Regional patterns in Covid-19 preparedness, impact, and economic response across the EU27

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In this study we classify the EU27 countries based on their Covid-19 national preparedness (human development index, hospital bed availability), health effects (excess mortality, reproduction rate), economic consequences of the crisis (GDP changes), and protective measures (stringency index, vaccination rates) during the coronavirus crisis and apply hierarchical clustering with Ward linkage to form comparable groups. Six clusters have emerged, four reflecting geographical patterns or institutionalized groups, such as the Baltic states, the Mediterranean countries, and the Visegrad Group 4 (V4), while Bulgaria constitutes a separate cluster. Central Europe is divided into Western and Eastern clusters. Additionally, the study examines the European Commission's State Aid Temporary Framework program using public data and reveals notable patterns in terms of economic support measures. This study is novel as it uses a multidimensional framework to assess Covid-19's impact and investigates both the early phase of the crisis and its later stages (January 2020–April 2022). One limitation is using averaged data, which smooths short-term fluctuations and wave-specific insights. Another limitation is the focus on European Commission-funded aid with the exclusion of national aid schemes. Our findings provide insight for policymakers and researchers on regional differences in pandemic response, economic impacts, and EU financial aid distribution.

Keywords:
European Union,
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state aid

Introduction

Covid-19 reached European countries in the spring of 2020, resulting in significant challenges to EU countries and revealing differences in preparedness, response coordination, and socio-economic resilience. Many nations had high health security capabilities, and their pandemic responses varied considerably, ranging from strict lockdowns and comprehensive financial aid packages to more relaxed measures with limited government intervention. These differences highlight the complex interplay between economic structures, healthcare systems, and policy decisions in shaping pandemic outcomes. Previous studies have focused only on specific phases of the pandemic, limiting the understanding of its broader impacts, which emphasizes the need to examine the whole two-year period (2020–2021) of the Covid-19 crisis across all EU27 countries.

Despite extensive research on Covid-19's health and economic impacts, there is a lack of integrated, multidimensional, cross-country analyses covering the whole crisis period. Much of the literature focuses on the initial phase of the pandemic (Aristodemou et al. 2021, Dzurova–Květoň 2021, Roman et al. 2022) or isolates either epidemiological (Ziakas et al. 2022, Sobczak–Pawliczak 2022) or economic aspects. This study addresses this gap by combining preparedness, policy responses, health outcomes, and economic effects to offer a holistic view of how EU27 countries navigated the pandemic. It also covers the European Commission's State Aid Temporary Framework, accounting for structural and regional differences.

Our dataset was from public records and was structured around four key dimensions. 1.) Preparedness was measured using the human development index (HDI) and hospital bed availability. 2.) Protective measures were assessed by the Oxford Covid-19 stringency index (Hale et al. 2021), capturing government interventions such as lockdowns and movement restrictions, and vaccination coverage measured by the % of the population vaccinated at least once. 3.) Health impact was evaluated through excess mortality and the reproduction rate, reflecting the direct and indirect consequences of the pandemic. 4.) Finally, economic impact was quantified through GDP change between 2019 and 2020, highlighting the financial disruption caused by the pandemic in the first year.

The primary goal of the research is to uncover similarities and differences between the EU27 countries based on selected variables related to Covid-19, such as pandemic response measures, economic performance, and the resilience of healthcare systems, that reflect the multifaceted impacts of the Covid-19 pandemic. By grouping countries into clusters, we aim to highlight patterns that may reveal underlying structural characteristics and response strategies across the European Union. To explore these patterns further, we address the following research questions:

RQ1: How can the EU27 countries be grouped based on their preparedness for the challenges of Covid-19, as well as their responses to protection measures and the resulting health and economic impacts?

Financial support policies are important in supporting and compensating businesses for the restrictions implemented. Countries introduced temporary state aid measures backed by the European Commission in different degrees and forms (EC 2022a).

RQ2: How do the levels (as a percentage of GDP) and forms of European Commission-backed state aid measures differ across the identified clusters of EU27 countries?

This research presents a novel, multidimensional approach to assessing the impact of the Covid-19 pandemic covering the period from January 2020 to April 2022. The findings offer valuable insights for policymakers, economists, and public health officials as they highlight regional differences in pandemic preparedness, health impacts, and economic outcomes across the EU27. The study can help us learn from the EU's crisis response, the allocation of financial support, experiences, and consequences for the EU27, supporting future decision-making on crisis management and targeted interventions.

The remainder of the study is structured as follows: it begins with a literature review, followed by the presentation of the database and methodology. After discussing the results, the study ends with the conclusions.

Literature review

Covid-19 was first reported in November 2019 in Wuhan. On January 30, 2020, the World Health Organization (WHO) declared Covid-19 a public health emergency of international concern. Following March 11, 2020, Covid-19 was characterized as a pandemic (Kavaliunas et al. 2020, Cho 2020). The Covid-19 pandemic first broke out in China and then in Italy, which was particularly hard hit by the first wave of the outbreak, and only China recorded more cases (Remuzzi–Remuzzi 2020, Chen et al. 2020). Despite their high health security capabilities, most European countries struggled to respond quickly and effectively (Forman–Mossialos 2021). While the European Commission implemented common measures for member states and several strategies to address the emerging Covid-19 crisis (Goniewicz et al. 2020, Forman–Mossialos 2021), the pandemic still posed significant challenges for EU countries, revealing gaps in preparedness and coordination (Alemanno 2020).

As a first step of protection, governments tried to reduce the spread of the virus through general lockdowns to limit the health impact of the Covid-19 pandemic (Green–Loualiche 2021, Belitski et al. 2022). National responses varied widely based on administrative systems and health system capacities. France's centralized approach contrasted sharply with Germany's decentralized model, while countries like Belgium and Italy adopted intermediate strategies (Bouckaert et al. 2020). Stricter restriction measures were often imposed in nations with weaker healthcare systems, such as Greece and Croatia, reflecting an inverse relationship between health system preparedness and the severity of restrictions (Aristodemou et al. 2021). Sweden's

Covid-19 response differed from many European countries by relying primarily on voluntary measures and individual responsibility (Kavaliunas et al. 2020), and implementing the least restrictive measures, such as public event cancellations, home confinement, workplace closures, and travel restrictions (Aristodemou et al. 2021). While this approach resulted in higher mortality compared to neighbouring Nordic countries, it was lower than in several other European nations (Kavaliunas et al. 2020). This diversity in policy approaches, described as „coronationalism", hindered broader European cooperation and coordination. Institutional settings and administrative systems influenced the differences in crisis management strategies among countries (Bouckaert et al. 2020). However, the pandemic also highlighted structural challenges in the EU. Countries with high government effectiveness and trust, such as Sweden and Germany, were slower to adopt restrictive measures and relied more on voluntary compliance. In contrast, Eastern European nations acted swiftly but struggled to sustain measures during subsequent waves, often misinterpreting early successes (Toshkov et al. 2022). The socio-economic impacts were uneven, with countries like Lithuania and Spain facing severe unemployment and fiscal pressures, while Hungary and Austria experienced relatively milder economic consequences (Aristodemou et al. 2021). The Visegrád Four (V4) countries – Poland, Hungary, the Czech Republic, Slovakia – have long cooperated on matters of shared interest within the Central European region, supported by their common cultural and political roots (Urbanovics et al. 2021). During the Covid-19 pandemic, researchers increasingly focused on this region, highlighting both similarities and differences in pandemic responses. Early studies (Podvrsic et al. 2020, Czech et al. 2020) revealed significant economic downturns across all four countries after the first wave, with Poland showing relative resilience due to its more diversified economy and lower reliance on the automotive sector (BNP 2021).

The Covid-19 pandemic caused substantial excess mortality across European countries during 2020–2021, with marked regional disparities. Prior studies attribute these differences to a combination of structural, policy, and demographic factors. Healthcare capacity, such as hospital bed availability and staffing, played a critical role in mitigating mortality (Ziakas et al. 2022, Remuzzi–Remuzzi 2020), while the timing and stringency of restriction policies significantly influenced outcomes, especially during early waves, when vaccines were unavailable (Sobczak–Pawliczak 2022). Socio-economic conditions – including income inequality, education levels, and baseline health status – also contributed to mortality risk. Countries with lower life expectancy and GDP per capita tended to experience higher excess mortality (López-Gigosos et al. 2023). Vaccination became a decisive factor from late 2020 onwards. Studies found a strong inverse relationship between vaccination coverage and excess mortality (Citi–de la Porte 2022, Ziakas et al. 2022). EU-level coordination through centralized procurement and distribution, as well as the establishment of joint health institutions, improved response effectiveness (Deters–Zardo 2023, Goniewicz et al. 2020, Pacces–Weimer 2020).

The mandatory social distancing and government-imposed lockdowns resulted in economic shocks for many economic actors (Kuckertz et al. 2020), and economic activity declined at an unprecedented rate (Coibion et al. 2020, Ravindran–Shah 2020). Governments provided immediate support to maintain adequate liquidity for companies and to ease the immediate negative impact of the sudden freeze in economic activity. As a quick response, national authorities introduced moratoria on loan repayments for borrowers in financial difficulty, as well as different public guarantee schemes to support the banks' lending activity (ECB 2020). In response to the Covid-19 pandemic's economic effects, the European Union also introduced the Covid Temporary Framework for State Aid, allowing member states to provide targeted and flexible support to businesses through guarantees, loans, and direct grants. Between mid-March 2020 and the end of 2021, member states committed budgets totaling approximately EUR 3.01 trillion for state aid measures, of which around EUR 940 billion – 3.4% of the EU's GDP on an annual basis – was actually used (Cannas et al. 2022). This framework was adapted six times to address the evolving challenges of the pandemic, enabling unprecedented levels of aid while offering a range of options to strengthen the economies of the European Union effectively.

Several studies have used cluster analysis to examine variations in Covid-19 impacts and policy responses across European countries or regions. Bucci et al. (2022) identified regional disparities in pandemic outcomes, showing that some areas recovered after early waves, while others experienced later surges. Dzurova–Květoň (2021) found that stricter early interventions correlated with lower mortality but were associated with later challenges, as seen in Czech Republic. Aristodemou et al. (2021) linked health system resilience to government responses, showing that less-prepared countries, like Hungary and Croatia, imposed stricter measures with significant socio-economic costs. Furthermore, their findings highlighted that stricter measures were associated with more substantial socio-economic consequences, emphasizing the trade-offs governments faced in balancing public health and economic stability. Roman et al. (2022) assessed tourism disruptions, highlighting severe declines in tourism-dependent economies. Czeczeli et al. (2020) explored fiscal and labour market vulnerabilities, finding that job-preserving policies mitigated unemployment despite industrial slowdowns. Despite differing focuses, these studies underscore the utility of clustering methods in identifying pandemic patterns and informing crisis management strategies.

Database and methodology

The analysis relies on the publicly available daily epidemiological situation and healthcare capacity data sourced from the Our World in Data platform and downloaded on March 6, 2023 (Mathieu et al. 2020) and on the GDP-related information obtained from the Eurostat database available up to March 4, 2023 (Eurostat 2023). We consider data for the period from January 2020 to April 2022. First, the examined country-level data exhibit high variability, particularly across different pandemic waves, making a two-year timeframe essential for capturing more stable trends and mitigating the impact of short-term fluctuations. Second, by early 2022, the health crisis in Europe had significantly eased, supported by a relatively high vaccination rate and the progressive relaxation of restrictive measures. In line with this, the European Commission announced in May 2022 that the State Aid Covid Temporary Framework would not be extended beyond June 30, 2022, reflecting a shift in crisis management policies. Additionally, in February 2022, the outbreak of the Russian–Ukrainian conflict marked the beginning of a broader period of polycrisis, introducing economic and geopolitical uncertainties that extended beyond the direct impacts of Covid-19 (Rokicki et al. 2023).

Variables

The variables were carefully chosen to capture the multidimensional nature of the Covid-19 crisis and enable meaningful comparisons across countries. In the first round, we investigated several variables to represent the four aspects under study. These seven variables capture the stringency of government responses, health impacts, and socio-economic conditions shaping countries' pandemic experiences (see in Appendix Table A1). As cluster analysis requires minimal correlation between variables, we narrowed the range of variables along the four aspects to avoid intercorrelation. Lastly, seven variables with sufficiently low intercorrelation were chosen, offering a comprehensive assessment of the Covid-19 pandemic across four distinct dimensions, providing a holistic perspective (see in Appendix Table A2).

Countries' preparedness was measured using two variables: *the human development index (HDI) and the number of hospital beds per 1,000 people (number of hospital beds).* The HDI is a composite measure of life expectancy, education, and income levels; we took the 2019 data. HDI values reflect broader socio-economic conditions that influence a country's ability to respond to crises. The *number of hospital beds* was used as a proxy for healthcare system preparedness. For this analysis, we relied on 2019 data, which offer a pre-pandemic baseline for evaluating each country's capacity to manage healthcare demands during a crisis. Similar indicators were used by Aristodemou et al. (2021) in their health system preparedness index, while Simakhova et al. (2022) also examined HDI and healthcare financing to assess healthcare preparedness across Europe.

We used two factors to consider the protective measures against the spread of the virus. The first line of protective measures was the implementation of lockdowns, quantified by the stringency index. The second was vaccination, which became available in Europe at the beginning of 2021, in the second year of the pandemic. This was assessed as the percentage of the population vaccinated. The Oxford Covid-19 stringency index is a composite metric derived from nine government response indicators, including school and workplace closures, restrictions on gatherings and internal movements, stay-at-home orders, public information campaigns, and international travel controls. Each indicator contributes to a daily score ranging from 0 (no restrictions) to 100 (strictest response). For this study, the average stringency score for each country was calculated from January 2020 to April 30, 2022. This metric reflects the overall intensity of government measures to restrict the virus's spread during the pandemic. The *vaccination rates* were calculated as the proportion of the population that received at least one vaccine dose by April 30, 2022. A related approach was taken by Aristodemou et al. (2021) in their *government response confinement index*, which measured lockdown severity across six dimensions, while Dzurova–Květoň (2021) examined restrictions like border closures and emergency declarations to assess policy responses in Europe.

The health impact was assessed using two variables. First, *excess mortality* was included, representing the number of excess deaths per one million inhabitants. It was calculated by comparing the actual number of deaths during a specific period with the expected number of deaths for the same period if the Covid-19 pandemic had not occurred. We used data up to April 30, 2022. Overall, these metrics help understand mortality impacts, including indirect effects such as healthcare system overload, and countries can be compared on this basis. A comparable approach was taken by Simakhova et al. (2022), who analysed Covid-19-related deaths per million people as a key indicator of health impact. Similarly, Dzurova–Květoň (2021) examined case fatality rates and crude death rates to assess the severity of the pandemic across European countries. Second, the *reproduction rate* was considered, which is the median number of new infections caused by a single infected individual. If the rate exceeds 1, the infection can spread within the population. If it falls below 1, the number of cases in the population will gradually decline to zero. We calculated the reproduction rate range during the period, as this metric effectively reflects the extremes of the virus's spread and the critical points of the epidemic's dynamics. The value of the metric is calculated as the distance between the maximum and minimum values.

The pandemic's **economic impact** was captured using GDP changes between 2019 and 2020. This variable reflects the economic disruption caused by the lockdowns imposed to mitigate the spread of the pandemic. Aristodemou et al. (2021) included GDP changes in their *socio-economic impact index* alongside unemployment and fiscal stimulus, while Roman et al. (2022) linked GDP declines to tourism losses, highlighting industry-specific impacts.

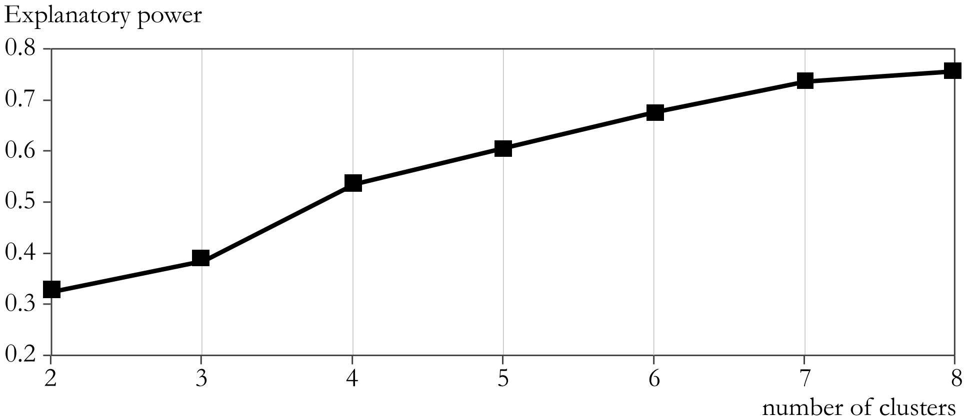
Cluster analysis

By selecting seven minimally correlated variables across four key dimensions, we used a multidimensional approach that ensures the clustering reflects the complex interplay of factors and highlights the heterogeneity among countries during the crisis. In cluster analysis, variations in the measurement scale or magnitude of variables can introduce implicit weighting, potentially distorting the calculated distances between observations. To ensure equal weight for all variables, we standardized them using Z-scores (mean = 0, standard deviation = 1). For hierarchical cluster analysis, we used agglomerative methods, which begin by treating each observation as its own cluster and progressively merging clusters based on distance or similarity. We aimed to identify a few relatively large, well-separated, and homogeneous clusters of approximately equal size. Therefore, we used the squared Euclidean distance measure in combination with Ward's method. Ward's method minimizes the variance within clusters by merging those that result in the smallest increase in total variance, producing highly homogeneous groups (Simon et al. 2024). The dendrogram (see in Appendix Figure A1) illustrates the agglomeration schedule and the relative distances between clusters, scaled to a maximum distance level of 25 units. Beyond its role in clustering, the dendrogram provides insights into the optimal number of clusters. By cutting the linkage just below the relative distance level of 5 (red vertical line in Figure A1), we identify six homogeneous and relatively large clusters, with Bulgaria forming a single-element outlier cluster. Further reducing the cut-off point to a relative distance level below 4 would introduce an additional small cluster comprising Cyprus and Greece. However, this would excessively fragment the groups, making the clustering less meaningful and reducing the interpretability of the results. Therefore, the chosen cut-off point ensures a balance between cluster size and homogeneity.

The optimal number of clusters was also determined using the *elbow method*, following Thorndike (1953). K-means cluster analyses were run in SPSS for cluster numbers from k=1 to k=8 using standardized variables (Z-scores). For each cluster configuration, cluster membership variables were analysed using one-way ANOVA. The ratio of the between-groups sum of squares to the total sum of squares indicates the explanatory power, which is plotted against the number of clusters in Figure 1. The breakpoint (elbow) in the graph indicates the point beyond which adding more clusters does not significantly increase explanatory power. As shown in Figure 1, the elbow occurs between 6 and 7 clusters. Adding a sixth cluster increases explanatory power by 8 percentage points, while the increase from 6 to 7 clusters is only 5 percentage points, and from 7 to 8 clusters, just 2 percentage points. Given the need to avoid creating small, less meaningful clusters (e.g., Cyprus and Greece), the optimal number of clusters is 6, as confirmed by the k-means analysis.

Figure 1

The cluster Elbow method



The 6 clusters look as follows and correspond mostly to 6 geographic European regions (see in Appendix Figure A2):

- Dark blue – West-European cluster (west): Austria, Germany, Belgium, France, and Slovenia;
- Red – Southern countries cluster (south), which equals to the Mediterranean: Cyprus, Greece, Portugal, Spain, Italy, and Malta;
- Green – The typical North countries cluster (north): Ireland, Netherlands, Denmark, Finland, Sweden, and Luxembourg; containing three countries from the Nordic region;
- Grey – Baltic States (Baltic): Latvia, Lithuania, and Estonia, which are often referred to collectively with the political term „Baltic states";
- Light blue – Europe's middle cluster (CEE): the Visegrad Group (V4) countries (Poland, Slovakia, Czech Republic, Hungary), Romania, and Croatia;
- Orange – Quasi outlier: Bulgaria.

As the final step in the cluster analysis, we examined the ANOVA table for the six clusters to assess the role of each variable in cluster formation. The p-values in the last column of Table 1 are close to 0, indicating that all standardized variables significantly contribute to cluster formation at commonly used significance levels (1% and 5%). The F-values help rank the variables by their importance in forming the clusters. Notably, the number of available hospital beds and the human development index (HDI) emerged as the strongest determinants of cluster formation, while the *stringency index* had the least influence.

Table 1

ANOVA (k = 6 clusters) – SPSS

Variables	Cluster		Error		F	Sig.
	mean square	df	mean square	df		
Zscore (stringency index)	2.820	5	0.567	21	4.975	0.004
Zscore (GDP change from 2019 to 2020)	3.558	5	0.391	21	9.105	< 0.001
Zscore (excess_mortality)	3.704	5	0.356	21	10.396	< 0.001
Zscore (reproduction rate)	3.098	5	0.500	21	6.191	0.001
Zscore (vaccinated)	3.303	5	0.452	21	7.312	< 0.001
Zscore (hospital beds)	4.043	5	0.276	21	14.67	< 0.001
Zscore (HDI)	4.002	5	0.285	21	14.036	< 0.001

Notes: The F-tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

Based on the data published by the European Commission (2022b), we analysed the EU support measures utilized by individual countries covering two years (2020–2021). The downloaded data present the nominal value of support measures, categorized by type and country, including 15 different types of support measures; however, our analysis focuses on the four most significant categories: direct grants (TF 3.1 and Treaty), subsidized loans (TF 3.3), guarantees on loans (TF 3.2 and Treaty), and wage subsidies (TF 3.10). These four types account for 95% of the total support utilized. Therefore, the remaining support types were grouped under the „Other/non-classified" category. The analysis considers the distribution of aid both in nominal and relative terms, as a proportion of each country's GDP (2019), assessing the types of state aid measures employed, first at the national level and then by aggregating the data to identify patterns within the defined clusters.

Results

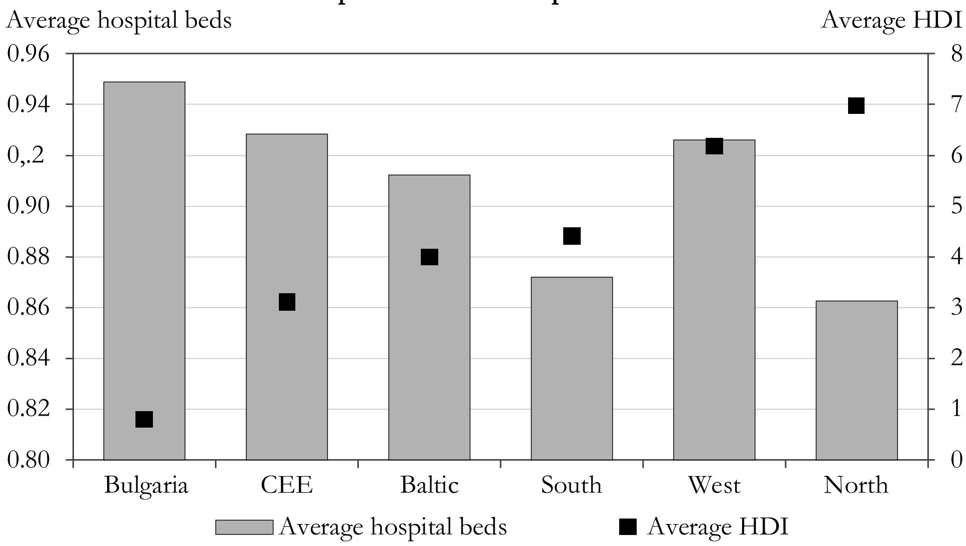
In Appendix Table A3, we presented the mean, minimum, maximum values, and standard deviation of the variables analysed by country and cluster. In the following, we introduce the characteristics of each cluster along with the variables.

Characteristics of clusters along the variables

The clusters were initially analysed based on their preparedness for Covid-19, using HDI and the number of hospital beds as key indicators. Figure 2 presents the clusters in ascending order of HDI growth. With the lowest HDI, Bulgaria has the highest number of hospital beds. The CEE, the Baltic, and the west exhibit medium HDI levels. Notably, as HDI increases, the number of hospital beds generally decreases. The west deviates from the general trend of increasing HDI and decreasing hospital beds, as it exhibits a middle HDI, and high values for hospital beds, similar to the CEE. The north has the highest HDI, with the lowest number of hospital beds. In conclusion, in terms of HDI, the north, west, and south cluster countries are the most advanced, while Bulgaria, the CEE, and the west are the most advanced regarding hospital beds.

Figure 2

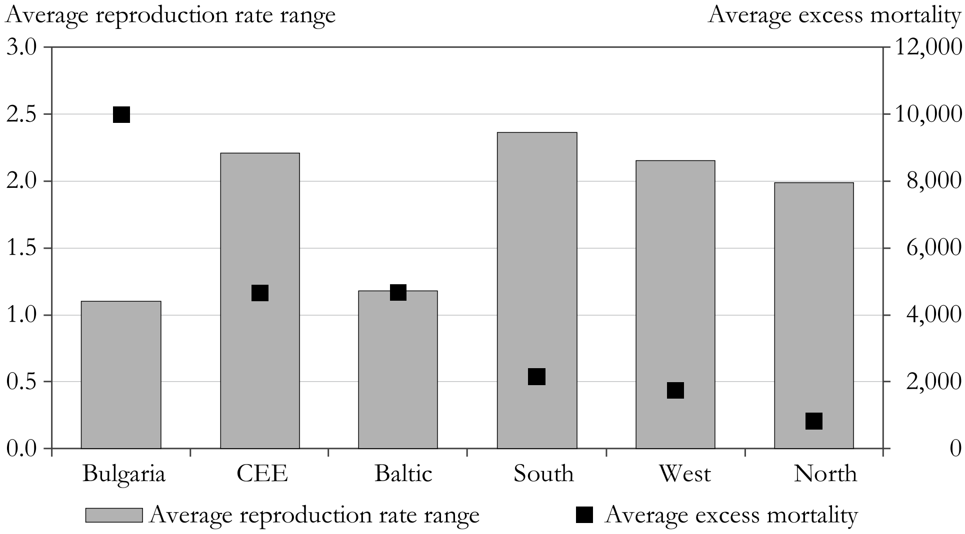
Preparedness for the pandemic



After examining preparedness, we now turn to the health effects of Covid-19. Excess mortality serves as the primary indicator of health impact, for which the reproduction rate was also considered. Excess mortality emerged as the third most significant clustering factor, with an F-value of 10.3, while the reproduction rate ranked sixth among the seven variables, with an F-value of 6.2. Figure 3 displays the clusters in ascending order of HDI growth, revealing a clear trend: excess mortality decreases as HDI increases. Despite having one of the lowest reproduction rates, Bulgaria recorded the highest excess mortality. In contrast, with high vaccination coverage, the north cluster experienced the lowest excess mortality.

Figure 3

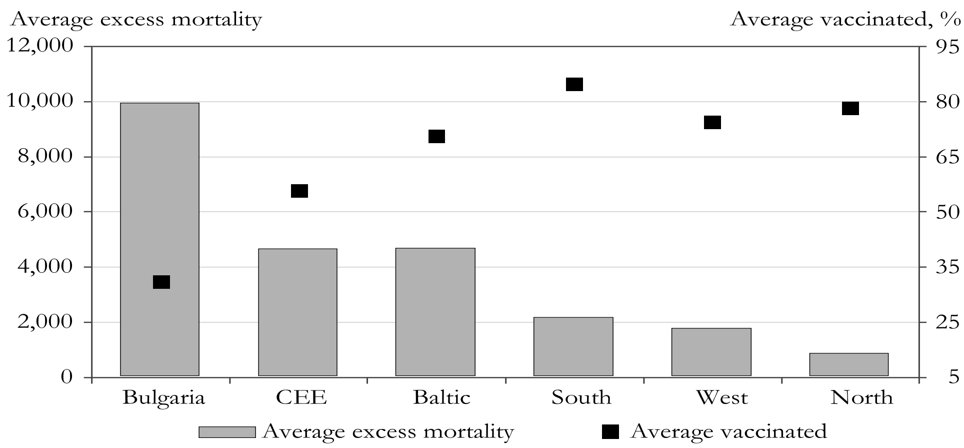
Health effect of the pandemic



Protective measures were assessed using two key variables: the stringency index and the proportion of the population vaccinated. Continuing with the health impact, Figure 4 illustrates the number of deaths alongside vaccination rates, with the clusters ordered by HDI. As HDI increases, so does the vaccination rate, with the highest vaccination coverage observed in the south cluster. The graph reveals an inverse relationship between vaccination rates and mortality rates. Bulgaria, with the lowest vaccination rates, also experienced the highest death rates, while an opposite trend was observed in the north cluster.

Figure 4

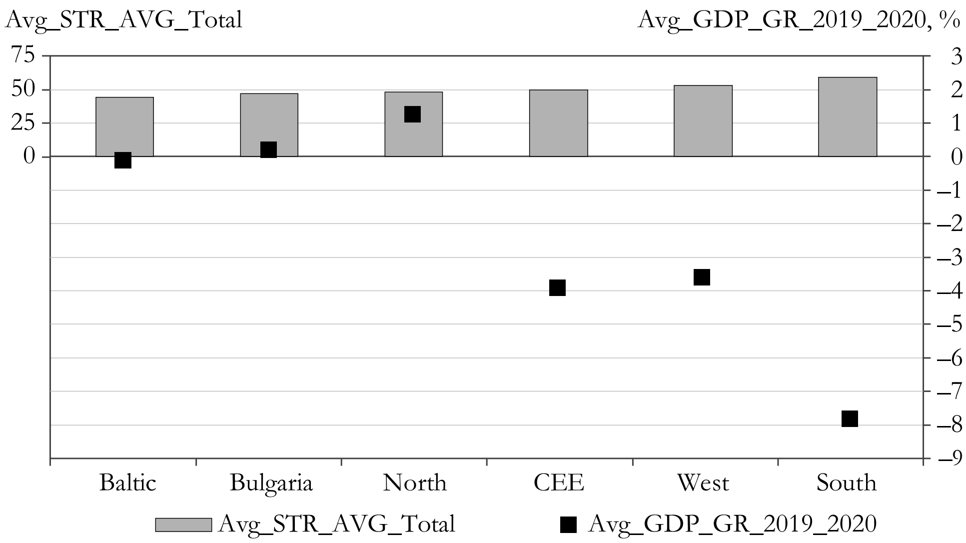
Average share of vaccinated citizens and average excess mortality



The first protective measure against the spread of Covid-19 was the implementation of lockdowns by the governments; however, these measures had a significant negative impact on the economy, as reflected in GDP changes between 2019 and 2020. Bulgaria, the Baltic, and the north implemented less stringent measures to control the spread of the virus. As shown in Figure 5, the south typically introduced the most stringent measures, and it experienced the sharpest GDP decline, approaching 8%. The south cluster enforced these measures early on, as they were among the first EU27 countries to face severe health consequences from the pandemic. While effective in mitigating health risks, these lockdowns led to the most significant economic downturns in the EU27. In contrast, the lowest stringency levels were observed in the Baltic and Bulgaria, which experienced more moderate economic downturns. Notably, northern countries adopted moderately stringent measures and achieved slight economic growth, distinguishing themselves from other EU27 clusters.

Figure 5

Protective measures – stringency index and economic impact



The European Commission's Temporary Framework for State Aid

In this section, we analyse the implementation of measures under the European Commission's Covid-19 Temporary Framework for State Aid (EC 2022b), focusing on the extent of financial support utilized by EU27 countries. The analysis considers aid distribution, both in nominal and relative terms, as a proportion of each country's GDP. Furthermore, we assess the types of state aid measures employed, first at the national level and then by aggregating the data to identify patterns within the defined clusters. The EU support measures are shown in relative terms (as a percentage of GDP) in Appendix Figure A3 and Table 2.

Figure A3 shows the deployment of the state aid measures' budget by member states, which vary widely across the countries. In relative terms, the deployment corresponds to an average of 4.2% of the national GDP. Italy received the most aid (11.4%), ahead of France (9.0%) and Spain (9.7%). Conversely, the countries that employed the least state aid relative to GDP were Ireland (0.5%), Sweden (0.6%), and Luxembourg (1.2%).

Regarding the form of support, EU27 countries adopted different strategies to assist companies, reflecting varying policy priorities and economic conditions. Approximately 43% of total aid expenditure (EUR 409 billion) was in the form of loan guarantees under the temporary framework. Italy, Romania, Portugal, and France allocated over 70% of their total domestic expenditure to guarantees. Other significant users included Hungary (47%), Croatia (45%), and Spain (41%).

The second most-used measure was limited-amount grants (i.e. direct grants, EUR 270 billion, i.e. 29% of the total), which allowed member states to set up schemes where aid can take various forms (direct grants, tax and payment advantages or other forms such as repayable advances). Countries like Poland (86%), Greece (84%), and Slovenia (68%) relied heavily on this measure. Germany (EUR 77.56 billion) and France (EUR 49.56 billion) provided the largest absolute amounts.

The third most employed measure was the subsidized interest rates for loans, which were used in some countries, especially in Croatia, Cyprus, Estonia, Germany, Hungary, Latvia and Lithuania. The usage of wage subsidies played a significant role in Cyprus, Bulgaria, Malta and Slovakia.

Finally, favourable loans (section 3.3) constituted one-fourth of Germany's Covid-19 aid (EUR 54.71 billion), and Lithuania and Estonia also relied heavily on this measure.

In terms of clusters, Figure A3 shows that south cluster countries primarily relied on guarantee programs based on the allocated amounts and employed substantial funding relative to GDP (4–11%). An exception among these countries is Malta, which, instead of heavily utilizing guarantee programs, directed EU funds towards wage subsidies (6.5% relative to GDP). Within the CEE region, Hungary stands out with a GDP-proportional employment of 8.7%, also primarily due to the reliance on guarantee programs.

For the Baltic and north countries, the forms of aid employed were mixed (Table 2). However, they relied less on guarantee programs for corporate loans, favouring direct grants, subsidized loan schemes, and wage subsidies. Nonetheless, their allocated amounts were relatively modest, representing approximately 1–3% of GDP. Identified as an outlier, Bulgaria, which was significantly affected by the Covid-19 crisis, exhibited a surprisingly low relative size of aid employed (2.6%) despite its level of impact.

Table 2

Average state aid expenditure by cluster and type as a proportion of the countries' GDP (as of December 31, 2021)

(%)

Clusters	TF 3.1 Direct grants	TF 3.3 – Subsidized loans	TF 3.2 – Guarantees on loans	TF 3.10 – Wage subsidies	Other/ non-classified	Total
Bulgaria	0.8	0.0	0.3	1.5	0.0	2.6
CEE	1.7	0.3	1.6	0.5	0.1	4.1
Baltic	1.1	0.8	0.4	0.0	0.4	2.6
South	2.1	0.0	3.9	1.0	0.0	7.0
West	2.2	0.3	2.1	0.1	0.3	5.1
North	0.8	0.0	0.6	0.0	0.2	1.7
Total	1.6	0.2	1.8	0.4	0.2	4.2

Source: EC (2022b), Eurostat (2023).

Discussion

To answer RQ1, we analysed how the EU27 countries can be clustered based on their Covid-19 preparedness, responses to protective measures, and the resulting health and economic impacts. To address RQ2, we investigated the distribution and forms of European Commission-backed state aid across these clusters, revealing significant heterogeneity in the allocation of EU-backed financial support. The analysis has identified the following distinct clusters, presented with a summary of their key characteristics and the allocation of EU-supported state aid:

1 Bulgaria exhibited several extreme values across key indicators. In terms of preparedness, it had the lowest HDI value among the clusters (0.82) but the highest number of hospital beds (7.45). Regarding Covid-19's health impact, Bulgaria displayed a clear contrast: despite having one of the lowest reproduction rates (1.1, ranging from a maximum of 1.71 to a minimum of 0.61), it recorded the highest excess mortality among the clusters (9,942). This high mortality rate may be linked to the country's low protective measures or its overall lower standard of living (the lowest-value HDI index). Bulgaria had the second-lowest average stringency index (46.66) following the Baltic, and the lowest vaccination rate among the EU27 (31.06%). In conclusion, Bulgaria experienced the lowest level of protection and the highest health impact in terms of mortality among EU27 countries. At the same time, its economic growth remained stagnant, with a marginal increase of 0.13% in 2020. Bulgaria also received a surprisingly low level of EC support (2.6% of GDP). It is noteworthy that Bulgaria uniquely spent a significant part of its support on wage subsidies, amounting to 1.5% of GDP.

2 The CEE region (0.86) occupied a median position in terms of HDI, alongside the Baltic (0.88) and south (0.89) clusters. In terms of hospital beds (6.42), it was

comparable to the west cluster (6.3). However, it is important to note that the west had a significantly higher HDI (0.92) than the CEE. Despite a high value of reproduction rate, the CEE recorded a much lower excess mortality rate than Bulgaria. CEE represents a moderate approach regarding the stringency index (49.43) and the vaccination rate (55.58%). In summary, the CEE countries adopted a middle-way strategy across multiple dimensions, resulting in a moderate economic contraction of –3.93%. In terms of EU support, the CEE is in the middle regarding the EC aid level calculated as a proportion of GDP (4.1%). Hungary stands out within the cluster with an exceptionally high rate of 8.7%, mainly due to its reliance on guarantee schemes.

3 The Baltic cluster, like the CEE region, occupies a median position in terms of preparedness, with an HDI of 0.88 and an average of 5.61 hospital beds. Similarly, their health impact was moderate. Although the Baltic region recorded the lowest reproduction rate, like Bulgaria, it still experienced higher excess mortality than the south, west, and north clusters, which had significantly higher reproduction rates but less than half the excess mortality. From a protection perspective, the Baltic had the lowest stringency index (44.09) among all clusters. This more relaxed approach contributed to a nearly stagnant economic performance with a minor GDP decline of –0.19% in 2020. Unlike the CEE region, however, the Baltic countries achieved higher vaccination coverage (69.81%) while maintaining the lowest stringency index. In summary, the Baltic countries adopted a „middle-way" policy, combining minimal restrictions with higher vaccination coverage. This approach resulted in moderate health outcomes and a nearly unchanged economic performance during the pandemic. Notably, the relative value of EU support utilized by the Baltic countries was below average, amounting to just 2.6% of GDP.

4 The south displayed moderate preparedness for Covid-19, characterized by a medium HDI (0.89) and the second-lowest number of hospital beds (3.61). Despite the limitations, the spread of the virus was the most severe in this cluster, with the highest reproduction rate (2.36). Strict measures were implemented to mitigate the health impact, which is reflected in the highest stringency index (59.4) and the highest vaccination coverage (~85%) among the clusters. These efforts effectively reduced excess mortality (2,138), which was the third lowest. However, these measures came at a significant economic cost, as the south experienced the sharpest GDP decline (–7.79%). In conclusion, the south adopted stringent closures and achieved high vaccination rates, which successfully curbed excess mortality but resulted in the most substantial economic contraction among the clusters. The south heavily relied on EU-funded state aid, averaging 7% of GDP – the highest among the clusters – primarily through guarantee programs. An exception is Malta, which, instead of heavily utilizing guarantee programs, directed EU funds predominantly to wage subsidies.

5 The west cluster ranks as the second-best in terms of preparedness, with an HDI of 0.92 and a high availability of hospital beds (6.3), the latter being similar to that of the CEE cluster. The spread of the virus was significant, slightly lower than in the south but similar to the CEE countries. Regarding protective measures, this cluster implemented strict lockdowns, with the second-highest stringency index of 52.97. Economically, it experienced a contraction of –3.93%, the second most severe. However, vaccination rates were high, similar to those in the south and north clusters, reaching approximately 75%. This contributed to relatively low excess mortality, making it the second lowest. In conclusion, while this cluster comprises some of the most economically developed countries, its stringent measures during the period effectively curbed mortality rates, albeit at the cost of a moderate economic decline. The west cluster utilized EU state aid programs at an above-average level (5.1%), with France standing out at 9%.

6 The north cluster exhibits the highest HDI at 0.94 and the lowest average number of hospital beds (3.13), reflecting two extremes in preparedness indicators. Regarding health impact, while the reproduction rate was relatively high at 1.98, excess mortality was the lowest among the clusters, totalling 830. In terms of protective measures, the vaccination rate reached 77.68%, and the stringency index, at 47.85, was in line with medium-stringency EU27 countries such as Bulgaria and the Baltic states. Economically, the north cluster was unique in achieving GDP growth between 2019 and 2020, with a modest increase of 1.18%. In summary, the north cluster implemented relatively less stringent measures while maintaining the lowest excess mortality rate, suggesting a balanced approach to public health and economic stability during the pandemic. The modest GDP growth of 1.18% in 2020 is particularly notable given that year's widespread economic contraction. The north received the lowest volume of EU state aid, amounting to only 1.7% of GDP.

Previous studies have not identified clusters with the same structure, which emphasizes the novelty of our approach. Notably, Bulgaria's extreme values in mortality and protective measures, along with the unique balance of low mortality and economic resilience observed in the north cluster, were not captured in earlier research. These differences can be attributed to variations in data selection, methodology, and the tendency of previous studies to focus on shorter timeframes or specific aspects of the pandemic. By encompassing the entire Covid-19 impact period, this study offers a more comprehensive analysis of national responses and long-term outcomes.

Conclusion

In this study we classify the EU27 countries based on the preparedness of healthcare, protective measures, and resulting health and economic impacts during the Covid-19 crisis. As a result, we identified six distinct clusters: the west, south, north, Baltic and CEE clusters, and Bulgaria as quasi-outlier, revealing notable differences among them. Additionally, the study examined how funds from the EC State Aid program were distributed and used across these clusters, highlighting significant variations in aid allocation.

Overall, countries with *higher human development index* (HDI) levels, such as the north and west clusters, generally achieved higher vaccination rates, implemented moderate lockdown policies and experienced lower excess mortality rates. In contrast, Bulgaria, with the lowest HDI and weakest protective measures, exhibited the highest excess mortality despite a relatively low reproduction rate. The south cluster implemented the most stringent lockdowns and achieved the highest vaccination coverage with moderate health impacts but suffered the most severe economic contraction. The Baltic and CEE regions adopted a more balanced approach, with lower restrictions and vaccination rates, resulting in moderate health and economic consequences. The north cluster uniquely combined high vaccination coverage with relatively less stringent measures while maintaining the lowest excess mortality and achieving positive GDP growth. These findings align with the conclusions of Aristodemou et al. (2021), who found that stricter confinement measures were typically implemented in countries with weaker healthcare preparedness, leading to more severe socio-economic consequences.

The study also emphasizes differences in allocating and utilizing EU financial support among the clusters. The highest support levels were observed in the south (7% of GDP) and the west (5.1%), primarily through guarantee schemes, while the lowest was in the north (1.7%). In general, countries facing more severe economic recessions, such as Italy, Spain, and France, accessed higher levels of state aid, which highlights the significance of the EU's targeted support framework. Bulgaria is a notable outlier, as it received one of the lowest levels of aid (2.6%) despite suffering the highest excess mortality. This suggests that EU-backed aid allocation was primarily driven by economic distress rather than public health impacts.

Based on this study's findings, several policy recommendations can guide more effective future crisis responses across the EU27. Given the heterogeneity of country clusters, pandemic strategies should be tailored to structural conditions. High-HDI countries with limited hospital capacity, such as those in the north, need flexible healthcare mobilization, while lower-HDI countries like Bulgaria require targeted social and health interventions. Higher vaccination rates were linked to lower excess mortality, highlighting the need for early procurement and strong public outreach. Health and economic responses must be better integrated – strict lockdowns curbed mortality but exacerbated economic decline, especially in the south. EU-level fiscal support should balance both priorities. The uneven use of EU state aid also calls for more impact-sensitive allocation criteria. Establishing a permanent EU preparedness and resilience framework could support knowledge sharing and cluster-specific policy design. National governments can use the results to identify strengths and gaps relative to similar countries, allowing for better-targeted policies. For researchers, the study's clustering approach provides a robust foundation for comparative analysis, enabling more refined empirical studies. Finally, financial and social policy planners can apply these insights to build proactive, evidence-based interventions that enhance systemic resilience in future crises.

Despite the robustness of the clustering approach, the study's limitations include the aggregation of data over two years, which obscures wave-specific dynamics, and the exclusion of nationally funded support programs, potentially overlooking additional financial interventions. Future research could enhance these findings by incorporating sector-specific impacts and extended policy evaluations. A key area for further study is the accuracy of reported reproduction rates, as Bulgaria's low reproduction and excess mortality rates raise concerns about data reliability or healthcare quality, despite its high hospital bed capacity. Additionally, the effectiveness of financial aid should be examined in greater detail, whether certain support measures inadvertently sustained unviable and highly indebted companies – commonly referred to as zombie firms – or provided support to businesses that were not negatively affected by the pandemic. Addressing these issues could provide deeper insights into the long-term economic and policy consequences of Covid-19 in the EU. The ethically sensitive question of valuing human life arises, as more detailed country-level calculations could help decision-makers fine-tune measures in future crises.

Appendix

Table A1

Variables

Factors	Meaning?	Category	Source
Stringency index	Composite measure based on nine response indicators regarding closure. Score ranging from 0% to 100%. Average stringency score from January 2020 to April 2022.	Protective measure	Our World in Data – Oxford database (Hale et al. 2021)
Vaccination rate	Total number of people who received at least one vaccine dose until April 2022, divided by the total population of the country.	Protective measure	Our World in Data (WHO 2023)
Excess mortality	The difference between the reported number of deaths from January 2020 to April 2022 and an estimate of the expected deaths for that period had the Covid-19 pandemic not occurred.	Health impact	Our World in Data (The Economist – Solstad 2021)
Reproduction rate	The reproduction rate represents the average number of new infections caused by a single infected individual. Daily data from January 2020 to April 2022, calculated the max-min values.	Health impact	Our World in Data (Arroyo-Marioli et al. 2023)
Available hospital bed	Hospital beds include inpatient beds available in public, private, general, and specialized hospitals (bed per thousand in 2019).	Preparedness	Our World in Data (World Bank Group 2023)
HDI	Measuring human development helps us understand how people's lives and livelihoods vary across the world and how they have changed over time. Score ranging from 0 to 1.	Preparedness	Our World in Data (UNDP 2020)
GDP change	GDP change in the first year of Covid-19 crisis: change between 2019–2020.	Economic impact	Eurostat (2023)

Table A2

Correlation analysis between variables – SPSS

Correlations		String-ency index	GDP change from 2019 to 2020	Excess mortality	Repro-duction rate range	Vacci-nated	Hospital beds	HDI
Stringency index	Pearson correlation	1	–0.430*	–0.056	0.341	0.263	–0.080	0.029
	Sig. (2-tailed)		0.025	0.780	0.082	0.185	0.691	0.888
	N	27	27	27	27	27	27	27
GDP change from 2019 to 2020	Pearson correlation	–0.430*	1	–0.041	–0.377	–0.246	0.029	0.275
	Sig. (2-tailed)	0.025		0.838	0.053	0.217	0.887	0.166
	N	27	27	27	27	27	27	27
Excess mortality	Pearson correlation	–0.056	–0.041	1	–0.197	–0.706**	0.553**	–0.774**
	Sig. (2-tail)	0.780	0.838		0.325	0.000	0.003	0.000
	N	27	27	27	27	27	27	27
Reproduction rate range	Pearson correlation	0.341	–0.377	–0.197	1	0.290	–0.040	0.080
	Sig. (2-tailed)	0.082	0.053	0.325		0.143	0.842	0.693
	N	27	27	27	27	27	27	27
Vaccinated	Pearson correlation	0.263	–0.246	–0.706**	0.290	1	–0.548**	0.611**
	Sig. (2-tailed)	0.185	0.217	0.000	0.143		0.003	0.001
	N	27	27	27	27	27	27	27
Hospital beds	Pearson correlation	–0.080	0.029	0.553**	–0.040	–0.548**	1	–0.454*
	Sig. (2-tailed)	0.691	0.887	0.003	0.842	0.003		0.017
	N	27	27	27	27	27	27	27
HDI	Pearson correlation	0.029	0.275	–0.774**	0.080	0.611**	–0.454*	1
	Sig. (2-tailed)	0.888	0.166	0.000	0.693	0.001	0.017	
	N	27	27	27	27	27	27	27

Note: * correlation is significant at the 0.05 level (2-tailed). ** correlation is significant at the 0.01 level (2-tailed).

Figure A1

Dendrogram using Ward linkage – SPSS

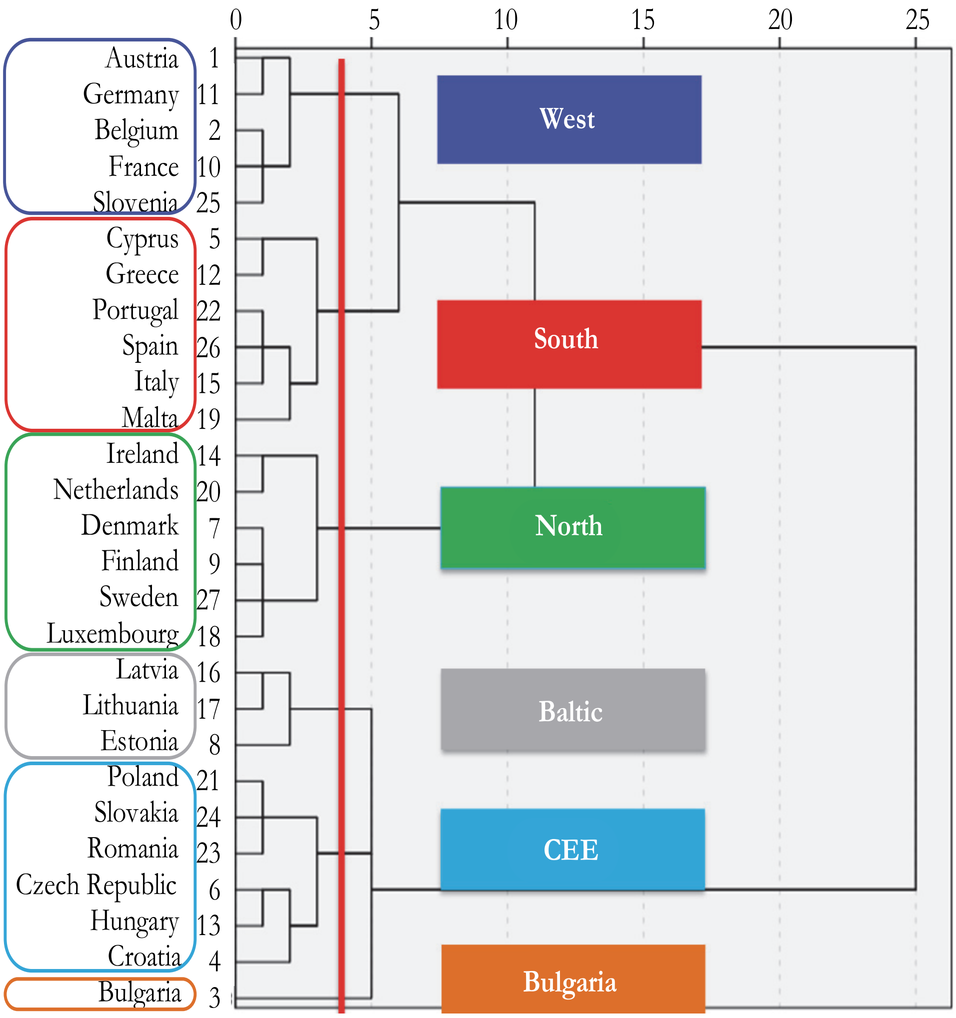
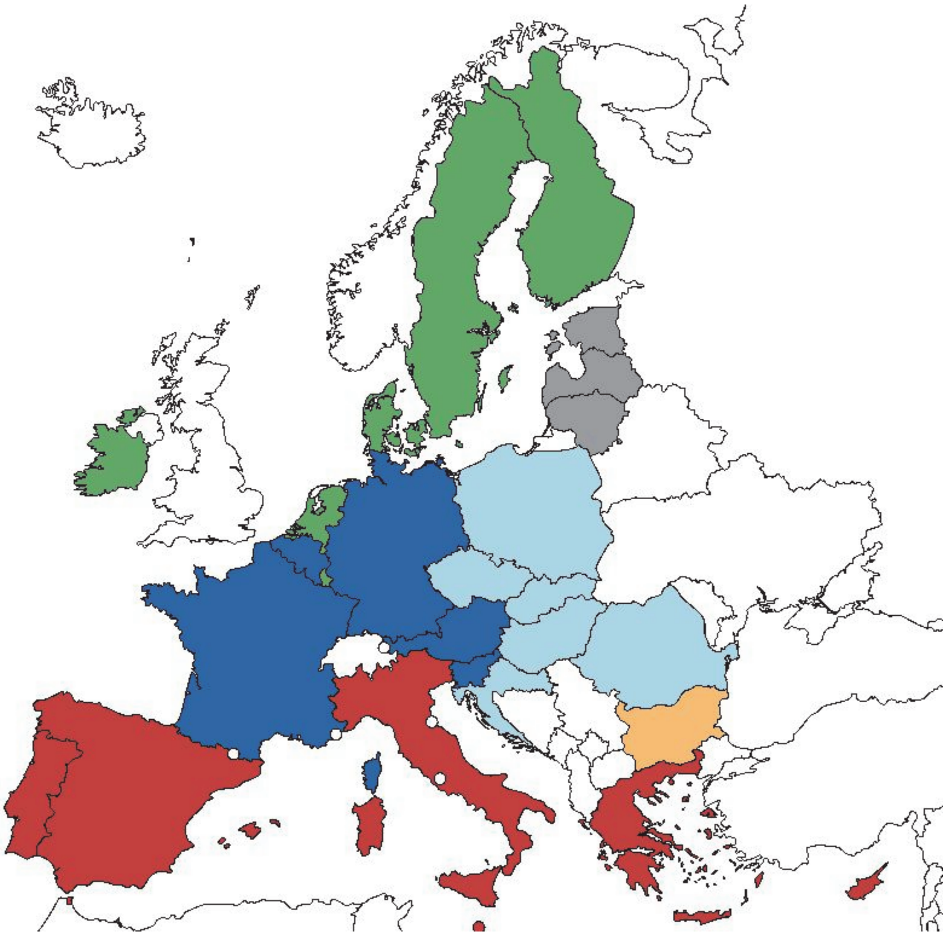


Figure A2

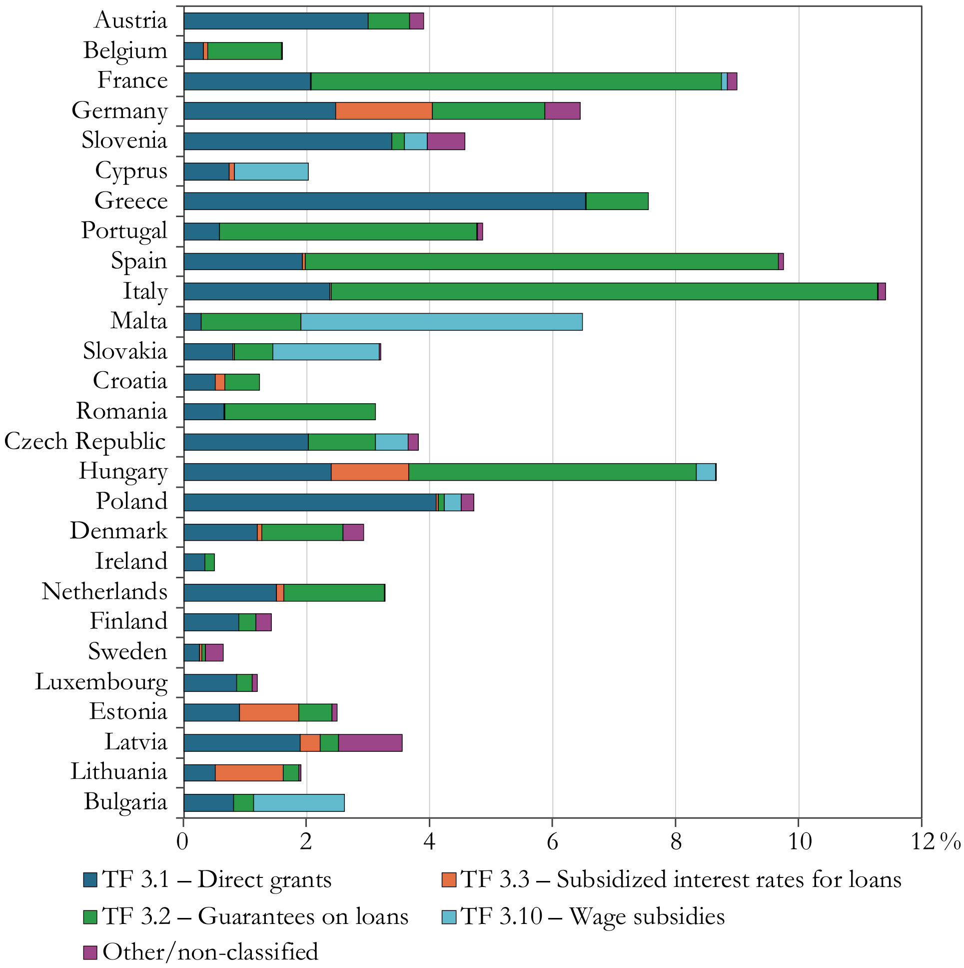
EU27 geographical grouping using hierarchical clustering



- West-European cluster (west): Austria, Germany, Belgium, France, and Slovenia
- Southern countries cluster (south), which equals to the Mediterranean: Cyprus, Greece, Portugal, Spain, Italy, and Malta
- The typical North countries cluster (north): Ireland, Netherlands, Denmark, Finland, Sweden, and Luxembourg
- Baltic states (Baltic): Latvia, Lithuania, and Estonia
- Europe's middle cluster (CEE): the Visegrad Group (V4) countries (Poland, Slovakia, Czech Republic, Hungary), Romania, and Croatia
- Quasi outlier: Bulgaria

Figure A3

Total state aid expenditure by EU27 under the temporary framework until December 31, 2021 (as a percentage of member states' 2019 GDP)



Source: EC (2022b), Eurostat (2023).

Table A3

Descriptive statistics

Country/region	Preparedness		Protective measures	
	hospital beds/ thousand people	HDI	average of stringency index	vaccination rates, %
Bulgaria	**7.45**	**0.82**	**46.66**	**31.06**
		CEE		
Croatia	5.54	0.85	42.16	57.59
Czech Republic	6.63	0.90	50.11	66.47
Hungary	7.02	0.85	47.27	64.42
Poland	6.62	0.88	51.37	57.38
Romania	6.89	0.83	54.96	41.64
Slovakia	5.82	0.86	50.69	46.00
Average	**6.42**	**0.86**	**49.43**	**55.58**
Min.	**5.54**	**0.83**	**42.16**	**41.64**
Max.	**7.02**	**0.90**	**54.96**	**66.47**
Standard deviation	**0.60**	**0.02**	**4.33**	**9.90**
		Baltic		
Estonia	4.69	0.89	39.12	65.54
Latvia	5.57	0.87	46.31	72.74
Lithuania	6.56	0.88	46.84	71.16
Average	**5.61**	**0.88**	**44.09**	**69.81**
Min.	**4.69**	**0.87**	**39.12**	**65.54**
Max.	**6.56**	**0.89**	**46.84**	**72.74**
Standard deviation	**0.94**	**0.01**	**4.31**	**3.78**
		South		
Cyprus	3.40	0.89	59.53	74.88
Greece	4.21	0.89	67.68	76.40
Italy	3.18	0.89	64.20	86.19
Malta	4.49	0.90	51.39	89.77
Portugal	3.39	0.86	56.37	95.23
Spain	2.97	0.90	55.09	86.93
Average	**3.61**	**0.89**	**59.04**	**84.90**
Min.	**2.97**	**0.86**	**51.39**	**74.88**
Max.	**4.49**	**0.90**	**67.68**	**95.23**
Standard deviation	**0.60**	**0.01**	**6.05**	**7.86**
		West		
Austria	7.37	0.92	56.68	77.17
Belgium	5.64	0.93	49.13	79.49
France	5.98	0.90	51.81	80.60
Germany	8.00	0.95	56.30	77.81
Slovenia	4.50	0.92	50.93	59.71
Average	**6.30**	**0.92**	**52.97**	**74.96**
Min.	**4.50**	**0.90**	**49.13**	**59.71**
Max.	**8.00**	**0.95**	**56.68**	**80.60**
Standard deviation	**1.40**	**0.02**	**3.36**	**8.63**
		North		
Denmark	2.50	0.94	43.91	81.35
Finland	3.28	0.94	40.28	81.66
Ireland	2.96	0.96	55.71	81.76
Luxembourg	4.51	0.92	46.50	74.42
Netherlands	3.32	0.94	54.99	72.74
Sweden	2.22	0.95	45.71	74.12
Average	**3.13**	**0.94**	**47.85**	**77.68**
Min.	**2.22**	**0.92**	**40.28**	**72.74**
Max.	**4.51**	**0.96**	**55.71**	**81.76**
Standard deviation	**0.80**	**0.01**	**6.19**	**4.33**

(Table continues on the next page.)

(Continued.)

Country/region	Health effect					GDP change 2019–2020, %
	excess mortality/ million people	minimum	maximum	average	range	
		of reproduction rate				
Bulgaria	**9,942**	1.71	0.61	1.05	**1.10**	**0.13**
CCE						
Croatia	4,942	3.29	0.14	1.06	3.15	–9.38
Czech Republic	4,043	2.26	0.63	1.07	1.70	–4.35
Hungary	3,756	2.11	0.56	1.10	1.76	–5.94
Poland	4,282	2.51	0.34	1.05	2.17	–1.19
Romania	6,103	2.61	0.51	1.05	2.67	–1.65
Slovakia	4 689	1.76	0.44	1.07	1.75	–1.08
Average	**5,394**	**2.42**	**0.44**	**1.07**	**2.20**	**–3.93**
Min.	**3,756**	**1.76**	**0.14**	**1.05**	**1.70**	**–9.38**
Max.	**6,103**	**3.29**	**0.63**	**1.10**	**3.15**	**–1.08**
Standard deviation	**837**	**0.52**	**0.18**	**0.02**	**0.60**	**3.31**
Baltic						
Estonia	2,638	1.63	0.57	1.04	1.06	–1.08
Latvia	4,455	1.81	0.59	1.06	1.22	–1.25
Lithuania	6,890	1.7	0.45	1.04	1.25	1.76
Average	**4,661**	**1.71**	**0.54**	**1.05**	**1.18**	**–0.19**
Min.	**2,638**	**1.63**	**0.45**	**1.04**	**1.06**	**–1.25**
Max.	**6,890**	**1.81**	**0.59**	**1.06**	**1.25**	**1.76**
Standard deviation	**2,134**	**0.09**	**0.08**	**0.01**	**0.10**	**1.69**
South						
Cyprus	1,351	1.83	0.59	1.07	1.47	–5.53
Greece	3,004	1.78	0.68	1.06	1.57	–9.79
Italy	3,145	3.54	0.58	1.09	2.99	–7.55
Malta	1,203	3.62	0.11	1.01	3.51	–7.14
Portugal	2,022	2.69	0.57	1.08	2.28	–6.46
Spain	2,104	2.96	0.65	1.15	2.31	–10.24
Average	**2,138**	**2.74**	**0.53**	**1.08**	**2.36**	**–7.79**
Min.	**1,203**	**1.78**	**0.11**	**1.01**	**1.47**	**–10.24**
Max.	**3,145**	**3.62**	**0.68**	**1.15**	**3.51**	**–5.53**
Standard deviation	**809**	**0.80**	**0.21**	**0.04**	**0.79**	**1.86**
West						
Austria	1,785	2.89	0.46	1.07	2.43	–4.06
Belgium	1,832	2.43	0.74	1.11	1.80	–3.93
France	1,372	3.09	0.6	1.11	2.49	–5.22
Germany	1,109	3	0.52	1.12	2.48	–1.95
Slovenia	2,535	1.88	0.35	1.06	1.53	–3.12
Average	**1,727**	**2.66**	**0.53**	**1.10**	**2.15**	**–3.66**
Min.	**1,109**	**1.88**	**0.35**	**1.06**	**1.53**	**–5.22**
Max.	**2,535**	**3.09**	**0.74**	**1.12**	**2.49**	**–1.95**
Standard deviation	**542**	**0.50**	**0.15**	**0.03**	**0.45**	**1.21**
North						
Denmark	286	1.81	0.63	1.05	1.18	0.72
Finland	915	1.92	0.46	1.06	1.85	–0.76
Ireland	853	2.72	0.47	1.07	2.59	4.52
Luxembourg	209	2.37	0.58	1.10	1.96	3.86
Netherlands	1,673	2.8	0.36	1.06	2.44	–2.03
Sweden	1,042	2.29	0.44	1.16	1.85	0.77
Average	**830**	**2.32**	**0.49**	**1.08**	**1.98**	**1.18**
Min.	**209**	**1.81**	**0.36**	**1.05**	**1.18**	**–2.03**
Max.	**1,673**	**2.80**	**0.63**	**1.16**	**2.59**	**4.52**
Standard deviation	**537**	**0.40**	**0.10**	**0.04**	**0.50**	**2.56**

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