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The COVID-19 pandemic and main economic convergence indicators in the EU

Madalina Ecaterina Popescu[a,b], Amalia Cristescu[b,c] and Ramona-Mihaela Paun[a]

[a]Department of Economic Informatics & Cybernetics, Bucharest University of Economic Studies, Bucharest, Romania; [b]The National Scientific Research Institute for Labour and Social Protection, Bucharest, Romania; [c]Department of Economics and Economic Policies, Faculty of Theoretical and Applied Economics, Bucharest University of Economic Studies, Bucharest, Romania

ABSTRACT
>The outbreak of COVID-19 pandemic caused an unprecedented global public health crisis, which led to a drastic decline in economic activity and sharp rises in government deficits and public debts. Our research aims to analyse the aggregated impact of COVID-19 pandemic on each EU country and their health systems and correlate it with the main economic convergence indicators for 2020. To this purpose, we built a composite COVID index using Principal Component Analysis, employed TOPSIS to rank the EU countries according to nominal and real convergence indicators, and correlate the index with each ranking. Our findings suggest that in the first year of the pandemic, nominal convergence indicators were more affected than real convergence indicators. Non-euro CEE countries managed to keep some of their convergence indicators at relatively sustainable levels despite having high COVID index values. Baltic and Scandinavian countries seem to have outperformed the others, the latter having an initially more relaxed approach to the restrictions imposed on the population. The risk of diverging during the pandemic crisis appears to be increasing in countries where there were imbalances prior to 2020.

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1. Introduction

At EU level, decisions regarding economic and monetary integration are centred around fulfilling nominal and real convergence criteria. The criteria for nominal convergence established by the Maastricht Treaty (TEU, 1992) apply to EU member states that have not yet adopted the single currency and tackle the sustainability of public finances, price stability, the long-term interest rate, and the exchange rate dynamics.

However, the Maastricht Treaty does not mention explicit criteria for real convergence, which are equally important for economic sustainability and implicitly for the

CONTACT Madalina Ecaterina Popescu madalina.andreica@csie.ase.ro

adoption of the euro. Real convergence is a long-term process in which the differences in real variables between lower-income economies and higher-income economies are narrowing down in an attempt to achieve greater similarity. Real GDP per capita is usually the main indicator used to measure real convergence (Bisciari et al., 2020). Several factors contribute towards the achievement of real convergence: improvements in institutional quality, trade openness, innovation, human capital, high investment rates, etc. (Żuk & Savelin, 2018).

To ensure that member states maintain sound public finances after the adoption of euro, EU proposed the Stability and Growth Pact that allows it to launch an excessive deficit procedure against a member state that is not respecting one of the following rules: i) not exceeding a budget deficit of 3% of GDP, or ii) having a government debt level above 60% of GDP that is not diminishing at a satisfactory pace.

The COVID-19 pandemic is a severe asymmetric shock (Greiner & Owusu, 2020; Odendahl & Springford, 2020) that is fundamentally disrupting the economies of the EU member states (Bodnar et al., 2020) and could have a significant impact on economic convergence (Bisciari et al., 2020; Claeys et al., 2021; Fedajev et al., 2022; Martinho, 2021). Drastic economic declines have been noticed in most European countries since the beginning of the pandemic (Fedajev et al., 2022; International Monetary Fund (IMF), 2021a, 2021b; Pinilla et al., 2021).

In the midst of such health crisis, most EU member states have temporarily introduced restrictive measures to reduce the number of infections and avoid putting pressure on health systems. They have also implemented macroprudential fiscal-budgetary policies and monetary surveillance measures to mitigate economic and social impact (Cheng et al., 2020; Claeys et al., 2021; Kinnunen et al., 2021; Thomas et al., 2021).

In this context, the anticipatory assessment of convergence is marked by a high degree of uncertainty as the impact of the pandemic crisis can best be assessed after all restrictions are lifted and all economic activities restarted. However, the extent to which the convergence criteria were affected thus far can still be observed by analysing the changes in the convergence related indicators in 2020 compared to 2019, particularly considering that, given the urgency, the activation of the general escape clause of the Stability and Growth Pact has allowed member states to deviate from the normally applicable budgetary rules.

To capture the undiluted impact of this shock and clearly reveal the economic and social effects (that may be absorbed in the long run through different measures taken), our analysis will be limited to a shorter period. We do not aim to perform an analysis of the convergence process at the EU level, but rather capture the short term impact of the coronavirus pandemic (COVID-19) on EU economies and their health systems and relate this with the main economic convergence indicators to see how each member state has coped with the challenges posed by the crisis in the first year of the pandemic.

Quantifying the aggregated economic impact of the current pandemic upon each EU country and its health system is a challenging multi-dimensional task; therefore, we decided to tackle this issue by proposing a novel methodological approach to measure the impact of the pandemic through a composite index.

We aim to build a COVID composite index that would measure not only the severity of the current pandemic through the total number of confirmed cases, hospital patients, intensive care unit (ICU) patients and confirmed deaths, but also the intensity of the government interventions to fight the spreading and the financial and economic repercussions of the pandemic.

Such composite index could become a powerful political tool that checks general patterns across the EU member states showing how governments responded to this threat and how affected each economy was. Moreover, such COVID index could be useful in addressing some policy implications concerning economic convergence of the European countries and in giving some insights on the economic changes that might have been associated with the current pandemic.

Considering the existing INFORM COVID Risk Index (Poljansek et al., 2020) which identifies countries at risk from health and humanitarian impacts, we were able to measure more accurately the aggregated economic impact of the COVID-19 pandemic upon each EU country and their health systems using a novel composite index.

The structure of the paper is the following: Sec. 2 is dedicated to the literature review, while the methodology and data are described in Sec. 3. The main results of the study concerning both the proposed COVID composite index and its relationship with the main economic convergence indicators of the EU countries are presented in Sec. 4, while Sec. 5 contains the main conclusions.

2. Literature review

The outbreak of COVID-19 drew significant attention on the issue of global health crises. Many countries have launched rapid assessments of the socio-economic impact of the pandemic, analysed potential scenarios and identified proper policy responses (United Nations Development Programme (UNDP), 2020).

Worth noting is the work of Ma et al. (2020) that analysed the six most recent health crises: Flu (1968), SARS (2003), H1N1 (2009), MERS (2012), Ebola virus disease outbreak (2014), and Zika (2016) with the intent to estimate a lower bound for the global economic effects of COVID-19. The authors showed that real GDP falls by around 3% in affected countries relative to unaffected countries in the year of the outbreak and although the bounce-back in GDP growth is rapid, output would stay below pre-shock level five years later.

The annual potential economic impact of COVID-19 outbreak worldwide was initially assumed to be close in magnitude to the annual losses of climate change, estimated at about 0.7% of global GDP (World Economic Forum, 2019). More recent estimates refer to a fall of 2%–4% of global GDP below the baseline in 2020 (Jackson et al., 2021; Maliszewska et al., 2020), with advanced economies taking the hardest hit (IMF, 2021a; World Bank, 2021).

Compared to the global economy, EU had a higher fall in real GDP at around 6.3% (European Commission, 2021a), while the euro area lost 6.8%–7.5% (IMF, 2021a; OECD, 2021; World Bank, 2021). Real GDP is expected to reach pre-crisis levels by mid-2022 in both EU and euro area (De Vet et al., 2021) after an asymmetric recovery in 2021.

Economies have reacted by developing different policy responses to fight the spread of COVID-19. These ranged from testing, contact tracing, isolation and quarantine to containment measures that may have reduced the number of infections and death by as much as 90% (Deb et al., 2022). Other measures aimed at addressing the short-term economic consequences of the pandemic without creating long-term distortions were implemented (Jackson et al., 2021). IMF (2021b) has created a policy tracker covering the key measures taken in 197 countries to limit human and economic impact of COVID-19.

Cheng et al. (2020) classified these policies from a multi-dimensional perspective, considering the type of implemented policy, the level of action, the direction (e.g., inbound or outbound), the mechanism, the enforcement and the timing of action.

Kinnunen et al. (2021) identified and clustered 179 countries with similar government strategies to mitigate the pandemic and according to their performance success. A composite COVID Mitigation Index was built for comparative purposes, using Factor Analysis with Principal Axis Factoring. Their main findings suggest that over time, the governments strategies converge and the diversity of mitigation policies decreases while the policy measures strengthen, suggesting that countries design and adapt their policy learning from their own experiences and the results of the better performing economies.

Eventually, it all comes down to finding, designing, and implementing the appropriate types of measures to ensure sustainable economic convergence. At EU level, decisions were made to ensure the asymmetric effects on member states will not lead of long-lasting divergence, particularly since the recovery is more even than initially projected (European Commission, 2021b). However, the issue of convergence within EU is not clear. Pre-COVID studies have shown income divergence tendencies within the groups of EU-15 and EU-12 countries following the financial crisis of 2008 and confirmed the existence of income convergence clubs considering a south vs. north and/or east vs. west grouping. Nominal divergence seems to be increasing too for euro area after 2008 (except for Baltic States) and is rather weak for new member states (Glawe & Wagner, 2021).

Fedajev et al. (2022) used the entropy method and cluster analysis to analyse the convergence among EU member states and concluded that COVID-19 will deepen the economic divergence. To ensure nominal and real convergence, measures should be adjusted to the specific conditions of each of the five clusters identified. A similar conclusion regarding existing of some potentially long-lasting divergence within EU and the need to use targeted measures is supported by Claeys et al. (2021) and Martinho (2021). Southern or south-Eastern Europe and countries with longer lockdowns are likely to experience larger and longer lasting recessions and diverge (Bisciari et al., 2020; Odendahl & Springford, 2020).

The empirical research that tackles the issue of quantifying the intensity and risks of the COVID-19 worldwide using composite indexes is quite scarce. Worth noting is the significant effort put in by Thomas et al. (2021) to collect daily data referring to 20 indicators that reflect containment and closure measures, economic response, as well as health systems measures from 185 countries to build and update the Oxford COVID-19 Government Response Tracker. Based on this data, several composite indexes are calculated: (i) the Overall Government Response Index, (ii) the Containment and Health Index, (iii) the Stringency Index and (iv) the Economic Support Index. These indexes are built using simple averages of individual indicators, with some indicators being used for computing multiple aggregate indexes.

Considering the few existing composite indexes concerning the COVID-19 pandemic, our approach differs threefold. First, we intended to measure the impact of the pandemic upon the EU countries from a broader and complex perspective, by extending the dimensionality of the existing COVID composite indexes, which either reflected only the intensity of governmental policy measures taken worldwide or the risk of the coronavirus spreading. To this purpose, generous datasets were collected to reflect several dimensions, such as: government interventions in response to the pandemic in terms of containment and closure, health systems and economic efforts, pandemic's pressure on health systems, as well as general health system indicators.

Second, we used indicators reflecting the relative impact of the intensity of the government responses over the total confirmed cases of each country or as percentage of GDP. Also, the total number of deaths was reported as ratio of total confirmed cases in each country, while the number of ICU patients were divided by the total hospital beds. In this manner, we adjust the degree of relevance of each outcome to the size and particularities of each EU country, allowing for a more accurate comparison between countries.

Third, in contrast to the commonly used technique to aggregate the initial indicators into a composite index using simple additive unweighted method, we applied a Principal Component Analysis (PCA) that computes weights via statistical methods, to avoid arbitrarily selected weights.

Given the limited empirical research in this field, it is hoped that this paper will bring more insights into the use of composite indexes that measure the impact of COVID-19 and how this relates to recent changes in the economic convergence of these EU countries.

3. Methodology and data

3.1. Building the composite index

Building a composite index is not always straightforward because of methodological challenges that can arise when selecting the component indicators, transforming the initial indicators, or combining and assigning weights (Freudenberg, 2003; Smith, 2002). To build a COVID composite index, we followed the methodology presented in (OECD & Joint Research Centre., 2008; Jacobs et al., 2004) that involves the following steps:

Step 1. Defining the main objective of the composite index

Our composite index aims to effectively measure the impact of the COVID-19 pandemic upon the EU member states, while capturing both the severity of the pandemic in terms of casualties, and the intensity of government responses to the outbreak for year 2020.

Step 2. Selecting the initial indicators for the composite index

We gathered an initial set of 28 indicators available for 27 EU countries for 2020 using two main data sources: i) Our World in Data statistics, and ii) the Oxford COVID-19 Government Response Tracker database.

The multi-dimensionality of the index is given by the following indicators (see Appendix A for detailed description), grouped in five main categories:

- government response to the pandemic in terms of containment and closure: School closing (C1), Workplace closing (C2), Cancel public events (C3), Restrictions on gatherings (C4), Close public transport (C5), Stay at home requirements (C6), Restrictions on internal movement (C7), and International travel controls (C8)
- health systems indicators: Emergency investment in healthcare (H1), Investment in vaccines (H2) and Protection of elderly people(H3)
- economic response: Income support (E1), Debt/contract relief (E2), Fiscal measures (E3) and International support (E4)
- pandemic's pressure on the health system: Deaths %cases (P1), Total deaths (P2), Total cases (P3), ICU patients (P4), Hospital patients (P5), Total cases %population (P6), ICU patients %hospital beds (P7), Positive rate (P8) and Total tests (P9)
- general health system indicators: Life expectancy (G1), Cardiovascular death rate (G2), Diabetes prevalence (G3) and Hospital beds (G4)

The indicators reflecting the government response to the pandemic were collected from the Oxford COVID-19 Government Response Tracker database. Most of these indicators were initially expressed in ordinal scale and normalized to produce scores between 0 and 100 by applying the formula described in OxCGRT technical documentation (see Appendix A).

To better reflect the intensity of government response in each EU country, we divided the scores resulted from the ordinal scale normalization by the total number of confirmed cases (in thousands) registered in 2020. Only indicator H3 was computed by dividing the intensity of the government response by the total share of population over 65 years old for each country.

On the other hand, indicators E3, E4, H1 and H2 expressed in monetary units ($) were computed as percentages of each country's nominal GDP to better reflect the intensity of the financial support allocated to fight the pandemic. The nominal GDP of each country for year 2020 was collected from the Eurostat Database.

The indicators reflecting the pandemic's pressure on the health system were collected from Our World in Data database and were checked against the World Health Organisation database. Most of these indicators reflect the total number of confirmed cases, deaths and tests performed until 31st of December 2020. Only indicators P4, P5, P7 and P8 were computed as average values of daily data for 2020.

Finally, the general health system indicators were collected from Our World in Data database and initially added to the composite index analysis to include the current particularities of health systems in each country (Asandului et al., 2014).

The constructed data set was then checked for multicollinearity and based on the results presented in the correlation matrix (see Appendix B) several indicators had to be excluded: C1, C3, C4, C6, C8, E1, E2, P9 and G2.

Step 3. Normalizing the individual indicators

Since not all initial indicators are expressed in the same measurement units and extreme values might be present, we standardized the initial data prior to aggregating them into the composite index by calculating the z-scores (see Appendix C).

Step 4. Building the composite index based on a decision rule

Using the simple additive unweighted method as in the case of the indexes presented in previous section usually works when the initial indicators are either highly correlated or uncorrelated at all (Joint Research Centre, 2002).

Alternatively, using distinct weights reflect the reliability or priority of those indicators (Freudenberg, 2003). Among the most common multivariate statistical techniques applied to build such composite indexes are PCA and Factor Analysis, which estimate weights based on the correlations between the initial data.

In this study, we apply PCA, which is a statistical procedure that reduces the initial dimensionality of data to a small number of uncorrelated factors (known as principal components) that account for much of the initial data variance. Each principal component (PC) measures different statistical dimensions of the initial data, being a weighted linear combination of the original variables. Based on the correlation matrix of the standardized data, PCA estimates the eigenvalues, giving distinct weights to each PC. The first PC reflects the largest variation of the original variables, the second PC reflects the maximum variation not contained in the first component and so on.

The main advantage of this procedure is that it will never rely on arbitrarily selected weights, but on weights computed via statistical methods.

Step 5. Sensitivity analysis to test the robustness of the composite index

Following the approach of Davidescu et al. (2015) and Popescu et al. (2018), we tested the robustness of the COVID composite index and evaluated the quality of the PCA results using statistical tests such as Bartlett's test of sphericity and the Kaiser-Meyer-Olkin test (KMO). The KMO test checks the sampling adequacy, while the Bartlett's test of sphericity identifies if there are any redundancy between variables and if there is correlation between the initial indicators.

Since the KMO test's value of 0.68 is higher than 0.5 we conclude that the sampling is adequate and the PCA is appropriate. Also, the Bartlett's test of sphericity, suggests that the correlation matrix is not an identity matrix and that initial indicators are related and thus suitable for structure detection (Approximate Chi-Square = 95.6).

3.2. Selection of convergence indicators

In the analysis of the convergence process, we focused on the sustainability of the public sector and chose as indicators the budget balance (budget deficit) and the public debt, both significant for nominal convergence as detailed in the Maastricht Treaty applicable to non-euro countries, but also in the Stability and Growth Pact valid for eurozone. We have also included the inflation rate and the long-term interest rate (long-term government bond yields).

Unlike the nominal convergence criteria, which are clearly established, in case of real convergence there is no pre-established list of indicators or numerical benchmarks. Following the European Central Bank analysis (2015), in order to cover real convergence we investigated indicators that are relevant for economic sustainability (real GDP growth rate), labour market sustainability (unemployment rate) and trade sustainability (current account balance). The data for 2020 were collected from World Data Atlas Database (The Worldwide Governance Indicators).

The EU countries were then ranked according to the nominal convergence indicators on one hand, and the real convergence indicators on the other, using TOPSIS multi-criteria method (Hwang & Yoon, 1981).

TOPSIS method was chosen as it allows ranking the EU member states considering various indicators. It does so by calculating the Euclidian distance between each country and an ideal solution which scores best under each convergence criteria (see Appendix D).

Next, we computed the Spearman correlation coefficients between the COVID effect and each set of convergence indicators, considering the country rankings resulted from the COVID index and the two types of convergence indicators.

4. Results and discussion

4.1. Calculation of COVID composite index

Out of 28 initial indicators, only 8 were kept in the COVID composite index (the rest were dropped due to severe multicollinearity or after applying PCA).

The eigenvalues resulted from the PCA are shown in Appendix E, together with the extracted components. Only the first three principal components are above 1 (λ_1= 3.58, λ_2 = 1.29 and λ_3 = 1.04), having a minimum informational loss of approximately 26% and, according to the Kaiser criterion, these were kept in the COVID composite index.

The first principal component (PC1) explains 44.8% of the total initial data variance and indicates the containment government response and the severity of the COVID-19 pandemic. The variables with which it is most correlated reflect the intensity of the government response to close workplaces and public transport and to impose restrictions on internal movement or to protect elderly people. PC1 strongly

Table 1. The principal components matrix.

PC Interpretation	Indicators for the COVID Index	Component 1	Component 2	Component 3
PC1—Containment government response and the severity of the COVID-19 pandemic	Zscore(C2)	.911	−.045	.004
	Zscore(C5)	.869	.249	.138
	Zscore(C7)	.882	.172	.052
	Zscore(H3)	.465	.316	.189
	Zscore(P1)	−.607	.455	.248
	Zscore(P8)	−.712	.497	−.261
PC2—Health systems pressure due to the COVID-19 pandemic	Zscore(P7)	−.234	−.791	.231
PC3—Financial government response	Zscore(E3)	−.267	.108	.893

Source: Authors' computation.

depends also on the severity of the pandemic spread, expressed by total number of deaths relative to total number of confirmed cases and the average daily positive rate.

The second principal component (PC2) explains 16% of the total initial data variance and reflects the health systems pressure due to the COVID-19 pandemic. PC2 is strongly correlated with the average daily number of patients confirmed with COVID-19 in the ICUs relative to the total hospital beds.

The last principal component (PC3) explains 13% of the initial data variance and indicates the financial government response to the severity of the COVID-19 pandemic, being strongly correlated to indicator E3.

The detailed description of the three principal components is presented in Table 1.

The non-standardized COVID index is computed as follows:

$$\begin{aligned} \text{COVID\_INDEX} &= \frac{44.8}{73.8}PC1 + \frac{16}{73.8}PC2 + \frac{13}{73.8}PC3 \\ &= 0.607 \cdot PC1 + 0.217 \cdot PC2 + +0.176 \cdot PC3 \end{aligned} \tag{1}$$

Finally, following the approach proposed in Davidescu et al. (2015), the composite index was then transformed using the percentile rank method in SPSS. The use of percentages for COVID index makes sense, as it facilitates the interpretation and comparison between EU countries. A higher percentage reflects a higher intensity of the aggregated impact and pressure exerted upon the economy and health systems due to the pandemic at country level in 2020.

The final hierarchy of the most affected EU countries by the COVID-19 pandemic, facing high pressure on their health systems, is presented in Figure 1. The COVID index places Bulgaria on top. Even though the total confirmed cases and deaths registered by the end of 2020 in Bulgaria is below the EU average, the relative number of total deaths over total confirmed cases was the highest. More precisely, Bulgaria

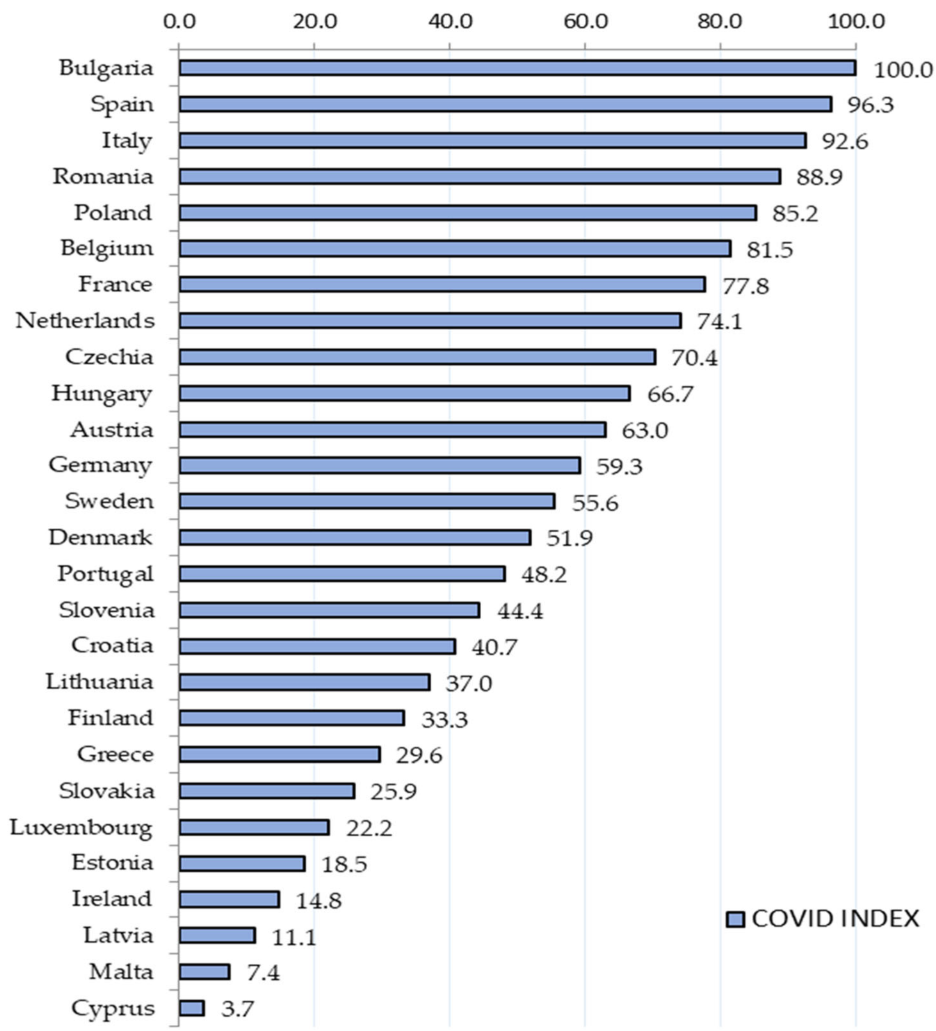

Figure 1. Hierarchy of the EU countries based on the COVID Index, 2020. Source: Authors' computation.

registered a 3.7% ratio, compared to the minimum ratio of 0.5% registered in Cyprus, which is placed last in the hierarchy, being the least affected by the pandemic so far.

Also, in terms of average daily positive rates, Bulgaria registered a very high rate (12%), being placed right after Poland (13%) in top of the EU countries with the highest share of positive COVID-19 tests. High values were also registered for Romania (10%), Netherlands and Belgium (9%), which ranked among the first 8 EU countries most affected by the pandemic.

The positioning of Spain and Italy in top 3 most affected EU countries comes as no surprise, as they registered the highest average daily number of patients confirmed with COVID-19 in the ICU relative to the total hospital beds, placing their health systems under high pressure. Even though their governments took immediate measures to fight the spreading of COVID-19, the total number of confirmed cases dramatically increased in these two countries.

Regarding the financial government response, Italy has allocated a very high percentage of GDP to fiscal measures to fight the pandemic (29.7%), while Spain's fiscal effort in 2020 was almost neglectable. The other EU countries with the highest announced economic stimulus spending in 2020 computed as percentage of GDP were: France (35%), Hungary (21.9%), Greece (19.2%), and Poland (15.1%).

Romania and Poland are ranked 4th and 5th in this top, mostly due to their high positive rates, high number of confirmed cases (above the EU average in 2020), and limited government response relative to total cases of COVID-19.

France's appearance on the 7th position is mostly justified by the high amount of money allocated by the government to fight the pandemic, and its high numbers of total cases and daily average ICU patients with COVID-19 relative to total hospital beds.

At the bottom of the hierarchy, we have Cyprus, Malta, Latvia, Estonia, with very low positive rates (ranging between 1–3%), and Ireland (8%). These countries were less affected by the COVID-19 pandemic in terms of total number of confirmed cases, and deaths. We also noticed that the lowest ratios of total deaths relative to each country's total confirmed cases of COVID-19 were in Cyprus (0.5%), Denmark (0.8%), Estonia (0.8%), Luxembourg (1.1%) and Slovakia (1.2%), while the highest were in Bulgaria (3.7%), Italy (3.5%), Greece (3.5%), Belgium (3%), Hungary (3%), Spain (2.6%), Romania (2.5%), and France (2.5%).

4.2. Analysing the convergence indicators for EU countries in the pandemic context

For nominal convergence, we considered the public debt and budget balance as shares in GDP, the inflation rate and the long-term interest rate. For real convergence, we analysed the real GDP growth rate, the unemployment rate and the current account as a percentage of GDP.

Given that the pandemic is still ongoing at the time of the research, and its economic and social effects are not yet fully quantified, we observed the changes in the relevant variables in 2020 compared to 2019 to capture its early effects on the convergence process (see Tables 2 and 3).

The economic crisis generated by the pandemic has significantly affected public finances at the European level, after a period of solid economic growth, in which the state budgets were on a general consolidation trend. In 2019, public finances recorded budget surpluses in 17 member states. The other States, except Romania, were below the 3% budget deficit, in compliance with the nominal convergence criteria. The situation of public finances in the EU has suddenly worsened, and budget surpluses have quickly turned into large deficits in 2020. The most significant deteriorations of the budget balance were registered for the developed economies. Among the emerging economies, the most affected were Poland, Slovenia and Croatia. Italy is the only case experiencing a drop in its budget deficit.

At EU level, the public debt reached an average percentage of 89.9% of GDP in 2020, increasing by 13.5pp compared to 2019. The most affected countries were those

Table 2. The dynamics of the nominal convergence indicators of the EU countries in 2020 vs. 2019.

	Nominal convergence							
Country	Government gross debt (% GDP)		Government budget balance (deficit) (% GDP)		Inflation rate (%)		Interest rates (Long term government bond yields)	
EU-27	13.5	↑	−7.6	↑	−1.0	↓	−0.4	↓
Austria	14.5	↑	−10.6	↑	−0.1	↓	−0.3	↓
Belgium	19.0	↑	−9.5	↑	−0.8	↓	−0.3	↓
Bulgaria	5.5	↑	−1.0	↑	−1.3	↓	−0.2	↓
Croatia	14.5	↑	−8.5	↑	−0.8	↓	−0.5	↓
Cyprus	22.9	↑	−7.3	↑	−1.6	↓	−0.2	↓
Czechia	8.9	↑	−7.6	↑	0.7	↑	−0.4	↓
Denmark	5.1	↑	−7.8	↑	−0.4	↓	−0.2	↓
Estonia	10.3	↑	−6.4	↑	−2.9	↓	−0.4	↓
Finland	8.8	↑	−5.9	↑	−0.7	↓	−0.3	↓
France	19.9	↑	−7.8	↑	−0.8	↓	−0.3	↓
Germany	13.8	↑	−9.7	↑	−1.0	↓	−0.3	↓
Greece	24.3	↑	−9.6	↑	−1.8	↓	−1.3	↓
Hungary	11.1	↑	−6.4	↑	0.0	↓	−0.3	↓
Ireland	6.4	↑	−6.4	↑	−1.4	↓	−0.4	↓
Italy	27.0	↑	0.3	↓	−0.7	↓	−0.8	↓
Latvia	7.3	↑	−5.8	↑	−2.6	↓	−0.4	↓
Lithuania	10.6	↑	−7.0	↑	−1.1	↓	−0.1	↓
Luxembourg	4.8	↑	−9.1	↑	−1.6	↓	−0.3	↓
Malta	14.1	↑	−9.9	↑	−0.7	↓	−0.2	↓
Netherlands	10.9	↑	−10.5	↑	−1.6	↓	−0.3	↓
Poland	14.0	↑	−9.8	↑	1.6	↓	−0.9	↓
Portugal	19.5	↑	−8.6	↑	−0.4	↓	−0.3	↓
Romania	8.0	↑	−5.0	↑	−1.6	↓	−0.7	↓
Slovakia	13.8	↑	−7.5	↑	−0.8	↓	−0.3	↓
Slovenia	14.9	↑	−9.3	↑	−2.0	↓	−0.2	↓
Spain	27.5	↑	−11.3	↑	−1.1	↓	−0.3	↓
Sweden	7.0	↑	−6.3	↑	−1.0	↓	−0.1	↓

Source: World Data Atlas Database.

already hit hard by the Great Recession (Spain, Italy, Greece, Cyprus, France and Portugal).

The inflation rate also declined in all EU countries, especially in Baltic countries, Slovenia and Greece. The decrease in inflation was determined by a reduction in demand against the background of restrictions imposed by the COVID-19 crisis, but also by economic and social uncertainties. The fall in prices has also led to a decrease in the supply of goods and services.

Long-term interest rates fell as well in all European states in 2020 (especially in Greece, Poland and Italy) to encourage investment in a period of economic decline.

The COVID-19 crisis had a major impact on the labour market, leading to rapid changes, from reduced working time, telework or technical unemployment, to higher unemployment rate in all EU countries (except Croatia), especially in sectors most affected by the crisis (Khamis et al., 2021).

International trade has also suffered as restrictions on transport were imposed, and uncertainties -especially related to revenue- led to contractions in demand and supply of goods and services. As a result, many European countries recorded deteriorations in their current accounts, particularly those known as tourist destinations (France, Spain, Greece and Croatia). The crisis reduced the trade within the EU more sharply compared to the non-EU trade.

Table 3. The dynamics of the real convergence indicators of the EU countries in 2020 vs. 2019.

	Real convergence					
Country	Real GDP growth rate		Unemployment rate		Current account balance (% GDP)	
EU-27	−8.2	↓	1.6	↑	−0.1	↓
Austria	−8.0	↓	1.3	↑	−0.2	↓
Belgium	−8.1	↓	0.7	↑	6.7	↑
Bulgaria	−7.9	↓	1.4	↑	−1.4	↓
Croatia	−11.9	↓	−1.5	↓	−6.0	↓
Cyprus	−9.5	↓	0.9	↑	−0.8	↓
Czechia	−7.9	↓	1.1	↑	−0.7	↓
Denmark	−5.5	↓	1.2	↑	−1.4	↓
Estonia	−7.9	↓	3.4	↑	0.4	↑
Finland	−4.1	↓	1.6	↑	−6.0	↓
France	−11.3	↓	0.4	↑	−1.2	↓
Germany	−5.5	↓	1.2	↑	−1.3	↓
Greece	−11.1	↓	2.6	↑	−5.6	↓
Hungary	−10.7	↓	3.0	↑	−0.8	↓
Ireland	−2.2	↓	0.6	↑	16.4	↑
Italy	−10.9	↓	1.1	↑	0.2	↑
Latvia	−5.6	↓	2.7	↑	2.5	↑
Lithuania	−5.1	↓	1.9	↑	2.9	↑
Luxembourg	−3.6	↓	1.1	↑	−0.7	↓
Malta	−12.5	↓	0.6	↑	−2.0	↓
Netherlands	−7.1	↓	2.1	↑	−2.3	↓
Poland	−7.2	↓	0.5	↑	2.6	↑
Portugal	−12.5	↓	1.6	↑	−3.0	↓
Romania	−8.9	↓	4.0	↑	−0.7	↓
Slovakia	−7.5	↓	2.0	↑	−0.2	↓
Slovenia	−8.7	↓	3.4	↑	−1.2	↓
Spain	−14.8	↓	2.7	↑	−1.5	↓
Sweden	−4.2	↓	1.9	↑	3.7	↑

Source: World Data Atlas Database.

Overall, the containment and lockdown measures has made all member states' economies in 2020 function below their potential and the path suggested by pre-crisis projections (Bodnar et al., 2020).

The negative impact of the crisis has been asymmetric across member states' economies because of uneven recovery capacity conditioned by the speed in lifting stringency measures and the importance of services such as tourism and financial resources. This conclusion is in line with European Commission (2021a, 2021b) and Odendahl and Springford (2020).

4.3. Correlation between COVID composite index and economic convergence in the EU

We used TOPSIS multi-criteria method to rank EU countries according to nominal and real convergence indicators and computed a Spearman correlation coefficient to check the connection between COVID effects (represented by the composite index) and each of the two sets of convergence indicators for year 2020. The rankings generated by TOPSIS reflect a static image of the positioning of EU countries in 2020 based on convergence indicators with uneven importance weights (see Appendix D). The rankings of the EU countries are summarised in Table 4.

Table 4. The EU country rankings of the COVID-19 effects and the nominal and real convergence indicators.

Country	COVID-19 effects ranking	Nominal convergence ranking	Real convergence ranking
Austria	11	19	15
Belgium	6	12	16
Bulgaria	1	22	12
Croatia	17	18	23
Cyprus	27	3	25
Czechia	9	24	11
Denmark	14	9	4
Estonia	23	1	12
Finland	19	12	12
France	7	14	23
Germany	12	9	6
Greece	20	9	27
Hungary	10	27	16
Ireland	24	1	1
Italy	3	15	21
Latvia	25	6	8
Lithuania	18	20	1
Luxembourg	22	5	4
Malta	26	20	16
Netherlands	8	16	3
Poland	5	25	8
Portugal	15	6	16
Romania	4	26	21
Slovakia	21	23	16
Slovenia	16	4	6
Spain	2	6	25
Sweden	13	17	8
Spearman correlation coefficient with the COVID-19 effects		−0.471 ($p = 0.01$)	−0.155 ($p = 0.439$)

Source: Authors' computation.

In 2020, Ireland was best performing in terms of real and nominal convergence, having a high life expectancy and a very high compliance with public health measures. Ireland also had a comprehensive and timely response to the pandemic and made extensive use of technology and media to daily inform the population, which have played a major role in fighting the pandemic (Kennelly et al., 2020).

The case of Cyprus is also interesting, as our rankings placed Cyprus in top 3 best nominal convergence performers, but among the worst real convergence performers. In fact, Cyprus had a strong position when entering the COVID-19 crisis but registered financial losses as its economy depends on tourism. Nevertheless, Cyprus managed to avoid high unemployment and widespread defaults due to prompt policy support.

The CEE emerging non-euro zone economies (except for Croatia) characterised by high COVID index values managed to keep the real convergence indicators at relatively good levels and have low government debt, despite having the highest inflation and interest rates. To support our findings, Martinho (2021) and Bisciari et al. (2020) also highlight the potential of CEE countries to assure faster convergence in the EU, the former pointing in particular to countries like Romania, Lithuania and Latvia for strategy implementation, as potential determinants for international geostrategy.

According to our findings, the most divergent performers in terms of real convergence are Greece, Spain and Cyprus, similar with Bisciari et al. (2020). Relying heavily on labour-intensive activities, like tourism, hospitality and transport, which have been particularly hit by the pandemic, these countries have experienced significant drops in their GDP growth rates and high rises in their unemployment rates. To strengthen the public health systems, save jobs and subsidize SMEs, these economies had to increase public spending while also cancel some taxes and social security contributions, which have weakened their public finance (Fedajev et al., 2022).

In terms of policy implication, even though measures were taken to reduce labour costs for affected companies, more sustainable solutions should focus on employment contract protection and comprehensive part-time job program implementation. This is especially important for Greece, with its already high public debt and less fiscal space available to fight the crisis. Moreover, prudent fiscal positions and debt sustainability should be pursued by these countries in the recovery phase.

Compared to past crisis episodes, policy actions taken have been forceful and overall well-coordinated at EU levels. Moreover, since our analysis only covers year 2020, when the effects of COVID-19 on convergence were not very acutely felt, the Spearman correlation coefficients are rather low. Our findings suggest a weak negative correlation of −15.5% between COVID index and real convergence that is statistically insignificant. However, in case of nominal convergence, the correlation with the COVID index turns out to be stronger, at −47.1%, and significant. These findings are similar to those presented by Bisciari et al. (2020) that showed that in times of crises, convergence has been slowed down for EU28 and sometimes divergence occurred for EU15.

Our results indicate that in 2020, the nominal convergence indicators were more affected. Clearly, the increase in health spending, social spending and other related expenditures caused by the pandemic has led to the largest increase in budget deficits, and implicitly to the increase of public debts for most EU countries. The inflation rates decreased in all EU countries, mainly due to declining consumption as a result of lockdowns, reduced working hours and incomes, as well as economic and social uncertainties. The long-term interest rate has fallen slightly in 2020 in most EU countries to encourage investment.

In terms of real convergence, the most affected indicator was the real GDP growth rate, as the economic activity contracted since the beginning of the pandemic crisis. The countries most affected by the pandemic (high COVID index) also experienced the most significant economic decline (Spain, Italy, France). However, the current accounts were not very unbalanced as contractions in consumption and production meant less imports of goods and services and raw materials. The unemployment rates did not increase significantly in 2020 either, because no radical measures were taken at first, as countries switched to work from home, part-time work, or short-term technical unemployment. As crisis unfolded, however, most indicators deteriorated in 2021.

Although all member states experienced a sharp economic contraction, the depth of the downturn and the recovery speed has been very uneven. The different recovery pace stems from a number of factors, such as: the length and stringency of lockdown measures dictated by health conditions, differences in the underlying economic structures and the specialization in activities restricted by the pandemic (e.g., tourism, hospitality), the trade openness of the country, as well as the extent and type of policy responses. These factors generated the most important changes in real and nominal convergence indicators.

Our findings are consistent with the results reported by Fedajev et al. (2022) that concludes that the divergence process is explained by significant increases of budget deficit in Spain, Belgium, France, and Italy, and that the pandemic has affected nominal convergence in terms of budget balance. Belgium, France, Italy, Greece, Spain, and Portugal have been identified as having significant debt compared to new member states, except for Cyprus. Greece, Italy and Spain are also pinpointed as contributing the most to the divergence of the unemployment rate, and being, in general, in the most unfavourable position, highly contributing to divergence among EU member states.

Overall, the risks of diverging and passing through a period characterized by economic instability as a result of the COVID-19 crisis appear to be higher in countries where there were already imbalances prior to 2020, mainly due to lingering effects of 2008 financial crisis. This may lead to the appearance of income convergence clubs following a north/south or north-west/south-east divide, which is also the conclusion on Glawe and Wagner (2021).

5. Conclusions

In 2020, the EU faced an unprecedented economic shock caused by the COVID-19 pandemic. Economic, health and isolation measures, as well as their effects on production, demand, and trade, have reduced the economic activity and led to higher unemployment rates, a sharp drop in corporate incomes, higher government deficits and public debts, thus exacerbating intra- and inter-state disparities at the European level.

Our research focused on how the pandemic affected the member states and whether convergence indicators have suffered in both euro and non-euro zones in 2020. Given that the COVID-19 pandemic is still an ongoing phenomenon in Europe, and therefore we lack post-crisis data and the time frame was short, we were limited in the choice of the methodological tools to use. Both the composite index and the TOPSIS rankings on real and nominal convergence only reflect a static image of the relative position of EU countries in 2020. Further research that makes use of more advanced methodological tools is needed to fully assess the impact once this crisis is over.

Despite the fact that the nature of the current crisis is different from the Great Recession, the impact on economic stability indicators is similar, which may pose new challenges for the economic convergence within the EU. The economies of Greece, Italy, Spain and even France appeared to have taken the hardest hit in both crises.

Following the correlation of COVID composite index with specific convergence indicators, we noticed that the CEE countries (emerging non-euro zone economies), although affected by the pandemic crisis (as shown by the high COVID index values), managed to keep some of their convergence indicators at relatively sustainable levels. This was also facilitated by the fact that, being outside the euro-zone, the rigors imposed in terms of nominal and real convergence criteria were much stricter prior to the pandemic, giving them the leeway to increase their fiscal-budgetary indicators, without greatly exceeding the imposed limits.

Baltic and Scandinavian countries seemed to be less affected in 2020 in both nominal and real convergence indicators, the latter also having a more relaxed approach to the restrictions initially imposed on the population, opting for 'herd immunization'.

In conclusion, we can say that in the context of the COVID-19 crisis, in terms of convergence and economic stability, the risks seem to be increasing in countries already facing imbalances prior to the pandemic's outbreak. The most affected countries seem to show significant worsening of the convergence indicators because the efforts to combat the pandemic were felt upon their economic sustainability, driving them further away.

As lessons learned so far in response to the pandemic, the most critical governmental policies should target the link between the financial sector and the financial health of households and businesses. Since the financial sector is vulnerable to loan defaults and insolvencies, governments should support households and small businesses to ensure sustainable debt burdens and accessible credits, which are essential for economic recovery. Moreover, when economic conditions allow, central banks should lower interest rates, inject liquidity into the market and facilitate refinancing to ensure financial sustainability.

The pandemic has also highlighted the lack of comprehensive electronic health record systems, as regular updates on the public health situation is vital to support high compliance by the public. The case of Ireland has proven that when technology and media are effectively and timely used, chances to better respond to the pandemic increase.

Sustained and dedicated policy efforts are needed to ensure the COVID-19 crisis leaves no durable scars on convergence. The effects of the pandemic are still unfolding and there are risks that asymmetric effects on economies and regions result in a protracted setback for economic convergence in the EU states. To further promote economic growth and convergence in the wake of the pandemic, dedicated policy action is needed, especially in areas of human capital and labour markets, the new sources of growth, including total factor productivity and the digital and green transitions, and institutional quality. The combination of such policies and the monetary and fiscal policies accommodation could support confidence to economic agents and cushion the impact on aggregate demand, which could mitigate economic divergence in the short-term. Thus, a timely and proper country specific implementation of the Recovery and Resilience Plans (RRPs) (with focus on both investments and reforms) will be required in the EU.

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ORCID

Madalina Ecaterina Popescu http://orcid.org/0000-0002-0589-4010
Ramona-Mihaela Paun http://orcid.org/0000-0002-2731-665X

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Appendix A

Table A1. Main indicators considered for the COVID Composite Index.

Indicators	Abbreviation	Definition	Units
School closing	C1	The intensity of the government response to close schools, relative to the total number of confirmed cases (per thousands). The School closing indicator is defined through an ordinal scale from 0–3, where 0—no measures; 1—recommend closing or all schools open with alterations; 2—require closing some levels or categories; 3—require closing all levels.	%
Workplace closing	C2	The intensity of the government response to close workplaces, relative to the total number of confirmed cases (per thousands). The Workplace closing indicator is defined through an ordinal scale from 0–3, where 0—no measures; 1—recommend closing (or work from home); 2—require closing for some sectors or categories of workers; 3—require closing for all-but-essential workplaces	%
Cancel public events	C3	The intensity of the government response to cancel public events, relative to the total number of confirmed cases (per thousands). The Cancel public events indicator is defined through an ordinal scale from 0–2, where 0—no measures; 1—recommend cancelling; 2—require cancelling.	%
Restrictions on gatherings	C4	The intensity of the government response to impose restrictions on gatherings, relative to the total number of confirmed cases (per thousands). The Restrictions on gatherings indicator is defined through an ordinal scale from 0–4, where 0—no restrictions; 1—restrictions on very large gatherings; 2—restrictions on gatherings between 101–1000 people; 3—restrictions on gatherings between 11–100 people; 4—restrictions on gatherings of 10 people or less.	%
Close public transport	C5	The intensity of the government response to close public transport, relative to the total number of confirmed cases (per thousands). The Public transport closing indicator is defined through an ordinal scale from 0–2, where 0—no measures; 1—recommend closing; 2—require closing.	%
Stay at home requirements	C6	The intensity of the government response to impose Stay at home requirements, relative to the total number of confirmed cases (per thousands). The Stay at home requirements indicator is defined through an ordinal scale from 0–3, where 0—no measures; 1—recommend not leaving house; 2—require not leaving house with exceptions for daily exercise, grocery shopping, and 'essential' trips; 3—require not leaving house with minimal exceptions.	%
Restrictions on internal movement	C7	The intensity of the government response to impose restrictions on internal movement, relative to the total number of confirmed cases (per thousands). The Restrictions on internal movement indicator is defined through an ordinal scale from 0–2, where 0—no measures; 1—recommend not to travel between regions/cities; 2—internal movement restrictions in place.	%
International travel controls	C8	The intensity of the government response to impose international travel controls, relative to the total number of confirmed cases (per thousands). The International travel controls indicator is defined through an ordinal scale from 0–4, where 0—no	%

(*continued*)

Table A1. Continued.

Indicators	Abbreviation	Definition	Units
		restrictions; 1—screening arrivals; 2—quarantine arrivals from some or all regions; 3—ban arrivals from some regions; 4—ban on all regions or total border closure.	
Income support	E1	The intensity of the government response to provide direct cash payments to people who lose their jobs or cannot work relative to the total number of confirmed cases (per thousands). The Income support indicator is defined through an ordinal scale from 0–2, where 0—no income support; 1—government is replacing less than 50% of lost salary (or if a flat sum, it is less than 50% median salary); 2—government is replacing 50% or more of lost salary (or if a flat sum, it is greater than 50% median salary).	%
Debt/contract relief	E2	The intensity of the government response to freeze financial obligations for households (such as stopping loan repayments, preventing services like water from stopping, or banning evictions), relative to the total number of confirmed cases (per thousands). The Debt/contract relief indicator is defined through an ordinal scale from 0–2, where 0—no debt/contract relief; 1—narrow relief, specific to one kind of contract; 2—broad debt/contract relief.	%
Fiscal measures	E3	The total announced economic stimulus spending in 2020 as % of GDP.	%
International support	E4	The total announced offers of COVID-19 related aid spending to other countries in 2020 as % of GDP.	%
Emergency investment in healthcare	H1	The total announced short term spending on healthcare system in 2020 as % of GDP.	%
Investment in vaccines	H2	The total announced public spending on COVID-19 vaccine development in 2020 as % of GDP.	%
Protection of elderly people	H3	The intensity of the government response to protect elderly people in Long Term Care Facilities and/or the community and home setting, relative to the total share of population over 65 years old. The Protection of elderly people indicator is defined through an ordinal scale from 0–3, where 0—no measures; 1—Recommended isolation, hygiene and/or elderly people to stay at home; 2—Narrow restrictions for isolation, hygiene and/or restrictions protecting elderly people at home; 3—Extensive restrictions for isolation, hygiene and/or all elderly people required to stay at home and not leave the home with minimal exceptions.	%
Deaths %cases	P1	Total number of confirmed deaths due to COVID-19 relative to total confirmed cases in 2020.	%
Total deaths	P2	Total number of confirmed deaths due to COVID-19 registered in 2020.	pers.
Total cases	P3	Total number of confirmed cases of COVID-19 registered in 2020.	pers.
ICU patients	P4	Total number of patients in intensive care (ICU) with COVID-19 registered in 2020.	pers.
Hospital patients	P5	Total number of hospital patients with COVID-19 registered in 2020.	pers.
Total cases %population	P6	Total number of confirmed cases of COVID-19 registered in 2020 relative to the total population of the country.	%
ICU patients %hospital beds	P7	Total number of ICU patients with COVID-19 registered in 2020 relative to total hospital beds.	%
Positive rate	P8	The share of total COVID-19 tests that were positive.	%
Total tests	P9	Total number of COVID-19 tests registered in 2020.	tests
Life expectancy	G1	The average number of years a person can be expected to live.	years

(*continued*)

Table A1. Continued.

Indicators	Abbreviation	Definition	Units
Cardiovascular death rate	G2	Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease.	%
Diabetes prevalence	G3	The prevalence rate attributed to diabetes diseases.	%
Hospital beds	G4	Total number of hospital beds per thousand registered in 2020.	beds

Sources: Authors' selection based on https://ourworldindata.org/coronavirus and https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker.
Note. Most indicators reflecting the government response to the pandemic (namely C1, C2, C3, C, C5, C6, C7, C8, E1, E2 and H3) were initially expressed in ordinal scale and normalized to produce scores between 0 and 100 by applying the formula described in OxCGRT technical documentation:

$$I_{j,t} = 100\frac{v_{j,t}-0.5\ (F_j - f_{j,t)}}{N_j} \tag{1}$$

where $v_{j,t}$ is the recorded policy value on the ordinal scale, F_j is a binary variable taking value 1 if the indicator has a flag in the database, $f_{j,t}$ represents the recorded binary flag for the indicator and N_j is the maximum value of the ordinal scale. For special cases when $v_{j,t}$=0 then $I_{j,t}$=0, while if $v_{j,t}=0$ then the function F_j−$f_{j,t}$ is also treated as 0.

Appendix B

Table B1. Correlation matrix of the initial data set.

	C1	C2	C3	C4	C5	C6	C7	C8	E1	E2	E3	E4	H1	H2	H3	P1	P2	P3	P4	P5	P6	P7	G2	G3	G1	P8	P9	G4
C1	1.00	0.97	0.97	0.98	0.74	0.85	0.87	0.97	0.92	0.92	−0.45	−0.13	−0.16	−0.29	0.21	−0.41	−0.38	−0.43	−0.20	−0.15	−0.25	−0.24	0.04	0.27	0.04	−0.60	−0.41	−0.07
C2		1.00	0.91	0.94	0.72	0.85	0.82	0.92	0.88	0.96	−0.47	−0.10	−0.15	−0.32	0.17	−0.51	−0.45	−0.50	−0.11	−0.13	−0.28	−0.18	0.03	0.16	0.02	−0.65	−0.47	−0.13
C3			1.00	0.99	0.69	0.80	0.92	0.99	0.95	0.85	−0.45	−0.12	−0.20	−0.25	0.10	−0.34	−0.34	−0.38	−0.14	−0.13	−0.20	−0.18	−0.09	0.32	0.19	−0.54	−0.37	−0.12
C4				1.00	0.75	0.86	0.93	0.97	0.94	0.91	−0.42	−0.11	−0.17	−0.28	0.12	−0.41	−0.37	−0.42	−0.17	−0.11	−0.15	−0.22	−0.07	0.30	0.15	−0.58	−0.39	−0.11
C5					1.00	0.95	0.82	0.69	0.81	0.78	−0.21	−0.07	0.13	−0.19	0.41	−0.36	−0.27	−0.30	−0.32	−0.08	−0.14	−0.30	−0.20	0.42	0.17	−0.43	−0.28	−0.21
C6						1.00	0.88	0.79	0.89	0.89	−0.29	−0.11	0.02	−0.28	0.29	−0.44	−0.35	−0.40	−0.26	0.02	−0.12	−0.28	−0.14	0.32	0.14	−0.57	−0.36	−0.18
C7							1.00	0.88	0.94	0.81	−0.38	−0.14	−0.01	−0.27	0.20	−0.29	−0.35	−0.40	−0.24	−0.03	−0.13	−0.28	−0.24	0.29	0.32	−0.48	−0.38	−0.19
C8								1.00	0.94	0.85	−0.48	−0.09	−0.20	−0.26	0.14	−0.36	−0.34	−0.38	−0.10	−0.16	−0.30	−0.14	−0.05	0.35	0.13	−0.58	−0.36	−0.12
E1									1.00	0.83	−0.46	−0.09	−0.10	−0.27	0.16	−0.39	−0.35	−0.39	−0.14	−0.04	−0.20	−0.16	−0.20	0.36	0.26	−0.57	−0.35	−0.21
E2										1.00	−0.35	−0.12	−0.14	−0.33	0.18	−0.56	−0.41	−0.46	−0.12	−0.09	−0.19	−0.20	0.03	0.19	0.00	−0.64	−0.44	−0.10
E3											1.00	0.01	−0.01	0.17	−0.18	0.46	0.39	0.31	−0.12	0.23	0.20	−0.12	−0.02	−0.14	−0.03	0.35	0.29	0.16
E4												1.00	−0.12	−0.13	−0.21	−0.30	−0.14	−0.12	0.34	−0.16	−0.15	0.45	−0.26	−0.03	0.08	−0.25	0.15	−0.40
H1													1.00	−0.24	0.26	0.12	0.11	0.08	−0.18	0.08	0.08	−0.15	0.17	−0.33	−0.19	0.25	0.06	0.11
H2														1.00	−0.19	0.04	0.07	0.19	−0.24	−0.29	0.17	−0.23	−0.11	0.37	0.05	0.48	0.01	0.09
H3															1.00	0.14	0.02	−0.01	−0.31	−0.33	−0.49	−0.28	0.05	0.11	−0.01	−0.03	−0.02	−0.14
P1																1.00	0.61	0.56	−0.01	0.03	−0.10	0.03	−0.17	−0.15	0.29	0.53	0.47	0.01
P2																	1.00	0.98	0.48	−0.27	0.07	0.50	−0.33	−0.05	0.37	0.48	0.93	−0.20
P3																		1.00	0.47	−0.30	0.11	0.50	−0.31	0.01	0.34	0.55	0.92	−0.16
P4																			1.00	−0.20	−0.15	0.98	−0.45	−0.15	0.44	−0.18	0.64	−0.57
P5																				1.00	0.24	−0.23	0.28	−0.11	−0.28	−0.13	−0.30	0.45
P6																					1.00	−0.15	−0.02	0.04	−0.02	0.33	0.03	0.26
P7																						1.00	−0.49	−0.08	0.45	−0.16	0.70	−0.61
G2																							1.00	−0.25	−0.95	0.04	−0.46	0.85
G3																								1.00	0.18	−0.10	0.00	−0.12
G1																									1.00	−0.07	0.46	−0.81
P8																										1.00	0.28	0.36
P9																											1.00	−0.43

Source: Authors' computation.

Appendix C

Calculation of z-scores: For any country *i*, the standardized values of an indicator X are determined using the z-scores, as follows:

$$X_{std,\,i} = \frac{X_i - \overline{X}}{\sigma_X} \tag{2}$$

where $\overline{X}$ is the mean of indicator X, and σ_X is the standard deviation of X.

Appendix D

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method was applied by taking the following steps:

Step 1. Normalize the evaluation matrix $A(a_{ij})$

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}},\ i = 1, m \ \text{and}\ j = 1, n \tag{3}$$

Step 2: Compute the weighted normalised decision matrix $V(v_{ij})$, where $v_{ij} = p_j{}^* r_{ij}$, using the following importance criteria coefficients p_j according to their economic convergence relevance:

- for nominal convergence indicators: 35% for government deficit, 35% for government gross debt, 20% for inflation rate and 10% for long-term interest rate
- for real convergence indicators: 50% for real GDP growth rate, 25% for unemployment rate and 25% for current account

Step 3: Determine the worst alternative $V^-(v_{ij}^-)$ and the best alternative $V^*(v_{ij}^*)$, where:

$$V^* = \left\{ \left(\max_i v_{ij} \middle| if \quad C_j \ \ is \ \ maximized\right), \left(\min_i v_{ij} | if \ \ C_j \ \ is \ \ minimized\right) \right\} \tag{4}$$

$$V^- = \left\{ \left(\min_i v_{ij} \middle| if \quad C_j \ \ is \ \ maximized\right), \left(\max_i v_{ij} | if \ \ C_j \ \ is \ \ minimized\right) \right\} \tag{5}$$

For each convergence indicator C_j we specified whether it should be minimized or maximized.

Step 4: Compute the Euclidian distances between each country's alternative and both the worst and the best alternatives:

$$S_{i^*} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^*\right)^2} \text{and} S_{i^-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2},\ \ i = \ 1, m \tag{6}$$

Step 5: Compute the similarity to the worst condition $C_{i^*} = \frac{S_{i^-}}{(S_{i^-} + S_{i^*})}$ and rank the countries in a descending order.

Appendix E

Table E1. The total variance explained.

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.583	44.785	44.785
2	1.286	16.071	60.856
3	1.038	12.974	73.830
4	.820	10.246	84.076
5	.691	8.643	92.719
6	.313	3.912	96.631
7	.171	2.137	98.768
8	.099	1.232	100.000

Source: Authors' computation.