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European countries' vulnerability to COVID-19: multicriteria decision-making techniques

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ABSTRACT

COVID-19 has triggered an unprecedented health crisis, crippling economic activity around the world. The aim of this paper is to analyse European countries' vulnerability to the associated consequences. The analysis will focus on three areas that *a priori* are expected to be most severely affected by the pandemic – health, society and work – examining the possible relationship with countries' wealth. The multicriteria decision-making *Technique for Order Preference by Similarity to the Ideal Solution* (TOPSIS) will be used to generate a ranking of countries based on criteria that define each of these three areas. The findings will provide authorities with quantitative information to guide their aid policies. The results show that Eastern European countries should direct their resources towards addressing health-related and social issues. Conversely, those that have higher GDP per capita and that have been hardest hit by coronavirus will have to make changes to their labour systems in order to minimize the fallout.

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1. Introduction

In the current global health crisis, the need to contain the spread of COVID-19 is forcing governments of all countries to take action, with a devastating impact on economic activity (Valle, 2020). From late March 2020, the evolution of the pandemic in different territories began to visibly differ, with Europe being the hardest hit continent in terms of deaths (27,953) and confirmed cases (437,674), followed by Asia and North America (Appendix Table A1). Faced with this situation, European Union (EU) member states are implementing policies to shore up liquidity and increase the capacity of their healthcare systems, providing assistance to the most severely affected citizens and sectors. In addition, the European Central Bank has approved the launch of an emergency programme to combat the effects of the coronavirus pandemic, with a fund of 750 billion euros to purchase private and public sector securities. This purchase programme will be in effect until the end of 2020. Moreover, the European

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Commission has put together a 25 billion euro investment fund and has agreed to a more relaxed policy on budget rules to encourage public spending and the provision of support to affected businesses by their corresponding government (Nicola et al., 2020).

Numerous studies have emerged on the economic implications of the need to contain the spread of the disease; in just six months a broad literature on the subject has become available (Baker et al., 2020; Guerreri et al., 2020; Jorda et al., 2020; Maliszewska et al., 2020; McKibbin & Fernando, 2020; OECD, 2020; Orlik et al., 2020, among others). Authors such as Noy et al. (2020) concluded that most of the economic risks from COVID-19 occur in countries and regions that do not get much global attention in this pandemic – Sub-Saharan Africa, South Asia, and Central Asia. However, as 2020 comes to an end, it has been observed from European Centre for Disease Prevention and Control that the rapid spread of the virus is calling into question the measures taken by the most developed Western countries, where the second wave could surpass the devastating figures of the first.

Some studies have compared the effects of COVID-19 in different European countries. For example, Horobet et al. (2020) matched COVID-19 comorbidities with causes of death in 28 EU countries for the total population, concluding that the heat maps of EU populations' vulnerability to diseases based on mortality indicators constitute the basis for more targeted health policy strategies in a collaborative effort at the EU level. In the same context, Kashnitsky and Aburto (2020) showed the contribution of regional differences in population age structures to the magnitude of the pandemic. Using the INFORM index for risk management developed by the European Commission, Wong et al. (2020) concluded that reducing vulnerability and enhancing capacity to cope could potentially mitigate the impact of the COVID-19 pandemic.

The concept of “vulnerability” was introduced in the early 1990s in the study of the impact of natural disasters on populations, as a test of society's ability to make vulnerable populations resilient when disaster strikes (Horobet et al., 2020). Drake et al. (2012) argued that the vulnerability to infectious disease outbreaks is much higher in low- and middle-income countries, especially the vulnerability to mortality and morbidity risk. Cartaxo et al. (2020) compared official indicators to identify which vulnerabilities were the main determinants of the exposure risk to COVID-19 in the most and least affected countries around the world. They concluded that the highest-risk group included the US, Brazil, and India.

Against this backdrop, the aim of this paper is to identify which European countries are most vulnerable to the COVID-19 health crisis from the point of view of society, work and health. An understanding of the levels of vulnerability to COVID-19 is crucial in order to tackle its consequences and establish the most appropriate policies to soften the blow to the economy. Codagnone et al. (2020) argued that economic vulnerability is associated with a strong risk of stress and worsening mental health. They estimated that around 42.8% of the population of Italy, Spain and The United Kingdom is at risk because of the negative shocks and conditions of economic vulnerability in developed countries. Thus, focusing the analysis on European countries, this research aims to test the following hypotheses:

H1: There is a correspondence between the virulence of COVID-19 and the wealth of European countries.

H2: Countries' vulnerability in the social, work, and health spheres affects their capacity to cope with the spread of the virus.

H3: European countries reach the same level of vulnerability in the social, labour and health spheres.

To that end, a ranking is produced for each of these three areas using the multicriteria decision-making method, Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), and comparing countries' vulnerability to the virus with their level of wealth. An economic crisis of unprecedented scale is anticipated due to the lockdown measures implemented by authorities. An analysis of the 2018 levels of labour market insecurity,¹ poverty and health funding make it possible to identify the most economically dependent countries and, therefore, those in greatest need of public aid. The results will enable national and international agencies to target funds towards alleviating the consequences of this pandemic.

The rest of the paper is structured as follows. Section 2 presents the methodology used in the research and the sample database. Section 3 details the results of the empirical analysis. Lastly, Section 4 explains the main findings.

2. Methodology and sample

This research uses a multicriteria decision-making technique to produce a ranking of countries based on their vulnerability to COVID-19 in both health and economic terms. Multicriteria decision-making (MCDM) methods have become established as an ideal tool for gaining a better understanding of decision-making processes, facilitating the comparison between alternatives. These techniques have been used to solve area problems such as energy, environment, sustainability, management or even well-being (Balešentis et al., 2011; Hu et al., 2020; Kaynak et al., 2017; Mandić et al., 2017; Mardani et al., 2015) According to Triantaphyllou (2010), the central problem lies in evaluating a set of alternatives in terms of multiple criteria. MCDM has proved extremely useful for solving decision-making problems by ranking the different alternatives. As a case in point, Majumder et al. (2020) use the TOPSIS method to select the most significant risk factor and for the continuous monitoring of death due to COVID-19, while Shrestha et al. (2020) have used it to calculate a pandemic vulnerability index, creating a quantitative measure of potential global health.

TOPSIS was first proposed by Hwang and Yoon (1981). This method is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. An assumption of TOPSIS is that the criteria are monotonically increasing or decreasing. This method consists of seven consecutive stages, which are summarized in the following diagram (Figure 1) (Karabiyik & Kutlu, 2018).

A higher value of relative closeness indicates higher preference order, meaning the alternative in question is preferred (Lin et al., 2008; Lourenzutti & Krohling, 2016). The TOPSIS method offers two main advantages: its mathematical simplicity and substantial flexibility in the definition of the choice set. However, one drawback of

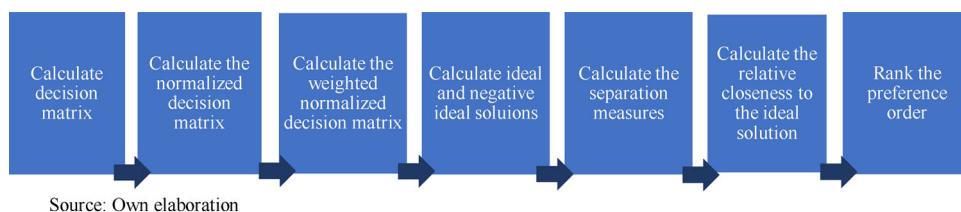


Figure 1. TOPSIS algorithm.

TOPSIS is the so-called inverse order problem: that is, the ranking of the alternatives is very sensitive to the composition of the sample; any alteration in it substantially modifies the results (Saaty & Sagir, 2009; Wang & Luo, 2009).

The database used in the empirical analysis comprises 29 European countries (including Norway, Switzerland, Iceland and all the EU-28 countries except for Greece and Slovakia²), with data from Eurostat for 2016, 2017 and 2018, depending on the most recently available information on the variables. The ranking of the countries is based on criteria relating to their healthcare system as well as various socio-economic factors characterizing the observations in the sample. These criteria can be used to identify the countries that are most vulnerable to the disease and most exposed to the economic consequences stemming from the restrictive measures taken to curb the spread of the virus. The countries are the alternatives in the TOPSIS model, while the criteria are determined by the variables presented in Table 1.

To apply the method, it is first necessary to distinguish between the variables to be maximized and those to be minimized. Given the particular features of each criterion and the aim of this research, the variables to be maximized/minimized are as follows: (1) regarding health, the death rate from influenza and the average length of a hospital stay should be minimized, while the other three criteria should be maximized; (2) in terms of society, the percentage of people working from home should be maximized and the rest of the criteria minimized as they are indicators of poverty or finding it difficult to get by financially; (3) with respect to work, all the criteria should be minimized, as they relate to issues that indicate labour market insecurity and its sensitivity to adverse economic situations. In the case of self-employment, it is not entirely clear what sign should be expected. There are important advantages associated with self-employment that would support the decision to maximize it; for example, it provides an ideal path out of unemployment. According to Blundell and Machin (2020), the self-employed have been hit particularly hard by the COVID-19 crisis, with approximately three-quarters reporting less work in April 2020 than usual. Thus, it has been decided that this criteria should be minimized given the high level of risk associated with this type of work during periods of recession, when freelancers' and small businesses' capacity to respond to the situation and access financing are very limited.

The situation in the countries under study differs widely: none of them occupies a top position in all of the variables analysed, revealing substantial divergence among them that does not correspond to questions of wealth. Highly developed nations such as Switzerland score highest in *Healthcare expenditure and Psychiatrist*, as Sweden does in *People working from home*, while the Netherlands holds the lowest position in

Table 1. Main statistics for the criteria in the sample.

Criteria	Units	Mean	Max	Min	St. Dev.
Health					
Healthcare expenditure (2017)	Euro per inhabitant	3,035.31	8,785.06	493.78	2,109.34
Psychiatrists (2017)*	Per hundred thousand inhabitants	18.65	51.72	7.77	8.27
Healthy life years (2017)	No. years	62.27	72.70	51.40	5.36
Average length of a hospital stay (2017)	No. days	7.34	9.80	4.5	1.38
Death rate from influenza (2016)	Rate	1.28	4.19	0.09	0.89
Society					
People working from home (2018)	% employed persons	10.21	29.40	0.30	8.04
People at risk of poverty (2018)	Percentage	21.04	32.80	12.20	5.35
Inability to face financial expenses (2018)	Percentage	31.77	55.30	13.90	10.70
Arrears on utility bills (2018)	Percentage	7.58	30.1	1.50	5.89
Overcrowded dwellings (2018)	Percentage	15.43	46.30	2.50	13.72
Work					
Self-employment (2018)	Thousand persons	1,015.55	4,643.00	20.60	1,380.09
Part-time employment (2018)	% total employment	16.01	46.80	1.80	10.46
Temporary employment (2018)	% total employment	9.44	22.30	0.80	5.56
Precarious jobs (2018)	% active population	2.17	6.90	0.20	1.77
Unemployment rate (2018)	% active population	5.23	13.70	1.90	2.36

*Psychiatrists are considered vitally important to alleviate the effects of the lockdown.

For each variable used, the year corresponding to the most recent information available is shown in parentheses.

Source: Own elaboration. Data from Eurostat (<https://ec.europa.eu/eurostat/web/covid-19/data>).

Arrears on utility bills and *Luxembourg in Self-employment*. Conversely, Bulgaria, Romania and Latvia have their lowest scores in variables associated with health and highest in those related to society.

3. Results

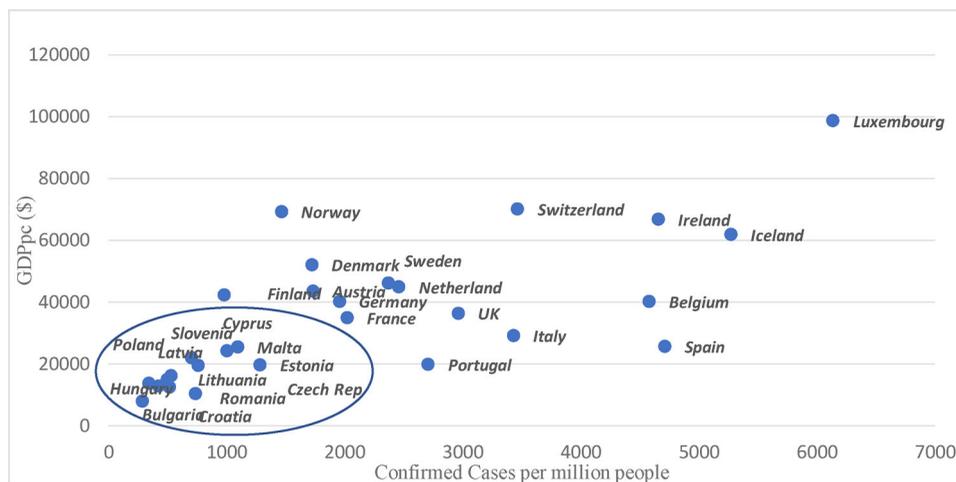
The worldwide spread of COVID-19 led to it being declared a pandemic by the World Health Organization (2020), pointing to over 3 million cases and 207,973 deaths in 213 countries and territories in March 2020. Devastating repercussions are expected in all sectors of the economy, the intensity of which will depend on the length of the lockdown, the responsiveness of the business sector and the support measures implemented by governments. Countries with well-prepared health systems and healthy economies, and with a workforce capable of adapting to environmental circumstances, will be able to minimize the aftermath of this disease. There is a need for cooperation that extends beyond individual territories, COVID-19 knows no borders and so countries in all continents must fight together to eradicate it and mitigate its effects. However, although this is clear in theory, different governments' particular interests often prevail. For example, France, Germany, and the Czech Republic have introduced limits on exports of protective medical equipment such as face masks, despite severe shortages elsewhere (Anderson et al., 2020). There have even been disputes within the EU over the structuring of financial instruments to assist member states.

Wealth will be a weapon of defence against the economic, social and labour market crisis beginning to emerge as a result of COVID-19. In order to gain an understanding of the differences in the sample analysed, the countries have been classified into four groups according to their level of GDP at market prices, euro per capita (GDPpc) (Table 2).

Table 2. Countries divided into quartiles based on their wealth (2018).

Q1	GDPpc	Q2	GDPpc	Q3	GDPpc	Q4	GDPpc
Bulgaria	7,980	Estonia	19,740	France	34,980	Sweden	46,310
Romania	10,510	Portugal	19,870	U. Kingdom	36,480	Denmark	52,010
Croatia	12,620	Slovenia	22,080	Belgium	40,210	Iceland	61,800
Poland	12,950	Cyprus	24,290	Germany	40,340	Ireland	66,670
Hungary	13,690	Malta	25,490	Finland	42,350	Norway	69,230
Latvia	15,080	Spain	25,730	Austria	43,640	Switzerland	70,120
Lithuania	16,160	Italy	29,210	Netherlands	44,920	Luxembourg	98,640
Czech Rep	19,530						

Source: Own elaboration.

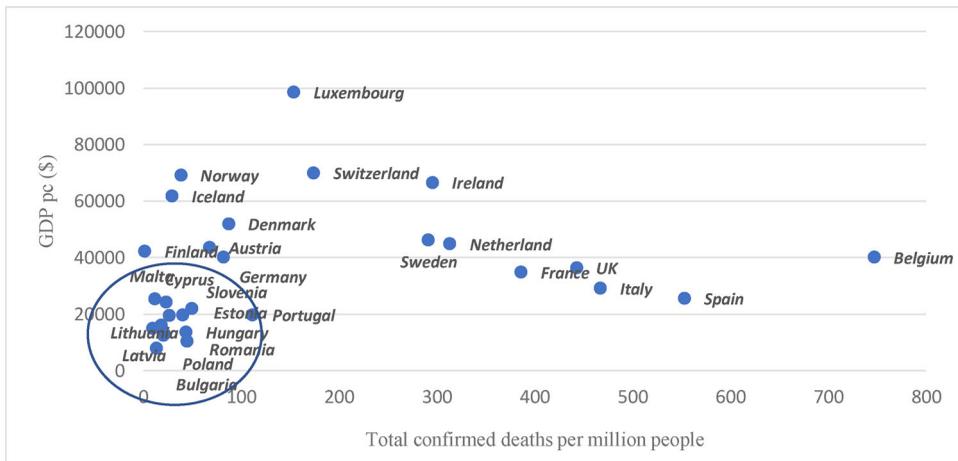


Source: Own elaboration

Figure 2. GDPpc and confirmed cases per million people.

Figures 2 and 3 analyse the correspondence between the virulence of coronavirus and countries' level of wealth, using figures provided by the *European Centre for Disease Prevention and Control* on infections and deaths due to COVID-19. Bearing in mind that the evolution of the pandemic has not been uniform over time, 70 days have been counted from the time when the country recorded an infection rate of between 0.1 and 0.3 per million people. This ensures homogenized information in terms of evolution, which is needed to be able to make cross-country comparisons.

The pandemic has spread all over the world regardless of countries' wealth, registering extremely high figures in the US and as well as some emerging market countries. According to Baldwin and di Mauro (2020), the pandemic has affected all major economies including the G7 countries, who jointly account for 60% of world supply and demand (GDP). Fernandes (2020) concluded that the health risk (actual mortality and infection rates) is not necessarily correlated with the economic risk to the global economy. However, comparisons within Europe have shown a positive correlation between GDP and the number of confirmed COVID-19 cases per million of population (correlation coefficient = 0.71); as a case in point, Luxembourg has the highest per capita income (\$98,640) and the highest number of infections (6,134 cases). On the other hand, the weaknesses of less developed European countries are



Source: Own elaboration

Figure 3. GDPpc and confirmed deaths per million people.

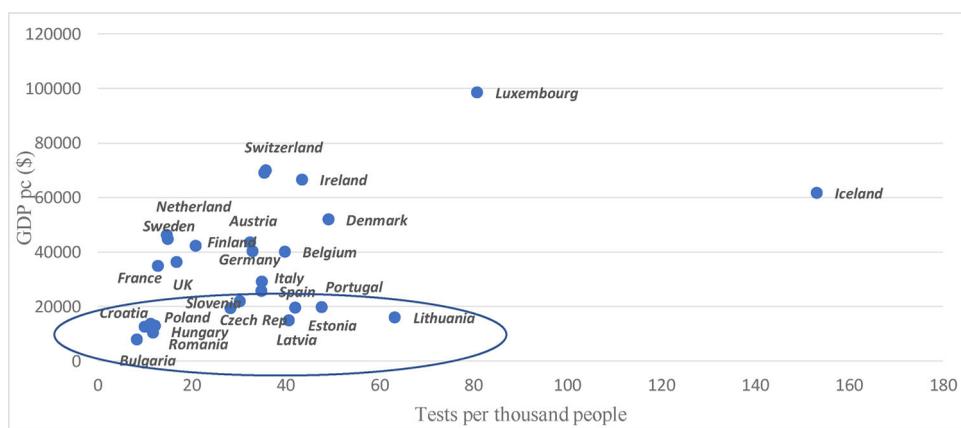
offset by the fact that COVID-19 is less virulent there; the lowest number of infections is registered in Bulgaria, with only 282 cases. However, the deaths due to COVID-19 do not show such a clear relationship with GDPpc (correlation coefficient = 0.2), as can be seen in [Figure 3](#).

The Eastern European countries have registered the fewest deaths, and are also those in the bottom quartile of GDP, Q1. However, there is greater dispersion in the other, larger group of European nations. For example, whereas Belgium has the highest confirmed death rate per million of population and is in Q3 according to its GDP pc, Luxembourg has registered 153 deaths but holds the top position in Q4, with the highest GDP pc in Europe.

The lower rates of infections and confirmed deaths in Eastern European countries cannot be attributed to the number of tests carried out. As can be seen in [Figure 4](#), with the exception of Luxembourg and Iceland, the approximate number of early detection tests performed by the rest of the European countries lies between 10 and 40 per thousand people, with no correlation observed with the level of wealth. For example, Lithuania – a country classified in Q1 – is among the countries that have suffered the fewest infections and deaths, and yet it is one of the countries that have performed the most tests.

The TOPSIS method can be used to obtain the relative closeness index, which, together with the distance to the positive and negative ideal solution, will provide the values needed to establish the ranking of the countries according to their vulnerability to COVID-19, understood in relation to the three proposed aspects. The results are shown in [Table 3](#), where countries have been ranked from highest to lowest in terms of their capacity to respond to the adverse situations caused by the disease.

The groups of European countries in the bottom and middle quartiles in terms of income (Q1 and Q2, as shown in [Table 2](#)) have different vulnerabilities in the areas analysed ([Table 3](#)). They are much more vulnerable in the areas of health and society (where almost all of them hold a below-average position) than they are in terms of work. In the particular case of those classified in Q1, it is important for them to



Source: Own elaboration

Figure 4. GDPpc and tests per thousand people.

Table 3. Ranking of European countries' vulnerability to COVID-19.

Health				Society				Work			
TR	Country	CI	Q	TR	Country	CI	Q	TR	Country	CI	Q
1	Switzerland	0.807	Q4	1	Netherlands	0.861	Q3	1	Bulgaria	0.901	Q1
2	Germany	0.610	Q3	2	Sweden	0.856	Q4	2	Czechia	0.858	Q1
3	Luxembourg	0.570	Q4	3	Iceland	0.828	Q4	3	Malta	0.850	Q2
4	Denmark	0.546	Q4	4	Luxembourg	0.801	Q4	4	Estonia	0.849	Q2
5	Austria	0.536	Q3	5	Denmark	0.787	Q4	5	Lithuania	0.842	Q1
6	Norway	0.526	Q4	6	Belgium	0.758	Q3	6	Romania	0.841	Q1
7	Ireland	0.521	Q4	7	U. Kingdom	0.756	Q3	7	Latvia	0.832	Q1
8	Belgium	0.510	Q3	8	Finland	0.733	Q3	8	Hungary	0.830	Q1
9	Italy	0.508	Q2	9	Austria	0.708	Q3	9	Ireland	0.764	Q4
10	U. Kingdom	0.507	Q3	10	France	0.704	Q3	10	Norway	0.763	Q4
11	France	0.498	Q3	11	Norway	0.669	Q4	11	Cyprus	0.760	Q2
12	Hungary	0.477	Q1	12	Switzerland	0.668	Q4	12	Denmark	0.753	Q4
13	Iceland	0.466	Q4	13	Ireland	0.663	Q4	13	Luxembourg	0.753	Q4
14	Lithuania	0.463	Q1	14	Germany	0.659	Q3	14	Iceland	0.730	Q4
15	Sweden	0.461	Q4	15	Estonia	0.651	Q2	15	Austria	0.726	Q3
16	Netherlands	0.461	Q3	16	Portugal	0.648	Q2	16	Slovenia	0.675	Q2
17	Bulgaria	0.459	Q1	17	Czechia	0.643	Q1	17	Switzerland	0.637	Q4
18	Romania	0.456	Q1	18	Malta	0.628	Q2	18	Portugal	0.637	Q2
19	Poland	0.455	Q1	19	Slovenia	0.584	Q2	19	Finland	0.627	Q3
20	Cyprus	0.454	Q2	20	Spain	0.582	Q2	20	Sweden	0.624	Q4
21	Croatia	0.441	Q1	21	Poland	0.527	Q1	21	Belgium	0.622	Q3
22	Portugal	0.411	Q2	22	Italy	0.519	Q2	22	Germany	0.567	Q3
23	Spain	0.407	Q2	23	Cyprus	0.512	Q2	23	U. Kingdom	0.564	Q3
24	Malta	0.401	Q2	24	Hungary	0.506	Q1	24	Croatia	0.557	Q1
25	Czechia	0.397	Q1	25	Lithuania	0.473	Q1	25	Netherlands	0.555	Q3
26	Slovenia	0.383	Q2	26	Latvia	0.364	Q1	26	Poland	0.547	Q1
27	Estonia	0.344	Q2	27	Romania	0.314	Q1	27	France	0.435	Q3
28	Latvia	0.279	Q1	28	Croatia	0.305	Q1	28	Italy	0.376	Q2
29	Finland	0.267	Q3	29	Bulgaria	0.144	Q1	29	Spain	0.371	Q2

TR: TOPSIS Ranking; CI: Closeness index; Q: Quartile of GDPpc.

Source: Own elaboration.

maintain the low infection rates: their health resources and clear inability to cope with adverse economic scenarios would put them in a very precarious situation if the pandemic were to strike them with any virulence. Indeed, of the 29 countries

analysed, Bulgaria has the lowest level of psychiatrists (7.77 per hundred), Romania registers the lowest health expenditure (493.78 euros per inhabitant) and Latvia has the lowest number of healthy life years compared to the other Europeans (51.4 years). However, all of them have an optimal employment situation: Bulgaria has the lowest value in *Part-time employment* (1.8%) and Romania the lowest value in *Temporary employment* (0.8%) and *Precarious jobs* (0.2%).

Conversely, the wealthiest countries in Europe (Q3 and Q4) are less vulnerable in the areas of society and health, but some show notable sensitivity in terms of work. They have been severely hit by the pandemic, as shown in [Figures 2 and 3](#), but their level of economic development should enable them to curb the indirect consequences of the spread of the virus. These results are supported by studies such as Mogi and Spijker (2020), who conclude that the Netherlands, Switzerland and Norway all score high on the socially and economically vibrant factor and have seen their number of coronavirus infections rise quickly during March despite households being almost exclusively single-person or nuclear. However, their well-developed healthcare systems, the higher standards of healthy living, as well as the financial solvency of their citizens should help to combat the consequences of the pandemic. For example, Germany has the most hospital beds per 1,000 people (8.3)³ and a robust sector of private and public laboratories, of which nearly 200 have capacity for SARS-CoV-2-testing, as indicated by [The Economist \(2020\)](#).

In short, both the EU and the authorities in each country are morally obliged to help the most vulnerable countries, such as those in Eastern Europe, by providing public funds. Resources should be allocated to bolstering their health and social systems in case the pandemic strikes more aggressively. For their part, the wealthiest countries will have to strengthen their labour policies to improve job security, reducing temporary employment and unemployment rates, aspects that are severely afflicted in situations of economic stress.

4. Conclusions

This analysis of European countries' vulnerability to the COVID-19 pandemic has identified the areas in which nations need to bolster their investments in order to alleviate the severity of the impact. Both domestic and EU funds should be allocated to these areas in order to ensure that their citizens are safe from the disease and, above all, protected from the related economic consequences. That said, Altig et al. (2020) argue that ongoing high levels of uncertainty do not bode well for a full and rapid economic recovery. Elevated uncertainty generally makes firms and consumers cautious, slowing investment, hiring and expenditure on consumer durables

According to the ranking calculated here, the least vulnerable countries are those in the centre/north of the continent; specifically, Germany in terms of health and Sweden in society, in contrast to work, where Bulgaria is at the top of the ranking. Conversely, those most exposed to the consequences of the pandemic are Finland in health, Bulgaria in society and Spain in work. These latter countries are going to be the least able to cope with the repercussions of the pandemic, and therefore have the greatest need in the areas indicated.

Given all the above, we can conclude that the level of wealth influences vulnerability in the health and social spheres. However, the relationship is not so clear with respect to work; as such, this issue merits particular attention. Economic development can lead to a high level of precarious employment, the fragility of which emerges in the face of extreme situations such as the current pandemic (hypotheses 1 and 3). It has also been shown that a favourable situation in countries' health and social spheres has not always been enough to combat the spread of this virus. Countries such as Belgium and Luxembourg, which hold high positions in terms of health and social vulnerability, have reported the highest number of deaths per million in the period analysed and highest number of confirmed cases, respectively (hypothesis 2).

Continuing on from this research, one of its main limitations should be addressed; namely, that all the countries analysed belong to the EU and have a high level of development. The analysis should thus be extended to other geographical areas with more diverse characteristics, in order to confirm the conclusions drawn here. In addition, following the study by Lenzen et al. (2020), further research should seek to demonstrate empirically whether the social and environmental consequences of the fight against the pandemic will be wider-ranging than the negative effects on employment and wealth.

Notes

1. As indicated by Karnon (2020), the economic effects of the COVID-19 crisis are predominantly falling on low-income earners.
2. These two countries have been excluded because they do not provide complete information on the variables used.
3. World Bank Data.

Disclosure statement

The authors declare that they have no conflict of interest.

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Appendix

Table A1. COVID-19 data by region as of 31st March 2020.

Region	Total confirmed deaths due to Covid-19	Total confirmed cases of Covid-19
Europe	27,953	437,674
Asia	6,671	170,037
North America	3,382	177,742
South America	305	11,249
Africa	166	5,137
Oceania	21	5324

Source: European Centre for Disease Prevention and Control.