstrated the changing spatial distribution of the epidemic within the country, based on spatial chains of the infection (Figure 5). Firstly, the capital city (Budapest) and its surroundings (Pest County) were also the most affected by the infectious disease, but at a slowly declining rate from the end of October 2020. Secondly, a high number of new confirmed cases affected all counties from the beginning of the second wave. Thirdly, the spatial pattern of new confirmed cases did not indicate a western-eastern division, because the number of new cases was high everywhere in the country during the second wave. Fourthly, the ranking position of counties based on new confirmed cases per 100,000 inhabitants was completely different week per week during the second wave. Fifthly, the continuous increasing tendency was experienced in new confirmed cases in all counties until the week of the peak during the second wave. Still, there were significant differences among counties in growth rates week after week.

The landing phase of the second wave did not bottom like the first wave did in the summer of 2020, because the third epidemic wave occurred unexpectedly at the end of February 2021. The taking off phase of the third wave resulted in the highest number of confirmed cases experienced in the Hungarian COVID-19 epidemic (Figure 6). During this taking off phase, Nógrád County, in the northern part of the country, was the most affected. On the other hand, it became obvious from the initial phase of the third wave that Budapest and Pest County were not the most infected areas according to the number of confirmed cases per 100,000. Another general observation was that the northern part of the country – especially Nógrád County – along the Slovakian border was the



(a) A week in the taking off phase (23 March 2020 – 29 March 2020) (b) The week of the peak (04 May 2020 – 10 May 2020)



(c) A week in the landing phase (22 June 2020 – 28 June 2020)

Data source: [koronavirus.gov.hu](https://koronavirus.gov.hu)

Note: Budapest – the capital city; Pest – the name of a county

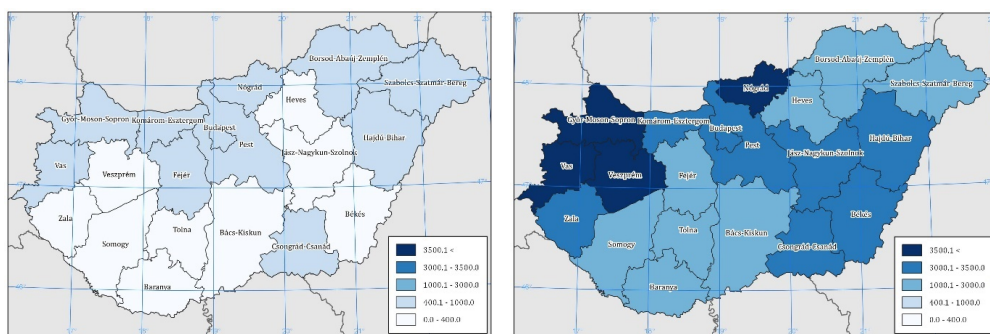
Figure 4: Total number of confirmed COVID-19 cases per 100,000 inhabitants in Hungarian counties (NUTS 3) during the different phases of the first wave, based on weeks

most affected area from the beginning of the third wave. The spatial distribution of the confirmed cases showed a very high number in all counties during the entire wave. At the same time, its spatial pattern also represented a combined western-eastern and northern-southern relation. Chains of infections influenced the spatial distribution of the third wave and resulted in a mass outbreak based on the spatial spreading of the Alpha variant of the new coronavirus. The landing phase of the third wave lasted more than one month, but the typical spatial distribution of confirmed cases based on western-eastern and northern-southern spatial pattern did not change at all.

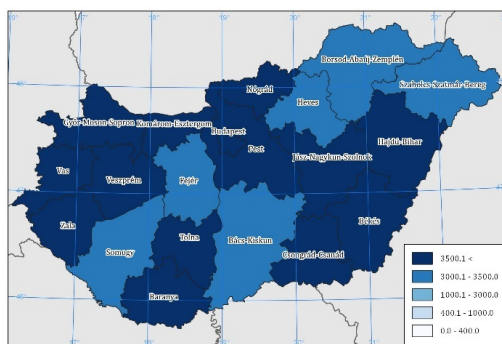
According to official epidemical data at the micro-regional level in Hungary (LAU 1 level), the spatial pattern is more sophisticated than could be seen at the county level.

There were 387,462 confirmed COVID-19 cases in Hungary between 4 March 2020 and 14 February 2021, while the number of deaths was 13,706. Among the 3,230 Hungarian settlements, only 71 averted infections during this period, while 1,197 settlements recorded no deaths from the infection.

The spatial distribution of the total number of confirmed patients per 100,000 inhabitants shows a pattern with increasing occurrence from the north and the north-western parts of the country to the south and the north-eastern areas (Figure 7). Developed and urbanised regions of the country were being affected by the pandemic, especially during the first two epidemic waves. However, another pattern appears in the spatial distribution of the total number of deaths per 100,000 inhabitants in Hungary (Figure 8). The deaths were primarily recorded in the less developed areas of the country, e.g. the north-eastern part or the southern borderline. A similar pattern can be observed in the rate of deaths among confirmed cases (Figure 9). On the one hand, the number of confirmed cases is higher in more developed parts of the country, but on the other hand, the



(a) A week in the taking off phase (12 October 2020 – 18 October 2020) (b) The week of the peak (14 December 2020 – 18 December 2020)



(c) A week in the landing phase (25 January 2021 – 31 January 2021)

Data source: [koronavirus.gov.hu](https://koronavirus.gov.hu)

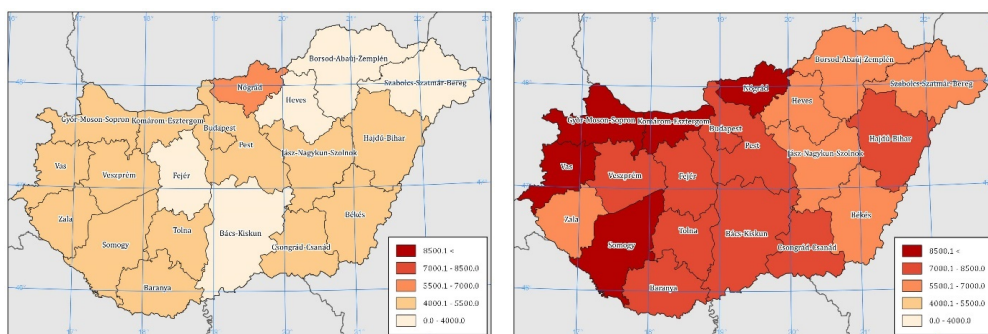
Notes: Budapest – the capital city; Pest – the name of a county

Figure 5: Total number of confirmed COVID-19 cases per 100,000 inhabitants in Hungarian counties (NUTS 3) during the different phases of the third wave, based on weeks

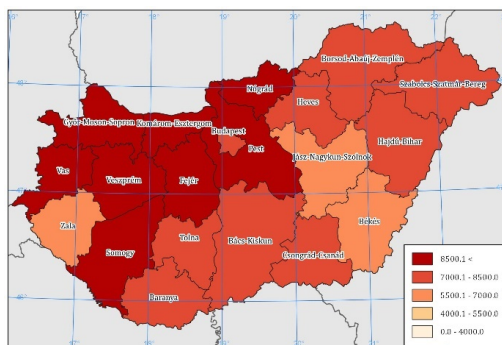
survival rate is better than the rate in less developed areas in Hungary. Namely, a higher number and rate of deaths caused by COVID-19 was experienced in the socioeconomically disadvantaged parts of the country, e.g., inner peripheries, southern border, north-eastern regions etc. Poor health, lower life expectancy and a higher rate of cardiovascular diseases are also prevalent in these areas (Uzzoli et al. 2020).

Pearson’s correlation coefficient values show a moderate connection between examined epidemiological data and different socioeconomic indicators in Hungary. Among them, income and unemployment rate as economic indicators, and life expectancy as a health indicator, are in a middle strong relationship with the variable of COVID-19 cases. This indicates that higher income and life expectancy, as well as lower unemployment, go together with a higher number of registered coronavirus cases. However, these economic indicators play a weaker role in the occurrence of deaths caused by COVID-19. The connection between health indicators and the number of deaths is stronger than the connection with economic indicators. In other words, health plays a larger role in COVID-19 deaths than financial status does.

The LQ analysis showed the micro-regional concentration of deaths and COVID-19-infected people compared to the national average. Using the LQ values of the micro-regions, we created three categories for each indicator. Those micro-regions, where the value of LQ exceeded 1.1 (at least 10% higher than the national average), represent a “high” level of concentration, while micro-regions, where the LQ value remained below 0.9 (at least 10% lower than the national average), suggest a “low” level of concentration. As we labelled the micro-regions by the concentration level of each indicator, nine different combinations of categories have been created (Figure 10). The results illustrate that the less developed micro-regions displayed a high concentration of COVID-19 deaths, even though the



(a) A week in the taking off phase (22 February 2021 – 28 February 2021) (b) The week of the peak (12 April 2021 – 18 April 2021)



(c) A week in the landing phase (24 May 2021 – 30 May 2021)

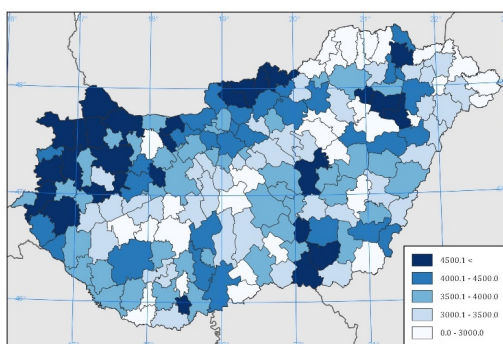
Source: [koronavirus.gov.hu](https://koronavirus.gov.hu)

Notes: Budapest – the capital city; Pest – the name of a county

Figure 6: Total number of confirmed COVID-19 cases per 100,000 inhabitants in Hungarian counties (NUTS 3) during the different phases of the third wave, based on weeks

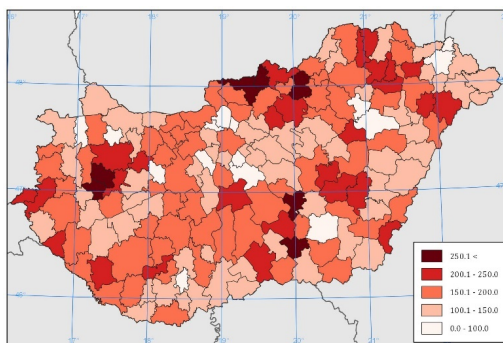
concentration of infected people was at moderate or low levels. However, there are some less developed regions (mostly in the southern and eastern parts of Hungary) in which the concentration levels of deaths and infected people were relatively low. This can be explained by the lower risk of serious infection due to social distancing. The concentration levels in the county seats and Budapest varied between moderate and low. The results of the cluster analysis provide a more detailed picture about the role of socioeconomic conditions (Figure 11). Clusters that had a relatively low death rate (Cluster 1 to 4) were indicative of a relatively high level of income per taxpayer, a high life expectancy at birth and a low unemployment rate. These groups include primarily urbanized and developed regions. In clusters (Cluster 5 to 8) where the income per taxpayer and life expectancy at birth was relatively low, the COVID-19 death rate was higher. Although these data provide only a snapshot of the possible relationship of socioeconomic conditions and the COVID-19 death rate in micro-regions, the results suggest that these conditions might influence the concentration of deaths and infected people.

Summarising the spatial relevance of the Hungarian epidemic waves highlights the following observations. Spatial diffusion of newly confirmed coronavirus cases was influenced by the community-based epidemic in the first wave, while the chain of infections affected the second and the third waves. Budapest and Pest County were the permanent population-based geographical centres of new infections during the waves, but the hotspots existed only in the first wave. In addition to Budapest and Pest County, some periodic spatial concentrations resulted in county-based hotspots in the country. This indicates that the spatial concentration of infections by county was permanently changing week after week. In the spring of 2021, COVID-19 infected more than 97% of Hungarian settlements, with 63% of these settlements recording at least one death from the virus.



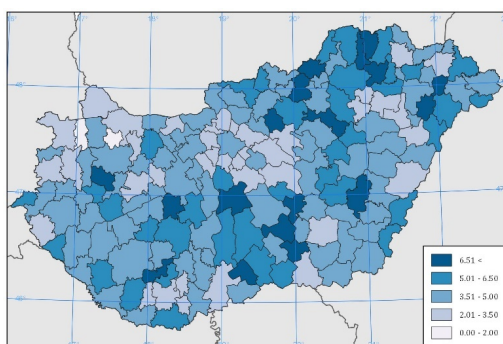
Data Source: K-Monitor

Figure 7: Total number of confirmed COVID-19 cases per 100,000 inhabitants at the micro-regional level of Hungary (LAU 1) between 4 March 2020 and 14 February 2021



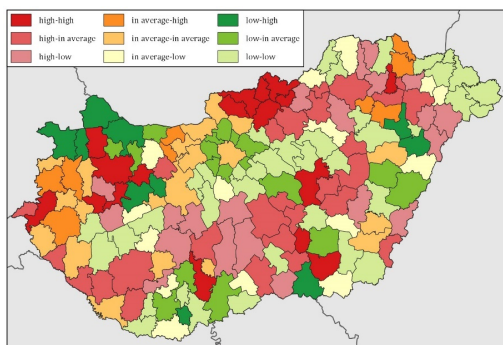
Data source: K-Monitor

Figure 8: Total number of deaths caused by COVID-19 per 100,000 inhabitants at the micro-regional level of Hungary (LAU 1) between 4 March 2020 and 4 March 2021



Data source: K-Monitor

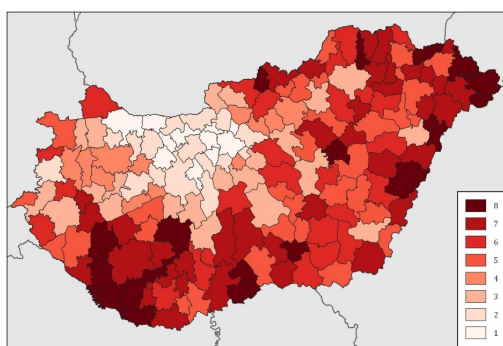
Figure 9: Rate of deaths among confirmed COVID-19 cases (%) at the micro-regional level of Hungary (LAU 1) between 4 March 2020 and 14 February 2021



*Data source:* K-Monitor

*Notes:* The red-coloured areas reported a high level ( $LQ > 1.1$ ), orange-coloured micro-regions had a moderate level ( $0.9 < LQ < 1.1$ ), while green-coloured areas showed a low level of concentration ( $LQ < 0.9$ ) of deaths. The darker coloured areas reported a high level, while lighter coloured micro-regions had a low level of concentration of infected people.

Figure 10: The spatial concentration of deaths (first term) and infected (second term) people at the micro-regional level in Hungary (LAU 1) between 4 March 2020 and 14 February 2021



*Data source:* K-Monitor

*Notes:* The darker, red-coloured areas reported a higher rate of death, while the lighter red-coloured micro-regions showed a lower rate of death.

Figure 11: Clustering of the micro-regions based on the death rate within COVID-19 infected people and various socio-economic indicators

At the county level, the typical spatial pattern of the epidemic waves was mainly based on a western-eastern division completed by a northern-southern spatial relation during the third wave. At the micro-regional level, centre-periphery relation was the dominant spatial pattern in the occurrence of the newly registered cases and deaths. The highest number of reported cases occurred in the most developed and urbanised micro-regions at the LAU 1 level. On the other hand, poor health conditions had a more substantial role in the number and rate of deaths with the most disadvantaged micro-regions experiencing the highest death rates. In other words, centres are significantly influenced by COVID-19 cases, while peripheries are primarily affected by COVID-19 deaths.

### 3.3 Spatial Relevance of Covid-19 Restrictions to the Pandemic in Hungary – Based on Continuous Tightening and Easing

In response to the emerging COVID-19 pandemic, the Hungarian government declared a state of emergency twice in 2020: initially, between 11 March and 18 June 2020, during the first epidemic wave, and again on 11 November 2020, during the second wave. The latter state of emergency has been continuously extended and is scheduled to end on 18 December 2021. Governments must design new, innovative instruments to counter the

health and socio-economic impacts of the pandemic and induced crisis. The restrictions under the state of epidemiological emergencies had similarities and differences during the three examined epidemic waves in Hungary according to the primary objectives of prevention. These policy responses were specially introduced at the national level. Still, due to the diverse spatial impacts of the epidemic, there is some degree of uncertainty about whether territorially sensitive measures should be among policy responses, and to what extent spatial aspects should be incorporated into these interventions.

During the first wave, the state of emergency restrictions required people to quarantine themselves, employees to engage in home office, and students to participate in online education. These restrictive measures affected the entire country, but municipalities were given the discretion to close various parts of their respective settlements in the intensive increasing phase of the epidemic. Various spatially sensitive protection measures were implemented in the territorial hotspots of the epidemic (e.g. the masks required to be worn on public transport and in stores in the capital city). The restrictions were lifted gradually from 4 May 2020, through the so-called sliding mode control displaying a marked spatial approach. It implied an easing of restrictions in less infected areas outside of the capital city and its neighbouring Pest County. In contrast, partial restrictions remained in force in Budapest and Pest County for two additional weeks, and preventive measures were strongly encouraged across the country. On 18 June 2020, the Hungarian government lifted the state of emergency and the lockdown imposed in spring to combat the COVID-19 pandemic. This allowed Hungarian employers to prepare for a return to business as usual.

Overall, the restrictive and mitigating measures designed to tackle the COVID-19 emergency had diverse spatial implications during the first wave of the epidemic in Hungary in the first half of 2020. In addition to granting settlements more room to manoeuvre concerning containment efforts, the location of territorial focal points was also taken into account (in a capital city-countryside context), and the role of geographical isolation was emphasised in preventing group infections. When the relaxation of restrictions produced a growing number of social interactions and, thus, a higher number of infections, it led to the enforcement of tighter restrictions nationally and regionally (e.g. specific counties). This foreshadowed the sustained presence of tightening and easing policies along with their cyclical nature and spatially heterogeneous distribution in the country over the year 2020. In the first wave of the fight against the pandemic, Hungary managed to avoid mass infections, but due to the permanent imminence of the pandemic threat, the state of epidemiological preparedness remained in force in the country over the second half of 2020 as well.

The anti-epidemic approach of epidemiological preparedness during the three epidemic waves was based on mainly national measures (e.g. masks required to be worn on public transport and in stores for the whole country) (Figure 12). In comparison to the beginning of the three waves, a significant gap emerged. At the beginning of the first wave, the nationally introduced general lockdown was combined with the state of emergency. The second wave saw only restrictions in two phases, which were ended in the third wave. The first phase of introduced restrictions during the second wave started on 1 September when the Hungarian borders were closed and some mask rules were tightened. In parallel with these national regulations, local and institutional competencies of restrictions against the COVID-19 pandemic were strengthened. For instance, employers could decide about ordering home office, or schools could choose between online and personal education or some mix of both (such as “hybrid education”), based on the number of infected students and teachers. Besides these new national rules and local opportunities in decision-making, anti-epidemic measures strongly highlighted the role of individual protection based on mask wearing, social distancing, and disinfecting. The second phase of newly introduced restrictions during the second wave was fittingly connected to the published emergency degree on 11 November. These new restrictions against COVID-19 were organised to be the strictest pandemic measures Hungary had taken: e.g. nightly curfew between 20.00-05.00; mask rules tightened; sports facilities closed to the public; a general events ban with very few exceptions; restaurants operating with take-out and delivery only; shops closed at 19.00; high schools and universities switched to remote learning, etc.



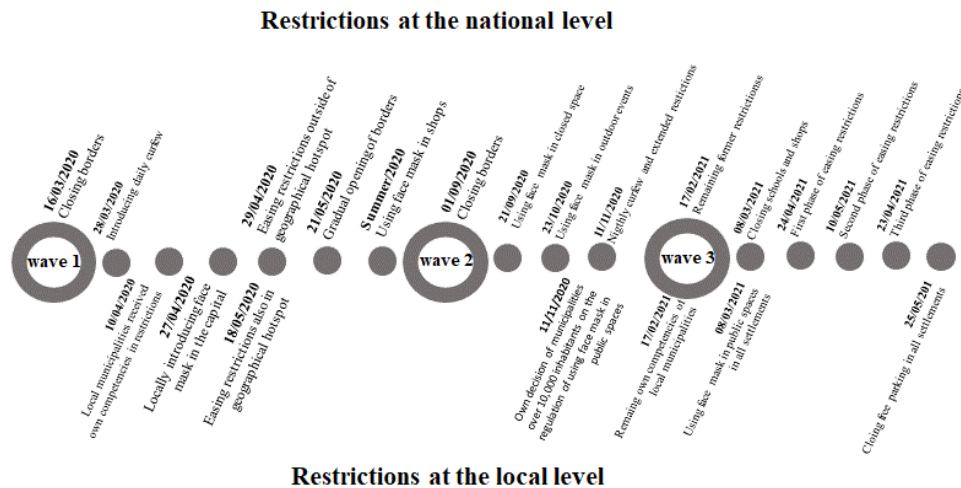


Figure 12: Restrictions regarding the COVID-19 epidemic waves in Hungary and their spatial relevance (04 March 2020 – 11 June 2021)

Masks were mandatory in all public spaces after 11 November. Still, municipalities also received the decree to make detailed local rules for public mask mandate in settlements with populations over 10,000.

This multi-stage regulation of anti-epidemic measures of the second wave was extended and completed during the third wave. New elements of restrictions, which had been in effect since November 2020, were introduced on 8 March 2021. During this lockdown, kindergartens, primary schools, and shops (except for hypermarkets, post offices, drugstores, and pharmacies) closed. Other measures (e.g. nightly curfew, public mask mandates, online education in secondary schools, etc.) remained unchanged. On the other hand, during the third wave, a new element of protection measures appeared in the form of vaccination. A new basis for organising Hungarian anti-epidemic measures emerged. The easing of multi-stage regulations was directly connected to the number of vaccinated inhabitants. The first phase of easing was triggered on 24 April 2021 when the goal of 3.5 million vaccinated people was reached; e.g. one of the eased measures was the reopening of restaurants. The second phase of multi-stage regulation of easing on 10 May was implemented after the 4 million mark was reached – e.g. school opening and the phasing out of home office. The third phase of easing on 22 May occurred after the 5 million threshold was reached, which represents roughly half of Hungary’s population. This third phase brought the greatest easing measures: e.g. lifting the curfew, dropping the mask mandate, permitting the organisation of private events with up to 50 people, etc. As part of the vaccination drive, people who received their first vaccine doses were issued government immunity certificates. On 24 June 2021, Hungary reopened the Schengen borders. Local authorities received some powers to introduce additional restrictions, e.g. closing the settlements to visitors on weekends.

Summarising our knowledge on the spatial relevance of restrictions resulting from the new coronavirus pandemic in Hungary, the most essential features are nationally-introduced regulations supplemented by local competencies. In addition to introduced restrictions, other tools could be deployed. For instance, targeted measures to reduce infection numbers could be taken in severely affected geographical locations.

The most important highlight is that national level mitigation measures play the primary role in the anti-epidemic approach in Hungary. The municipalities’ competencies in setting restrictions appeared in the very beginning of the Hungarian epidemic, but their function of secondary importance. The municipalities at the local level differed in taking measures because only settlements over 10,000 inhabitants could make their own decisions concerning face masks in public spaces. These decisions were not related to the

number of newly infected cases because there were no detailed epidemiological data at the local level (e.g. settlements). For example, there were no data about the number of PCR tests in the counties either. National-level restrictions implemented by policymakers were connected to the dynamics of the disease. These restrictions were based on multi-stage regulations related to the actual number of new daily confirmed cases from the second epidemic wave.

The government will have to use a greater number of tools based on spatially sensitive measures in potential epidemic waves. The number of possible scenarios is relatively high, depending on the actual epidemiological situation, based on the spatial spreading of the Delta variant during the summer of 2021.

#### 4 Conclusion

The COVID-19 pandemic has severely affected European countries and their healthcare systems. Many healthcare services in severely affected countries are undergoing decentralisation and fragmentation (Boccia et al. 2020).

According to their temporal appearance, the healthcare systems of developed countries have to face different health consequences of the COVID-19 pandemic. The short-term health consequences were manifest in a growing demand for the hospitalisation of confirmed patients. Massification risks overburden the health care system and may produce capacity shortages. In the medium to long term, a rise of non-communicable diseases can also be anticipated because non-coronavirus infected patients had many access barriers to healthcare services on various grounds during the epidemic waves (e.g. suspension of screening and the treatment of chronic patients), triggering a deterioration of health and avoidable deaths (Kovács, Uzzoli 2020). Among other things, social distancing during the epidemic may cause a deterioration in mental health (Grünhut, Bodor 2020, WHO 2020). The new coronavirus pandemic will also affect the spatial distribution of health inequalities in the future, leading to their intensification and the emergence of new types of inequalities (Bambra et al. 2020, Kovács et al. 2020). In addition, Hungary belongs to the middle-ground countries of the world according to the general state of health of the population (Uzzoli 2016). Poor Hungarian health indicators can lead to a further intensification of the COVID-19 pandemic with increased serious health consequences among confirmed cases.

Our study gives a concise summary in light of the findings regarding the study objective.

Firstly, significant differentiation can be detected among the parts of Hungary most affected by the pandemic. The most developed north-western region and the central part with the capital city and its surroundings exhibited the highest total number of confirmed infection cases. From a geographical point of view, the spatial diffusion of the virus referred to the number of social interactions, which increase from the bottom to the top of the settlement hierarchy, resulting in a higher number of infections in the most developed and urbanised geographical locations (Gu et al. 2020, Sigler et al. 2020).

Secondly, some parts of the country are affected most by higher numbers of COVID-19 deaths. These parts of the country differ completely from those which experienced higher numbers of new COVID-19 cases. Poor health and lower quality of life in the most disadvantaged parts of the country (e.g. inner peripheries, south-eastern border, north-eastern counties) go together with a shorter life expectancy. Poor health is one of the major risk factors of death caused by COVID-19 (Kovács, Uzzoli 2020, Uzzoli et al. 2021). Thirdly, the geographical location of infections and the spreading of the pandemic have spatially changed during the three examined epidemic waves in Hungary. The spatial pattern of the first epidemic wave was mainly affected by infections in institutional hotspots (hospitals, nursing homes) (Kemenesi et al. 2020). Still, the role of geographical hotspots came from the hierarchical spatial spreading of the pandemic (Lennert 2020). The community-based epidemic spreading of the first wave has transformed to the chain of infections within the country in the second and the third wave. At the county level, the typical spatial pattern of the epidemic waves was mainly based on a western-eastern division completed by a northern-southern spatial relation during the third wave. At the

micro-regional level, centre-periphery relation was the dominant spatial pattern in the occurrence of the newly registered cases as well as deaths.

Fourthly, our analysis on the micro-regional level suggests that the socioeconomic conditions of the micro-regions might also influence the spatial inequalities among the districts in terms of death rates and COVID-19 infections. Although the infection rate of urbanised areas implied they were infection hubs, the death rate was lower in these micro-regions than in the less developed ones. This result might also refer to the spatial differences of healthcare, which may have a central role in a pandemic situation.

Finally, the most important finding in the examination of the policy interventions is that the mitigation measures taken at the national level are primary in Hungary's anti-epidemic approach. The competencies of municipalities in restrictions were apparent at the very beginning of the Hungarian epidemic, but their role remained of secondary importance.

## References

- Amdaoud M, Arcuri G, Levratto N (2021) Are regions equal in adversity? a spatial analysis of spread and dynamics of COVID-19 in Europe. *The European Journal of Health Economics* 22: 629–642. [CrossRef](#).
- Appiah-Otoo I, Kursah MB (2021) Modelling spatial variations of novel coronavirus disease (COVID-19): Evidence from a global perspective. *GeoJournal*. [CrossRef](#).
- Bambra C, Riordan R, Ford J, Matthews F (2020) The COVID-19 pandemic and health inequalities. *Epidemiology and Community Health* 74: 964–968. [CrossRef](#).
- Bavli I, Sutton B, Galea S (2020) Harms of public health interventions against COVID-19 must not be ignored. *BMJ* 371. [CrossRef](#).
- Boccia S, Ricciardi W, Ioannidis JP (2020) What other countries can learn from Italy during the COVID-19 pandemic. *JAMA* 180: 927–928. [CrossRef](#).
- Everitt BS, Landau S, Leese M, Stahl D (2011) *Cluster Analysis* (5th ed.). Wiley, Chichester. [CrossRef](#).
- Gombos K, Herczeg R, Erőss B, Kovács SZ, Uzzoli A, Nagy T, Kiss S, Szakács Z, Imrei M, Szentesi A, Nagy A, Fábíán A, Hegyi P, Gyenesei A (2020) Translating scientific knowledge to government decision makers has crucial importance in the management of the COVID-19 pandemic. *Population Health Management* 24. [CrossRef](#).
- Grünhut Z, Bodor A (2020) A fizikai (társadalmi) távolságtartástól a társadalmi szolidaritásig – A bizalom kultúrájának próbatétele. A fizikai és lelki egészség, továbbá a társas kapcsolatok és a szubjektív anyagi helyzet összefüggései a bizalommal járványidőszakban. (the culture of trust is on trial. links among physical and mental health, social relations, subjective welfare and trust during pandemic). *Tér és Társadalom* 34: 26–45
- Gu C, Zhu J, Sun Y, Zhou K, Gue J (2020) The inflection point about COVID-19 may have passed. *Science Bulletin* 65: 865–867. [CrossRef](#).
- Kemenesi G, Kornya L, Tóth GE, Kurucz K, Zeghib S, Somogyi BA, Zöldi V, Urbán P, Herczeg R, Jakab F (2020) Nursing homes and the elderly regarding the COVID-19 pandemic: Situation report from Hungary. *GeroScience* 42: 1093–1099. [CrossRef](#).
- Kovalcsik T, Boros L, Pál V (2021) A COVID-19-járvány első két hullámának területisége Közép-Európában (the spatiality of the first two waves of the COVID-19 pandemic in Central-Europe). *Területi Statisztika* 61: 263–290. [CrossRef](#).
- Kovács SZs, Koós B, Uzzoli A, Páger B, Egyed I (2020) Regional effects of the COVID-19 pandemic and policy responses in Hungary. *R-Economy* 6: 208–221. [CrossRef](#).

- Kovács SZs, Uzzoli A (2020) A koronavírus-járvány jelenlegi és várható egészségkockázatainak területi különbségei Magyarországon (present and future health risks and their regional differences in Hungary regarding COVID-19 pandemic). *Tér és Társadalom* 34: 155–170
- Lennert J (2020) A SARS-CoV-2 vírus magyarországi területi terjedésének forgatókönyvei – egy ágens alapú modellezési kísérlete (Spatial spreading of SARS-CoV-2 virus in Hungary based on agent-based model). [http://www.docs.rkk.hu/rkkweb/Lennert\\_terjedes\\_model.pdf](http://www.docs.rkk.hu/rkkweb/Lennert_terjedes_model.pdf)
- Merkely B, Szabó AJ, Kosztin A, Berényi E, Sebestyén A, Lengyel Cs, Merkely G, Karády J, Várkonyi I, Papp Cs, Miseta A, Betlehem J, Burián K, Csóka I, Vásárhelyi B, Ludwig E, Prinz Gy, Sinkó J, Hankó B, Varga P, Fülöp GA, Mag K, Vokó Z, the HUNGarian COronaVirus-19 Epidemiological Research (H-UNCOVER) investigators (2020) Novel coronavirus epidemic in the Hungarian population, a cross-sectional nationwide survey to support the exit policy in Hungary. *GeroScience* 42: 1063–1074
- Pandey A, Prakash A, Agur R, Maruvada G (2021) Determinants of COVID-19 pandemic in India: An exploratory study of Indian states and districts. *Journal of Social and Economic Development*. [CrossRef](#).
- Remoundou K, Koundouri P (2009) Environmental effects on public health: An economic perspective. *International Journal of Environmental Research and Public Health* 6: 2160–2178. [CrossRef](#).
- Röst G, Bartha FA, Bogya N, Boldog P, Dénes A, Ferenci T, Horváth KJ, Juhász A, Nagy Cs, Tekeli T, Vizi Zs, Oroszi B (2020) Early phase of the COVID-19 outbreak in Hungary and post-lockdown scenarios. *Viruses* 12. [CrossRef](#).
- Sigler T, Mahmuda. S, Kimpton A, Loginova J, Wohland-Jakhar P, Edwards ECH, Corcoran J (2020) The socio-spatial determinants of covid-19 diffusion: The impact of globalisation, settlement characteristics and population. Research square. [CrossRef](#).
- Urbanovics A, Sasvári P, Teleki B (2021) Evaluation of the COVID-19 regulations in the Visegrad group. *Transforming Government: People, Process and Policy* 15: 645–657. [CrossRef](#).
- Uzzoli A (2016) Health inequalities regarding territorial differences in Hungary by discussing life expectancy. *Regional Statistics* 6: 139–163
- Uzzoli A, Egri Z, Szilágyi D, Pál V (2020) Does better availability mean better accessibility? Spatial inequalities in the care of acute myocardial infarction in Hungary. *Hungarian Geographical Bulletin* 69: 401–418. [CrossRef](#).
- Uzzoli A, Kovács SZs, Páger B, Szabó T (2021) A hazai COVID-19-járványhullámok területi különbségei (regional differences of the epidemic waves in Hungary). *Területi Statisztika* 61: 291–319
- Wang W (2020) Spatial-temporal pattern of novel coronavirus pneumonia (COVID-19) in Europe. IOP Conference Series: Earth and Environmental Science 546 042015
- WHO – World Health Organization (2020) The intersection of COVID-19 and mental health. *The Lancet Infectious Diseases*. [CrossRef](#).

