D2.2 – Healthcare system analysis

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Executive Summary

This deliverable focuses on health care systems in a rapidly spreading global pandemic. This study assesses how healthcare systems responded to the crises during the first wave of the COVID-19 pandemic in the spring of 2020. In the study we analyse how different health care system features, country characteristics, and COVID-19 non-pharmaceutical interventions affected the spread of the virus on healthcare systems in Europe in the spring of 2020 and how the health care systems responded.

There are five different focus areas in this deliverable: 1) statistical model for the advance of COVID-19, 2) preparedness assessment, 3) analysis of testing, 4) analysis of hospital intensive care units, and 5) analysis of the behaviour of healthcare professionals.

Results indicate that COVID-19 mortality, which is assumed to closely follow the advance of epidemic, was most efficiently decreased by such government interventions that reduced social interactions. Characteristics of countries and indicators that describe differences in healthcare systems did not have an as significant role as the interventions in health outcomes.

Even though preparedness of the healthcare systems was not the primary driver in stopping the virus from spreading, some healthcare services were essential in the response to the pandemic. Diagnosing the infected (testing) before they infect others was one of many successful pandemic suppression strategies. Furthermore, healthcare system capacity, particularly intensive care, played a role when treating infected patients. Whereas ICUs have normal state buffer capacities of ~30-40 %, the utilization exceeded 100 % of the normal state ICU capacity in spring 2020 in some locations in Europe. The utilization of ICU beds for COVID-19 patients varied within countries and there could have been potential to distribute the burden on ICU wards more evenly within regions or within one country.

The first wave of COVID-19 stressed especially the ICU hospitals and the ICU wards. There were initial shortages of ventilators and personal protective equipment, but one of the scarcest resources was personnel with ICU expertise. Doctors and nurses in the ICUs worked in crisis mode for weeks or even months. In the short-term, the personnel seemed to find the spirit to fight the new kind of virus and work overtime. However, in the long-term, there appears to be some accumulated stress since the overtime working hours have not been fully compensated for. This can be seen as especially worrying since the new wave of increased infections is rising in the start of autumn 2020.

The COVID-19 pandemic showed that the healthcare systems of European countries were ill equipped to manage the different effects of the pandemic regardless of having ample healthcare resources and ranking high in preparedness indices. Clearly, systems were slow to ramp up capacity required to test and treat COVID-19 patients. More cooperation across regional and national borders could have helped the areas worst affected by the pandemic.

The high-level lesson learned from the health care system study conducted in march- august 2020, was that social distancing interventions seemed to be more effective in preventing COVID-19 deaths than country characteristics and healthcare system responsiveness. In conducting the study, we also found that more reliable and current data regarding the utilization of critical services is required, if we wish to utilize the healthcare system networks more efficiently and enable sharing of resources across healthcare units and regions.

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1 Introduction

HERoS task 2.2 and this deliverable focus on healthcare systems during the early COVID-19 crisis in the spring of 2020. The initial spread of the novel COVID-19 virus challenged national and local healthcare systems worldwide in a way unprecedented in the modern era of healthcare services[1]. Some branches of the healthcare services were under heavy load as the COVID-19 patients flooded in as described in chapter 3 of this deliverable. At the same time, other healthcare service branches, required primarily by non-COVID-19 patients, faced the threat of undertreatment as the availability of personnel and activity of the non-COVID-19 patients decreased[2]. In addition to in-balance of the demand and the supply of services, the uncertainty related to the new disease has put a heavy burden on healthcare professionals. At certain locations, the total load on services and stress on professionals accumulated to a point where the word "meltdown" was used to describe the situation of the healthcare system[3].

Healthcare systems have previously been studied and compared mostly from a funding and resource perspective. Some common areas of research include the equality and the performance of different healthcare systems[4] [5] [6]. The COVID-19 pandemic has changed the way the healthcare systems operate in ways we cannot fully yet comprehend. As the impact of the pandemic has already accumulated for months, there is increasing number of research focusing on the different aspects of healthcare systems ranging from the estimates of the capacities[7] to analysing the different factors affecting the outcomes[8] and to estimates on the effects on the low-resource countries[9].

In task 2.2 we focus on healthcare services required directly by the COVID-19 patients and leave out the questions of undertreatment in other healthcare services. The basic dynamics of the infected and the related demand and supply of the healthcare services are illustrated in Figure 1. As the number of infected people increases, the number of patients requiring healthcare services increases accordingly. The supply of healthcare services, on the other hand, is often drawn as fixed at least in the short term. With service supply we mean the available capacity for the COVID-19 patients in the services they require. The dynamics of "available capacity" vary between the different services and is discussed more thoroughly in chapter 3 of this deliverable. The dilemma of increasing demand with fixed supply of services was made familiar also to the public with the call to "flatten the curve" which refers to keeping the healthcare service demand below

[1] World Health organization. *COVID-19 strategy update*. 14 April 2020.
https://www.who.int/docs/default-source/coronaviruse/covid-strategy-update-14april2020.pdf?sfvrsn=29da3ba0_19

[2] Finnish institute for health and welfare. *The coronavirus epidemic has reduced social interaction and the use of services – impact on lifestyles as well*. 25 May 2020.
https://thl.fi/en/web/thlfi-en/-/the-coronavirus-epidemic-has-reduced-social-interaction-and-the-use-of-services-impact-on-lifestyles-as-well

[3] The Wall Street Journal. *Lessons From Italy's Hospital Meltdown. 'Every Day You Lose, the Contagion Gets Worse.'* 17 March 2020.
https://www.wsj.com/articles/every-day-you-lose-the-contagion-gets-worse-lessons-from-italys-hospital-meltdown-11584455470

[4] Dixon-Woods, M., Cavers, D., Agarwal, S. et al. *Conducting a critical interpretive synthesis of the literature on access to healthcare by vulnerable groups*. BMC Med Res Methodol 6, 35 (2006). https://doi.org/10.1186/1471-2288-6-35

[5] Wendt, C. *Mapping European healthcare systems: A comparative analysis of financing, service provision and access to healthcare*. Journal of European Social Policy 19(5):432-445

[6] GBD 2016 Healthcare Access and Quality Collaborators. *Measuring performance on the Healthcare Access and Quality Index for 195 countries and territories and selected subnational locations: a systematic analysis from the Global Burden of Disease Study 2016.* Lancet 2018; 391: 2236–71

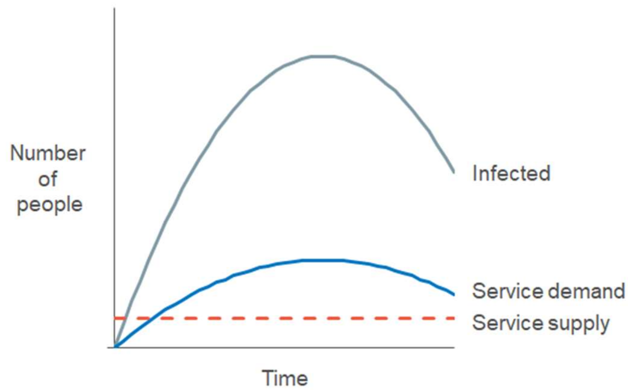
[7] Verelst F., Kuylen E.J., Beutels P. *Indications for healthcare surge capacity in European countries facing an exponential increase in COVID19 cases*. medRxiv 2020.03.14.20035980

[8] Chaudhry R. et al. *A country level analysis measuring the impact of government actions, country preparedness and socioeconomic factors on COVID-19 mortality and related health outcomes*. EClinicalMedicine 2020 100464

[9] Elhadi M. et al. *Concerns for low-resource countries, with under-prepared intensive care units, facing the COVID-19 pandemic.* Infection, Disease & Health Available online. 5 June 2020.

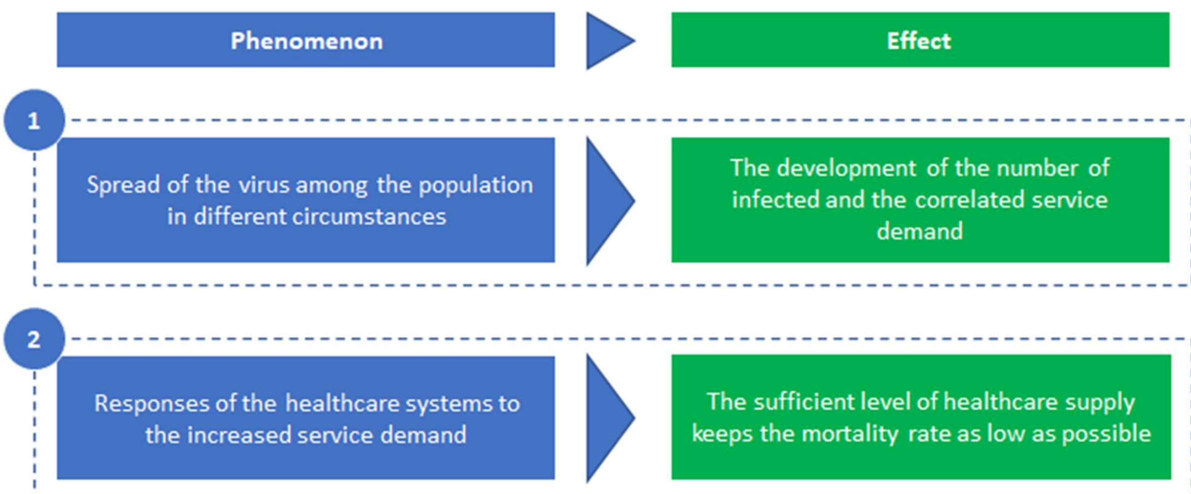
the service supply[10]. In the following chapters of this deliverable, we refer to situations where the service demand is greater than the supplied capacity in a certain moment as overload. .

Figure 1: Illustration of service demand and supply in relation to the infected



The perspectives we take in this paper to analyse the healthcare system can be divided into two main phenomena in Figure 2 below:

Figure 2: Healthcare system analysis perspectives



The reported pace of the spread of the virus varied significantly in different locations and over time[11]. There are various factors that have affected the actual pace of the spread including e.g. demographics, society structures, human behaviour and government non-pharmaceutical interventions such as closing schools or setting restrictions on gatherings. In addition to the differences in the actual pace of the spread, also the testing criteria and the reporting practices of the confirmed cases have been different in different locations and over time. One of the purposes of task 2.2 has been to assess the different factors affecting the spread of the virus and the interventions preventing it in a statistical manner, which is discussed more thoroughly in chapter 2.

[10] The New York Times. *Flattening the Coronavirus Curve.* 27 March 2020. https://www.nytimes.com/article/flatten-curve-coronavirus.html
[11] Johns Hopkins University & Medicine. *Coronavirus resource center*. https://coronavirus.jhu.edu/

The responses of the healthcare service systems in different countries and regions have been matched to the local service demand resulting from the local pace of the spread of the virus. As the absolute and relative numbers of the infected have varied significantly in different locations, also the required responses have varied significantly. Because of the differing responses, the purpose of this task is not to directly evaluate or rank the performances of different healthcare systems during the crisis. As we analyse the different responses, we also assess what has been the effect of the healthcare system in minimizing the number of infected or the mortality caused by the virus. During the process we aim to recognize best practices from different countries and to suggest recommendations for future response and co-operation in similar situations.

1.1 Objectives

The overall objective of the HERoS project is to improve the effectiveness and efficiency of the response to the COVID-19 outbreak. The main objectives of task 2.2 are to:

1. **Assess how different health care system features, country characteristics, and COVID-19 non-pharmaceutical interventions affected the spread of the virus on healthcare systems in Europe in the spring of 2020**
2. **Analyse the responses of different healthcare systems to the COVID-19 pandemic, and formulate recommendations to improve responsiveness**

As the task 2.2 is carried out during the summer of 2020, the time period under review is practically the first wave of COVID-19 that hit the European countries during the spring of 2020.

In chapter 2, the statistical part of this work, the death toll in selected countries is mirrored against different demographic and cultural characteristics as well as healthcare system features of the countries. These factors will be analysed controlling for the differing intervention decisions in each country. As a result, the study also aims to shed light on the effects of interventions chosen. In chapter 2, we went beyond the original research plan of creating theoretical scenarios for the first wave as there was already empirical evidence available and studied the actual response.

The responses of the different European healthcare systems are analysed from the perspective of the services required directly by the patients infected by the COVID-19. The possible effect of the COVID-19 crisis on other healthcare services (the undertreatment in preventive care for the chronic diseases, for example) have been left out of this study. The analysed perspectives will include the following questions:

- How do the health-related outcomes from the first wave compare to the expected preparedness measured by the existing preparedness indices on a country level?
- What kind of diagnostic strategies can be recognized for diagnosing the potentially infected and how are they related to other interventions and the health-related outcomes on a country level?
- Was there sufficient healthcare service capacity to treat the infected who required the hospital services in different phases of the crisis on a country and regional level?
- How did the crisis affect the behaviour of healthcare professionals working in the hospitals treating COVID-19 patients?

1.2 Overview of the contents

The task 2.2 touches on several focus areas related to the COVID-19 crisis. This report is structured to begin with the more general and macro-level focus areas (spread of the virus and preparedness on a country level) and to proceed into more specific focus areas (testing and hospital services on a country and even regional level). The first and last chapters summarize the starting points and the conclusions respectively. The complete structure is as follows:

The first chapter gives an overview to the task 2.2 as a whole and summarizes the main methods and data used in different perspectives

The second chapter assesses the spread of the virus in different countries taking into account the differing characteristics and intervention decisions in each country

The third chapter analyzes the theoretical responsiveness and empirical utilization of testing and hospital care services required by the COVID-19 patients

The fourth chapter analyzes the healthcare professionals' behaviour and the related risks in the most critical services required by the COVID-19 patients

The fifth chapter summarizes the findings and concludes the recommendations

1.3 Methods

Different methodologies are utilized in the different chapters and described in more detail in each chapter. The statistical model for COVID-19 spread utilizes a linear mixed effect model to find the correlations between different country features, interventions and the mortality change. Healthcare system preparedness, and testing utilize descriptive and statistical analysis of correlations between the capabilities, actions and health outcomes during the crisis. Hospital care utilizes descriptive analysis combining the demand and capacity data. The behaviour of professionals is analyzed with qualitative methods utilizing the interview data from the healthcare professionals.

The exact methods used in each chapter, perspective and analysis are described in more detail in each respective chapter.

1.4 Data

The different focus areas of the task 2.2 utilize different sets of data from both primary and secondary sources. This overview summarizes the COVID-19 -specific data utilized in several focus areas and the interview data collected primarily for this task. The secondary data combined with the COVID-19 data supporting the different analyses in different focus areas is described in more detail in respective chapters.

The most crucial is the data from secondary sources related to the spread and the health outcomes of COVID-19. This includes especially 1) diagnostics data related to testing the potentially infected 2) the data related to COVID-19 mortalities and 3) the data related to the number of COVID-19 patients requiring healthcare services. The data related to diagnostics and COVID-19 mortalities has been extracted from already compiled ready data banks whereas the data related to the number of COVID-19 patients requiring services has been manually collected from different public sources, mostly from national health authorities.

The diagnostics and the mortality data extracted covers almost all of the countries globally (188) whereas the number of patients in hospitals cover only selected European countries where the data has been available. The time span for the COVID-19 data starts from the first COVID-19 cases (or first death in some analyses) in each country. The research group has worked with different focus areas simultaneously which has resulted in different end dates for the data sets. However, the data covers the spring of 2020 and the first wave of COVID-19 in most of Europe.

The data related to the COVID-19 is primarily reported by the national health authorities. It is important to understand certain limitations related to the collection of the national data. For COVID-19, as for many infectious diseases, the true level of transmission is frequently underestimated because a substantial proportion of people with the infection are undetected either because they are asymptomatic or have only mild symptoms and thus typically fail to present at healthcare facilities. In the beginning of the crisis, the reported levels of the infected have been further from the true number of the infected due to the limitations in testing capacity[12]. The deaths caused by the virus have been diagnosed with better coverage since the infected with severe symptoms are more often directed to take the test. However, also the deaths caused by COVID-19 have been reported with different criteria in different countries with differences especially regarding the reporting of deaths outside hospitals[13]. The data related to a number of patients in hospital care is assumed more accurate as the reporting errors from events outside hospitals are avoided.

Some of the observations have also been added with a delay by the national authorities[14]. One reason for this is that as the reporting infrastructure was ramped up rapidly in the beginning of the crisis, some of the observations were manually gathered. When looking at the data, these data discrepancies often seem to smooth out when enough time has passed since the beginning of data gathering.

The limitations of the data have been taken into account in designing the different analyses. For example, mortality data is used as a proxy for the spread of the virus in the population instead of the reported number of infected. The possible effects of the data quality to the results is discussed in more detail in different chapters of the deliverable.

In addition to COVID-19 specific data, a large set of different statistical country level data regarding the healthcare system and general characteristics in the different countries has been utilized. Especially the statistical model described in more detail in the next chapter of this deliverable utilizes a wide spectrum of different publicly available data, mostly from ready databases such as the WDI gathered by the World Bank. This secondary data is described in more detail in the respective chapter.

In addition to quantitative data, we also collected primary data in the form of notes, recordings and transcripts from interviews in order to understand the behaviour of the healthcare professionals during the crisis. For the purposes of this deliverable, this data is collected from Finland, Italy and Sweden respecting the hectic working schedules of the healthcare personnel in hospitals treating the COVID-19 patients.

The data and sources used in different chapters and specific analyses is described in more detail in respective chapters. All data is managed according to HERoS data management plan.

[12] World Health Organization. *Estimating mortality from COVID-19.* 4 August 2020. https://www.who.int/news-room/commentaries/detail/estimating-mortality-from-covid-19

[13] Reuters. *Belgium says White House reading of its COVID-19 deaths unfair.* 22 April 2020. https://www.reuters.com/article/health-coronavirus-belgium-tally/belgium-says-white-house-reading-of-its-covid-19-deaths-unfair-idUSL5N2CA6JZ

[14] Reuters. *French coronavirus cases jump above China's after including nursing home tally*. 4 April 2020. https://www.reuters.com/article/us-health-coronavirus-france-toll/french-coronavirus-cases-jump-above-chinas-after-including-nursing-home-tally-idUSKBN21L3BG

2 Statistical model for COVID-19 spread

2.1 Introduction

What is the explanation behind the fact that the spread of the COVID-19 epidemic differs between countries? Were the chosen non-medical interventions effective, and which interventions had the greatest impact in preventing the death toll from rising?

In the statistical model, the death toll in selected countries is mirrored against different demographic and cultural characteristics as well as healthcare system features of the countries. These features are analysed controlling for the different social distancing interventions in each country. As a result, the study also sheds light on the effects of interventions chosen by governments.

To measure the advance of the epidemic, we used mortality figures instead of number of verified infections. The reliability of mortality data is better compared to information on the number of infected people because the latter can be affected by sampling bias due to the different testing protocols and capacity in each country. According to studies such as Havers et al. (2020)[15], the true number of COVID-19 patients has been manifold the number of verified infections. Although, death tolls on the other hand can have reliability concerns due to reporting procedures and due to different categorizing of the cause of death, statistics for number of dead due to COVID-19 is currently (August 2020) the most reliable proxy for the advance of the epidemic.

Data is derived from reliable public sources. The method utilized was a linear mixed effect model. The analysis was carried out on country level, since the majority of the data was available on a country level.

This chapter is structured as follows: 2.2 goes through the data utilized in the study, 2.3 covers the methodology used, 2.4 presents the summary results, and 2.5 concludes the analysis.

2.2 Data for statistical model

The statistical model for the COVID-19 spread in this study, utilizes three types of data, COVID-19 impact time-series data, intervention time-series data and country features cross-sectional data. All data is presented under respective sub-chapters.

Countries included in the study composed 33 countries, of which the majority are EU countries. The rest of the countries were other European countries, a few other countries were included in the study because of their phase of the COVID-19 epidemic – Those were also hit by the epidemic in the spring of 2020. In the selected countries the epidemic started in the spring of 2020 and enabled enough data to be collected for this study. From the EU countries, Cyprus, Latvia, Lithuania, Malta and Slovakia were excluded either due to few reported COVID-19 deaths, or a lack of data available.

All the included countries are presented in Table 1 below.

[15] Havers, F.P., Reed, C., Lim, T., Montgomery, J.M., Klena, J.D., Hall, A.J., Fry, A.M., Cannon, D.L., Chiang, C.F., Gibbons, A. and Krapiunaya, I., 2020. Seroprevalence of antibodies to SARS-CoV-2 in 10 sites in the United States, March 23-May 12, 2020. JAMA Internal Medicine.

Table 1: Countries included in the statistical model

Country	Abbreviation	Time series start / First death	Country	Abbreviation	Time series start / First death
Austria (EU)	AUT	12 March 2020	Netherlands (EU)	NLD	6 March 2020
Belgium (EU)	BEL	11 March 2020	New Zealand	NZL	29 March 2020
Bulgaria (EU)	BGR	11 March 2020	Norway	NOR	14 March 2020
Croatia (EU)	HRV	19 March 2020	Poland (EU)	POL	12 March 2020
Czechia (EU)	CZE	22 March 2020	Portugal (EU)	PRT	17 March 2020
Denmark (EU)	DNK	14 March 2020	Romania (EU)	ROU	22 March 2020
Estonia (EU)	EST	25 March 2020	Serbia	SRB	20 March 2020
Finland (EU)	FIN	21 March 2020	Singapore	SGP	21 March 2020
France (EU)	FRA	15 February 2020	Slovenia (EU)	SVN	14 March 2020
Germany (EU)	DEU	9 March 2020	South Africa	ZAF	27 March 2020
Greece (EU)	GRC	11 March 2020	South Korea	KOR	20 February 2020
Hungary (EU)	HUN	15 March 2020	Spain (EU)	ESP	3 March 2020
Ireland (EU)	IRL	11 March 2020	Sweden (EU)	SWE	11 March 2020
Israel	ISR	21 March 2020	Switzerland	CHE	5 March 2020
Italy (EU)	ITA	21 February 2020	Ukraine	UKR	13 March 2020
Japan	JPN	13 February 2020	United Kingdom	GBR	6 March 2020
Luxembourg (EU)	LUX	14 March 2020			

2.2.1 COVID-19 impact data and selection of the dependent variable

COVID-19 death data is provided by Johns Hopkins University[16]. The death time-series in each country begins from the first death and ends 12 August 2020.

The daily numbers of reported deaths have great variation due to deaths reported in bundles. For this reason, we utilized a 7-day moving average. Also, the number of deaths function has a peak (see time series in Figure 3) that linear models cannot model. The number of deaths first increases and then decreases. The change is not linear, and for that reason we processed the values of daily deaths to values of daily mortality change. Firstly, daily death figures were converted to cumulative death figures. Secondly, these figures were made relative by dividing them by the population in millions in each country. Thirdly, these time series were smoothed with a 7-day (+-3 days) moving average. Lastly, to account for the pace of the relative moving average deaths are changing, the relative percentage change was calculated from subsequent daily figures. As an end result, the daily mortality change (*DMC*) reflects the pace the death toll is either rising or decreasing, and provides a smoother data series compared to pure daily mortality figures.

The *DMC* as a function of time is closer to linear and can be modelled using linear models. The value of *DMC* is positive when numbers of deaths are increasing and negative when decreasing. The negative estimates (model coefficients) of the model can be interpreted that the variables reduced mortality rate. The positive estimates can be interpreted that the variables did not reduce mortality. We also included "number of days

[16] Johns Hopkins University. *Novel Coronavirus (COVID-19) Cases Data.* https://data.humdata.org/dataset/novel-coronavirus-2019-ncov-cases

since first death”, *day*, as a control variable to the models. The *day* variable accounts for the overall trend of decreasing mortality since the first epidemic wave and thus also makes the results more robust.

2.2.2 Country features data

Combining the country features dataset, we aimed to create a comprehensive selection of demographic, cultural and healthcare system specific data. We included demographic features portrayed in the public discussion[17] and in academic publications[18] [19] and potential risk factors identified in previous pandemics[20] [21] [22]. Additionally, a selected set of cultural characteristics was included to examine if those could explain the differences, instead of pure demographic features. In addition, some healthcare system features were included also to study their effect on the mortality figures.

Country features data was combined from several reliable public sources and represents data gathered and published 2017-2019. The majority of the used data came from the World Development Indicators (WDI) databank by the World Bank[23] (accessed 9 April 2020) as well as from the INFORM Epidemic Risk dataset[24] (accessed 14 April 2020).

The different variables have different measurement scales. For that reason, we utilized Z-score transformation, a process in which each observation was deducted with the mean of the observations, and after which this figure was divided with the standard deviation. This improves the modelling process and the interpretation of the results.

All utilized country features data is presented in Table 2 below. The table presents all factors with their type, abbreviation and data source. Different factor types include ‘demographic’, ‘population’, ‘healthcare system’, ‘culture’ and ‘other societal characteristics’. Type ‘other’ is associated to factors unable to be categorized under any of the specified categories. Exact figures are presented in Annex 1.

[17] NHS. Who's at higher risk from coronavirus. https://www.nhs.uk/conditions/coronavirus-covid-19/people-at-higher-risk/whos-at-higher-risk-from-coronavirus/

[18] Chaudhry, R., Dranitsaris, G., Mubashir, T., Bartoszko, J. and Riazi, S., 2020. A country level analysis measuring the impact of government actions, country preparedness and socioeconomic factors on COVID-19 mortality and related health outcomes. EclinicalMedicine, p.100464.

[19] Stojkoski, V., Utkovski, Z., Jolakoski, P., Tevdovski, D. and Kocarev, L., 2020. The socio-economic determinants of the coronavirus disease (COVID-19) pandemic. arXiv preprint arXiv:2004.07947.

[20] Morales, K.F., Paget, J. and Spreeuwenberg, P., 2017. Possible explanations for why some countries were harder hit by the pandemic influenza virus in 2009–a global mortality impact 8odelling study. BMC infectious diseases, 17(1), p.642.

[21] Nikolopoulos, G., Bagos, P., Lytras, T. and Bonovas, S., 2011. An ecological study of the determinants of differences in 2009 pandemic influenza mortality rates between countries in Europe. PloS One, 6(5), p.e19432.

[22] Viasus, D., Paño-Pardo, J.R., Pachon, J., Campins, A., López-Medrano, F., Villoslada, A., Farinas, M.C., Moreno, A., Rodríguez-Baño, J., Oteo, J.A. and Martínez-Montauti, J., 2011. Factors associated with severe disease in hospitalized adults with pandemic (H1N1) 2009 in Spain. Clinical Microbiology and Infection, 17(5), pp.738-746.

[23] The World Bank. *World Development Indicators.* https://databank.worldbank.org/source/world-development-indicators

[24] INFORM. *INFORM Epidemic Risk.* https://data.humdata.org/dataset/inform-epidemic-risk

Table 2: Country features data

Factor	Type	Abbreviation	Source
Total alcohol consumption per capita (litres of pure alcohol, projected estimates, 15+ years of age)	Culture / Other societal characteristics	alcohol	WDI, 2016-2019
International tourism, number of arrivals	Culture / Other societal characteristics	arrivals	INFORM / World Bank, 2017
Automated teller machines (ATMs) (per 100 000 adults)	Other societal characteristics	atms	WDI, 2017-2019
Population blood groups, %: O+; A+; B+; AB+; O−; A−; B-, AB-	Demographic / Population	blood_o_plus; blood_a_plus; blood_b_plus; blood_ab_plus; blood_o_minus; blood_a_minus; blood_b_minus; blood_ab_minus	Several country-specific sources, see summary at Wikipedia[25]
Raised blood pressure (SBP>=140 OR DBP>=90) (age-standardized estimate)	Demographic / Population	blood_pressure	WHO, 2015
Mean BMI (kg/m²) (age-standardized estimate)	Demographic / Population	bmi	WHO, 2016
Raised total cholesterol (>= 5.0 mmol/L) (age-standardized estimate)	Demographic / Population	cholesterol	WHO, 2008
Corruption Perception Index	Culture / Other	corruption	INFORM / Transparency International, 2019
Diabetes prevalence (% of population ages 20 to 79)	Demographic / Population	diabetes	WDI, 2019
GDP per capita (current US$)	Other societal characteristics	gdp	WDI, 2018-2019
GINI index (World Bank estimate)	Other societal characteristics	gini	WDI, 2012-2019, NZL: OECD 2014, SGP: CIA 2017
Government Effectiveness	Other societal characteristics	gov_eff	INFORM / World Bank, 2018
Current health expenditure per capita (current US$)	Healthcare system	hc_costs	WDI, 2016-2019
Current health expenditure (% of GDP)	Healthcare system	hc_costs_of_gdp	WDI, 2016-2019
Human Capital Index (HCI) (scale 0-1)	Other societal characteristics	hci	WDI, 2017-2019
Human Development Index	Other societal characteristics	hdi	INFORM, 2018
Geert Hofstede's 6-D Model: Power distance; Individualism; Masculinity; Uncertainty avoidance; Long term	Culture	hofstede_pdi; hofstede_idv; hofstede_mas; hofstede_uai;	Geert Hofstede, 2020

[25] Wikipedia. *Blood type distribution by country.* https://en.wikipedia.org/wiki/Blood_type_distribution_by_country

orientation[26]		hofstede_ltowvs	
Hospital beds (per 1 000 people)	Healthcare system	hospital_beds	WDI, 2012-2019 NLD: World Bank 2009, ZAF: World Bank 2005
Household size	Culture / Other societal characteristics	household	INFORM / UNDESA, 2006-2016, DNK: UN / Statistics of Denmark 2017, KOR: UN / DYB 2008, SWE: UN / Total Population Register 2015, CHE: UN / DYB 2000
Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%)	Demographic / Population	illnesses	WDI, 2016-2019
Individuals using the Internet (% of population)	Culture / Other societal characteristics	internet	INFORM / World Bank, 2017
Life expectancy at birth, total (years)	Demographic / Population	life_exp	WDI, 2017-2019
Mobile cellular subscriptions per 100 people	Culture / Other societal characteristics	mobile_subs	INFORM / World Bank, 2018
Nurses and midwives (per 1 000 people)	Healthcare system	nurses	WDI, 2014-2019
Out-of-pocket expenditure (% of current health expenditure)	Healthcare system	oop_hc	WDI, 2016-2019
Physicians (per 1 000 people)	Healthcare system	physicians	WDI, 2014-2019
PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)	Other	pollution	WDI, 2017-2019
Population density (people per sq. km of land area)	Culture / Other societal characteristics	pop_density	WDI, 2018-2019
Sex ratio at birth (male births per female births)	Demographic / Population	pop_gender	WDI, 2017-2019
Population, total	Demographic / Population	pop_tot	WDI, 2018-2019
Population living in urban areas (%)	Culture / Other societal characteristics	pop_urban	INFORM, 2018
Domestic private health expenditure (% of current health expenditure)	Healthcare system	priv_share	WDI, 2016-2019
Employment in services (% of total employment) (modeled ILO estimate)	Culture / Other societal characteristics	services_of_gdp	WDI, 2019
Smoking prevalence, total (ages 15+)	Culture / Other societal characteristics	smoking	WDI, 2016-2019
Unemployment, total (% of total labor force) (modeled ILO estimate)	Other	unemployment	WDI, 2019
Immunization, DPT (% of children ages	Healthcare system /	vaccine_dpt	WDI, 2018-2019

[26] Note: Geert Hofstede's 6th dimension, indulgence, not available for all countries studied and thus not included

12-23 months)	Culture / Other		
Immunization, measles (% of children ages 12-23 months)	Healthcare system / Culture / Other	vaccine_measles	WDI, 2018-2019
Ratio of female to male labor force participation rate (%) (modeled ILO estimate)	Culture / Other societal characteristics	women_labour	WDI, 2019

2.2.3 Intervention data

Intervention data is assembled by The Blavatnik School of Government (OXFORD COVID-19 Government Response Tracker)[27]. The interventions time-series were constructed with a 18-day lead, as the results from Zhou et al.[28] found that the median time from illness onset to death was 18 days. This means that the mortality data is lagged 18 days compared to the interventions data, i.e. the intervention data starts 18 days prior to the mortality data. As the evidence from COVID-19 accumulates in the future, this figure is open for adjustments, but as the aim of this study was to examine the first wave of the epidemic, we find using this figure justifiable.

Interventions taken by the governments have had a central role in the fight against COVID-19 epidemic[29], based also on findings from China in the early spring of 2020[30]. The Oxford COVID-19 Government Response Tracker tracks and compares government responses to the COVID-19 outbreak. The tracker collects information on several different common policy responses governments have taken, scores the stringency of these measures, and aggregates the scores into a stringency index. We have utilized both the data on individual interventions and the existing stringency index.

The utilized interventions are from two categories, 'Closures and Containment' (C) and 'Public health / Health System' (H), of which the former includes 8 interventions and the latter 3. Closures and Containment includes school closing (C1), workplace closing (C2), cancelling public events (C3), setting restrictions on gatherings (C4), closing public transport (C5), setting curfews (C6), restricting interval movement (C7) and controlling international travel (C8). Public Health / Health System includes public COVID-19 information campaigns (H1), testing policy (H2) and policy on contact tracing (H3).

All individual interventions include daily information on the level of that intervention, e.g. is that government response either recommended or required. Closures and containments offer both country level and targeted (regional) information on interventions. Due to clarity and also a small number of targeted interventions executed by countries, targeted interventions are not studied separately in detail, but are included in category-level intervention regressions. The stringency index with scale of 0-100 combines all 8 Closures and Containment interventions with H1, the public information campaigns, to create an approximation of each country's total intervention magnitude on any given date. The (general, country level) interventions are presented in Table 3 below.

[27] Hale, Thomas, Sam Webster, Anna Petherick, Toby Phillips, and Beatriz Kira, 2020. Oxford COVID-19 Government Response Tracker, Blavatnik School of Government. https://data.humdata.org/dataset/oxford-covid-19-government-response-tracker
[28] Zhou, F., Yu, T., Du, R., Fan, G., Liu, Y., Liu, Z., Xiang, J., Wang, Y., Song, B., Gu, X. and Guan, L., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The lancet.
[29] Deb, P., Furceri, D., Ostry, J.D. and Tawk, N., 2020. The effect of containment measures on the COVID-19 pandemic.
[30] Pan, A., Liu, L., Wang, C., Guo, H., Hao, X., Wang, Q., Huang, J., He, N., Yu, H., Lin, X. and Wei, S., 2020. Association of public health interventions with the epidemiology of the COVID-19 outbreak in Wuhan, China. Jama, 323(19), pp.1915-1923.

Table 3: Interventions, based on the Oxford COVID-19 Government Response Tracker

Intervention category	Intervention	Abbreviation
School closing	Recommend closing	c1_school_rec
School closing	Require closing (only some levels or categories, e.g. just high school, or just public schools)	c1_shool_req_some
School closing	Require closing (all levels)	c1_school_req_all
Workplace closing	Recommend closing (or work from home)	c2_work_rec
Workplace closing	Require closing (or work from home) for some sectors or categories of workers	c2_work_req_some
Workplace closing	Require closing (or work from home) all-but-essential workplaces (e.g. grocery stores, doctors)	c2_work_req_all
Cancel public events	Recommend cancelling	c3_events_rec
Cancel public events	Require cancelling	c3_events_req
Restrictions on gatherings	Restrictions on very large gatherings (the limit is above 1 000 people)	c4_gatherings_1000plus
Restrictions on gatherings	Restrictions on gatherings between 100-1 000 people	c4_gatherings_100_1000
Restrictions on gatherings	Restrictions on gatherings between 10-100 people	c4_gatherings_10_100
Restrictions on gatherings	Restrictions on gatherings of less than 10 people	c4_gatherings_10minus
Close public transport	Recommend closing (or significantly reduce volume/route/means of transport available)	c5_transport_rec
Close public transport	Require closing (or prohibit most citizens from using it)	c5_transport_req
Stay at home	Recommend not leaving house	c6_curfew_rec
Stay at home	Require not leaving house with exceptions for daily exercise, grocery shopping, and 'essential' trips	c6_curfew_req_loose
Stay at home	Require not leaving the house with minimal exceptions (e.g. allowed to leave only once every few days, or only one person can leave at a time, etc.)	c6_curfew_req_strict
Restrictions on internal movement	Recommend closing (or significantly reduce volume/route/means of transport)	c7_movement_rec
Restrictions on internal movement	Require closing (or prohibit most people from using it)	c7_movement_req
International travel controls	Screening	c8_travelctrl_screening
International travel controls	Quarantine arrivals from high-risk regions	c8_travelctrl_quarantine
International travel controls	Ban on high-risk regions	c8_travelctrl_ban_high_risk
International travel controls	Total border closure	c8_travelctrl_total_closure
Public info campaigns	Public officials urging caution about COVID-19	h1_campaigns_individual
Public info campaigns	Coordinated public information campaign (e.g. across traditional and social media)	h1_campaigns_coordinated
Testing policy	Only those who both (a) have symptoms AND (b) meet specific criteria (e.g. key workers, admitted to hospital, came into contact with a known case, returned from overseas)	h2_testing_criteria
Testing policy	Testing of anyone showing COVID-19 symptoms	h2_testing_symptoms
Testing policy	Open public testing (e.g. "drive through" testing available to asymptomatic people)	h2_testing_open
Contact tracing	Limited contact tracing - not done for all cases	h3_tracing_limited
Contact tracing	Comprehensive contact tracing - done for all cases	h3_tracing_comprehensive

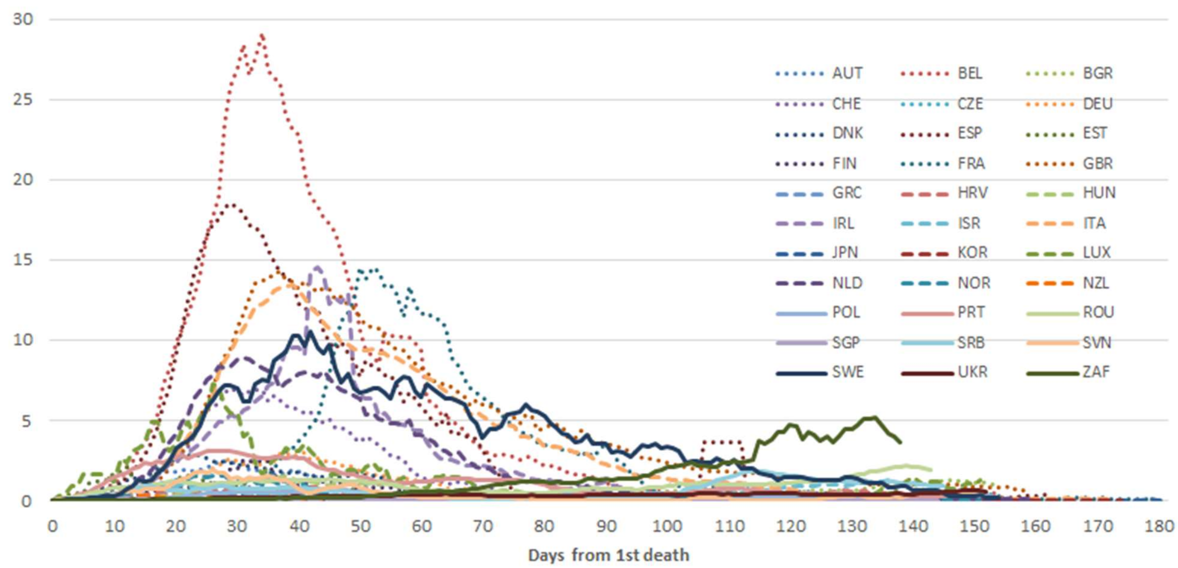
	Stringency index combining the info from C1-C8 and H1 on scale 0-100	stringency_index

2.3 Methods for data analysis

In this section, we explain and justify the selection of the modelling approach.

At the time period of the data collection for this study (August 2020), the countries included in the study seem to have experienced the first wave of COVID-19 as the number of deaths increased rapidly around March 2020 and then started to decrease around May 2020, as presented in Figure 3 below.

Figure 3: Daily mortality count, deaths per 1M population, 7 day moving average



We used linear mixed effect models[31] to identify factors with significance for the number of deaths. The linear models are easily interpreted. For example, a sign of an estimate indicates directly if the variable had an positive or a negative effect on the dependent variable. Mixed effect models can handle repeated and correlated measurements, such as the country specific daily deaths.

We collected and processed 49 country features variables for this study. It should be noted that the number of data points (countries) is too low (33) to fit all the variables in a multivariable model. Thus, we conducted a variable selection process before the modelling. In addition, we took collinearity into account by eliminating variables highly correlated. This selection process is presented later on in the Results section.

It should be noted that *DMC* values as a function of day from each country are repeated measures. Repeated measures violate the independence assumption of standard linear models[32]. That is, multiple responses from the same subject cannot be regarded as independent from each other. Every country has a

[31] Gałecki, Andrzej, Burzykowski, Tomasz, Linear Mixed-Effects Models Using R: A Step-by-Step Approach, Springer-Verlag New York, doi: 10.1007/978-1-4614-3900-4.

[32] Winter, B., 2013. Linear models and linear mixed effects models in R with linguistic applications. arXiv. arXiv preprint arxiv:1308.5499.

different course of mortality, and this is a factor that affects all responses as a function of time from the same country. In our study, we selected to use the mixed effect models that can handle the repeated measures by assuming different random intercept and/or slope for each subject. Our model includes random effects for countries, thus handling the repeated measures of *DMC*.

The model settings (e.g. random intercept and/or slope) were selected based on the model comparison tests. The utilized model includes only random intercept. Random slope was not included in the model based on AIC value test. In our models, random intercept means that each country has a different intercept value. That is, the model assumes that different countries can have different base values. All the tasks related to linear mixed effect modelling were performed using R language and Stats package functions.

One additional strength of the chosen method is its ability to deal with unbalanced panel data, allowing for all selected countries to be included in the study from the day of the first death in each country, until the data end 12 August 2020.

2.4 Summary of results

In this section, a summary of the initial results from the selected model specifications are presented. *The more detailed results are submitted for publication in peer-reviewed journal during Autumn 2020.*

First, country feature variable selection for the multivariate model is executed, and the selected country level features are brought together to study which features seemed to correlate to *DMC*, controlling for interventions with stringency index. Then, interventions are studied more in detail, first on a category-level and then independently, to find out which intervention categories and which interventions had the most correlation to *DMC*.

Variable selection for the eventual multivariable modelling was done by fitting models for all country features independently, as presented in Table 4 below. Each factor's effect on *DMC* was studied independently, controlled with stringency index and days from first death – The dependent variable was *DMC*, with interventions controlled with the stringency index and the overall decrease in the mortality controlled by *day*, the number of days from the first death in a specific country. If *DMC* p-value of the model coefficient for the country feature was lower than 0.10, the variable was selected for multivariable modelling. This deducted the number of variables to 16, as seen in Table 4 below. In all models, both days since first death and the stringency index had negative coefficients and impact on *DMC* was statistically significant ($p < 0.001$).

Table 4: Country features variable selection for multivariate modelling

Significance at the 0.1 %, 1 %, 5 % and 10 % level is indicated by ***, **, * and ., respectively.

Factor	Estimate	Confidence interval (95 %)	P-value
hci	**-1.46**	**-2.54 – -0.39**	**0.007 ** **
pollution	**1.36**	**0.28 – 2.45**	**0.014 ***
unemployment	**1.35**	**0.26 – 2.43**	**0.015 ***
gini	**1.36**	**0.26 – 2.45**	**0.015 ***
hdi	**-1.34**	**-2.43 – -0.25**	**0.016 ***
priv_share	**1.29**	**0.20 – 2.37**	**0.020 ***

diabetes	**1.27**	**0.16 – 2.37**	**0.024 ***
corruption	**-1.25**	**-2.35 – -0.15**	**0.025 ***
vaccine_dpt	**-1.23**	**-2.31 – -0.14**	**0.027 ***
gov_eff	**-1.20**	**-2.30 – -0.10**	**0.033 ***
vaccine_measles	**-1.18**	**-2.29 – -0.07**	**0.038 ***
blood_ab_plus	**-1.11**	**-2.20 – -0.03**	**0.043 ***
life_exp	**-1.14**	**-2.25 – -0.02**	**0.047 ***
blood_o_plus	**1.07**	**-0.04 – 2.18**	**0.058 .**
nurses	**-1.08**	**-2.19 – 0.04**	**0.059 .**
hofstede_mas	**1.01**	**-0.09 – 2.11**	**0.072 .**
arrivals	0.85	-0.25 – 1.96	0.130
pop_urban	-0.87	-2.00 – 0.26	0.131
illnesses	0.87	-0.27 – 2.00	0.135
household	0.85	-0.28 – 1.98	0.142
physicians	-0.81	-1.95 – 0.33	0.165
pop_gender	-0.76	-1.90 – 0.39	0.194
women_labour	-0.71	-1.84 – 0.43	0.223
atms	0.69	-0.44 – 1.82	0.229
blood_ab_minus	0.66	-0.47 – 1.78	0.255
blood_b_plus	-0.64	-1.77 – 0.50	0.270
smoking	0.63	-0.51 – 1.78	0.280
bmi	0.59	-0.55 – 1.73	0.314
cholesterol	-0.59	-1.74 – 0.57	0.320
gdp	-0.57	-1.72 – 0.59	0.334
blood_o_minus	0.51	-0.63 – 1.65	0.381
hofstede_ltowvs	-0.51	-1.66 – 0.64	0.382
pop_tot	0.47	-0.67 – 1.61	0.418
hospital_beds	-0.47	-1.61 – 0.67	0.423
hofstede_uai	0.44	-0.71 – 1.60	0.452
blood_a_plus	-0.44	-1.60 – 0.72	0.454
alcohol	-0.43	-1.59 – 0.73	0.468
hc_costs	-0.41	-1.57 – 0.75	0.489
oop_hc	0.40	-0.76 – 1.56	0.497
blood_a_minus	0.36	-0.78 – 1.50	0.537
internet	0.30	-0.86 – 1.46	0.614
blood_pressure	0.24	-0.92 – 1.40	0.687
mobile_subs	-0.19	-1.35 – 0.98	0.754
hofstede_pdi	0.16	-1.01 – 1.33	0.789
pop_density	-0.14	-1.31 – 1.04	0.82
hc_costs_of_gdp	-0.13	-1.30 – 1.03	0.823
hofstede_idv	0.05	-1.12 – 1.21	0.939
blood_b_minus	0.01	-1.15 – 1.17	0.984
services_of_gdp	0.00	-1.17 – 1.17	0.995

Furthermore, correlation analysis of the selected variables was used for eliminating collinearity. If two variables correlated (coefficient higher than .85), the other variable was dropped from the multivariable modelling. The choice on which variable to be dropped was based on the variable's correlation to the remaining variables. This further deducted the number of variables to 14, dropping Human Development Index (*hdi*) and Government Efficiency Index (*gov_eff*). The correlation table is presented in Annex 2.

The first model specification answers the question which country level features had correlation to *DMC*, controlling for country-specific intervention actions with the stringency index. The set of country features composes of factors with a statistically significant relation ($p < 0.10$) to *DMC* in the independent regressions, deducted with factors being highly correlated to deal with collinearity. Both day and stringency index have statistically significant negative estimates ($p < 0.001$), meaning that higher stringency index and the passing of days both have had a decreasing effect on *DMC*. Of country features, *hofstede_mas* and *diabetes* bear statistically significant results ($p < 0.05$). Geert Hofstede's masculinity, i.e. the extent to which the use of force is endorsed socially, correlates with higher *DMC*. Diabetes prevalence within the population is also correlated with higher *DMC*.

The second model specification answers the question which intervention categories correlate to *DMC*. Due to the high number of individual interventions within the studied 11 categories, it is first necessary to study them on category-level. The 'any measure', or *any_mes*, intervention factors simplify if any (country level or regionally targeted) intervention is in action and if that with the earlier explained 18-day lag has an effect on *DMC*. Based on these results, on category level many interventions have an effect on *DMC*. To compare the effectiveness of the interventions on this category-level, cancelling public events seems to have the largest impact, closely followed by controlling international travel and closing workplaces, respectively. On 95 % confidence level the other intervention categories do not seem to have effects on *DMC*.

The third model specification answers the question which interventions correlate to *DMC*. Studying interventions independently, not just by categories, offers more accurate analysis on the effects of interventions and enables to compare the interventions against each other both across and within different categories. Only country-wide, general, interventions are included in this analysis. Only interventions with country $N > 6$ are included, which excludes one intervention, the strictest curfew (*c6_curfew_req_strict*), and leaves a total of 29 independent interventions in the study. According to the model, requiring all school levels to close, seems to have been effective in reducing mortality. Cancelling public events, either recommending or requiring, seem to have both been highly effective in reducing mortality as well as recommending internal movement to be closed. In addition, all actions on international travel, screening, quarantine arrivals from high-risk regions, ban on high-risk regions or total border closure seem to have had a strong decreasing effect on mortality.

2.5 Discussion

The following section concludes the statistical model chapter. In addition to summarizing the main results, emphasis is given discussing both the robustness of these results and the potential for future studies.

The aim of this study was to examine why the COVID-19 epidemic expansion differed from one country to another. This was executed with data on daily mortality, data on country level intervention actions and a wide country level feature dataset consisting of demographic, cultural and healthcare system specific features.

Diabetes prevalence in the population proved statistically significant, being correlated with higher *DMC*. This finding is also supported by Guo et al. (2020)[33], who found that diabetes should be considered as a risk factor for a rapid progression and bad prognosis of COVID-19. Similar results are obtained also by Zhou et al. (2020)[34], who additionally find that increasing odds of in-hospital death are associated with older age, supporting also the country level findings from this study that indeed higher life expectancy is associated with higher *DMC*.

Another statistically significant country feature was Geert Hofstede's masculinity, i.e. the extent to which the use of force is endorsed socially, correlating with higher *DMC.* To our knowledge there is no prior studies to this topic, and this surely presents material for future studies.

To study the effects of interventions to *DMC*, interventions were first analyzed on category-level and then independently. In the category-level intervention analysis, closing schools and workplaces, cancelling public events and controlling international travel all had an effect to reduce mortality. Of these, the effects were the strongest in cancelling public events, controlling international travel and closing workplaces, respectively.

In intervention-level analysis, we analyzed the respective effect of each intervention. The results show that requiring all school levels to close, either recommending or requiring public events to be cancelled, recommending closing internal movement or intervening international travel in any fashion all had an effect to reduce mortality. In a recent study, Deb et al. (2020)[35] found supporting evidence, stating that across different types of containment measures, internal and international travel restrictions have been the most effective. Koh et al. (2020)[36] found that of different intervention types, border closures and lockdown-type measures have been effective in outbreak control. However, based on their results, recommended stay-at-home advisories and partial lockdowns have to be implemented early to be effective.

2.5.1 Limitations and further research

There are a number of limitations related to the modelling and variables. Many of the selected interventions are started and were in action at the same time (as seen in Annexes 3 and 4). The effects of distinct interventions were difficult to separate. Further study should be conducted to apply new methods to separate the effects of the concurrent interventions.

One of the main questions in studies of this kind is the selection of model variables, also a question raised in the COVID-19 context by Stojkoski et al. (2020)[37]. Country features included in the model were chosen from regressions including the feature, days since first death and stringency index controlling for the interventions, and had to have statistically significant relation to *DMC*.

[33] Guo, W., Li, M., Dong, Y., Zhou, H., Zhang, Z., Tian, C., Qin, R., Wang, H., Shen, Y., Du, K. and Zhao, L., 2020. Diabetes is a risk factor for the progression and prognosis of COVID-19. Diabetes/metabolism research and reviews, p.e3319.
[34] Zhou, F., Yu, T., Du, R., Fan, G., Liu, Y., Liu, Z., Xiang, J., Wang, Y., Song, B., Gu, X. and Guan, L., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The lancet.
[35] Deb, P., Furceri, D., Ostry, J.D. and Tawk, N., 2020. The effect of containment measures on the COVID-19 pandemic.
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[37] Stojkoski, V., Utkovski, Z., Jolakoski, P., Tevdovski, D. and Kocarev, L., 2020. The socio-economic determinants of the coronavirus disease (COVID-19) pandemic. arXiv preprint arXiv:2004.07947.

The models were sensitive for variable selection. By adding or removing variables impacted significantly on the other variables and the results. Sample size was small and more robust modelling results can be achieved when more data have been collected.

We did not study interaction effects. It can be expected that there are interactions between the variables. The performance of the models can improve by adding interaction terms assuming that the sample size (number of countries) is high enough.

The dependent variable was formed for the linear models used in the study. Further studies should be conducted to test different models and dependent variables to gain more understanding about the progress of the COVID-19.

In addition, death tolls have their problems regarding the reporting procedures and categorizing the cause of death as COVID-19. Also, because of different testing policies, death rate data differs largely between countries. For example, some countries only report COVID-19 deaths that occur in hospitals – COVID-19 deaths at home may not be recorded. Also, some countries only report deaths with a positive COVID-19 test – untested individuals may not be included.[38] Still, we see deaths as the most reliable proxy for the spread of the epidemic.

Connecting the country features with interventions is carried out in the first model specification, i.e. when the features are controlled with the stringency index. In the other model specifications, when interventions are studied, country features are not included in the models and thus not controlled for. This is due to the fact that otherwise the number of variables would have increased too high compared to the number of countries.

Comparing the effects of interventions and the country features, in all settings the interventions seem to have larger effects over the demographic, cultural or healthcare system characteristics of the countries. Thus, interventions affecting the actions of the citizens had a central role in fighting the epidemic. More patient level clinical analyses are needed to study the effects of e.g. other diseases to COVID-19 vulnerability, but accumulating such data sets takes time. In addition, during the last months interesting studies have been published analyzing some additional factors explaining COVID-19 mortality, such as the differing climate conditions around the world[39] and usage of masks[40]. During the model building and data gathering phase of this study, the role of masks was not seen as central as it has become.

Lastly, it should be noted that the data, and thus also the results, are valid only for the first wave of the COVID-19 epidemic, and thus we recommend the analysis be repeated if the epidemic advances. Also, the lack of publicly available, trustworthy and in-depth country level healthcare system data narrowed the universe of factors available to be included into the model. The next chapter will focus in more detail on the healthcare systems.

[38] BBC. Coronavirus: Why death and mortality rates differ?
https://www.bbc.com/future/article/20200401-coronavirus-why-death-and-mortality-rates-differ

[39] Bashir, M.F., Ma, B., Komal, B., Bashir, M.A., Tan, D. and Bashir, M., 2020. Correlation between climate indicators and COVID-19 pandemic in New York, USA. Science of The Total Environment, p.138835.

[40] Eikenberry, S.E., Mancuso, M., Iboi, E., Phan, T., Eikenberry, K., Kuang, Y., Kostelich, E. and Gumel, A.B., 2020. To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. Infectious Disease Modelling.

3 Healthcare system responsiveness

This chapter dives deeper into the responsiveness of different healthcare systems. Responsiveness is often defined as interaction between healthcare system and the population it serves[41].

Healthcare systems are usually defined to consist at least health-service financing and health service provision[42] [43].The WHO's healthcare system analyses from the early 2000s have been one of the most prominent classifications of healthcare systems[44] [45]. WHO suggested that the goals of a healthcare system are "good health, responsiveness to the expectations of the population, and fairness of financial contribution". Later on, WHO has elaborated on the elements of the healthcare system a bit further into a six-dimensional framework. This framework takes into account service delivery, financing, workforce, information, medical products and technologies and leadership and governance[46]. Healthcare systems can be divided into three or four categories based on funding source (the Beveridge Model, the Bismarck model, National Health Insurance Model and out-of-pocket model)[47] [48]. The capabilities of the healthcare systems of European countries are quite similar [49] [50] [51]. Here, capabilities refer to the dimensions of the earlier mentioned WHO's framework [43]. Thus, European countries are expected to share similar capabilities to perform during a crisis situation from the perspective of their healthcare system's normal state capabilities. Even though the capabilities to respond to crises are similar to one another in European countries, there are also major differences regarding the organization of healthcare services. These differences arise, for example, from perspectives of financing or organizing the provision of services publicly or privately [46]. The countries in southern Europe have a scarcer network of hospitals in relation to the population whereas the countries in northern Europe had more health centres per capita [52]. The higher number of health centres per capita might be explained by the smaller population density in the Nordics. However, neither of the indicators have straightforward correlation between healthcare expenditure or healthcare quality [46] [48].

Responsiveness of health care systems is studied from the perspectives of the theoretical expected preparedness and empirical findings from the COVID-19 crisis. The empirical findings are divided into two main focus areas within the services required by the COVID-19 patients: identification of the infected with diagnostics services (testing) and treating the infected requiring hospital services, with a focus on intensive care units.

As a response to the COVID-19 crisis, countries carried out diverse sets of different measures during the spring of 2020. For the purpose of clarifying the structure of this chapter, we have structured the different

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[49] World Health Organization, 2020. Global Health Expenditure Database. https://apps.who.int/nha/database/Select/Indicators/en

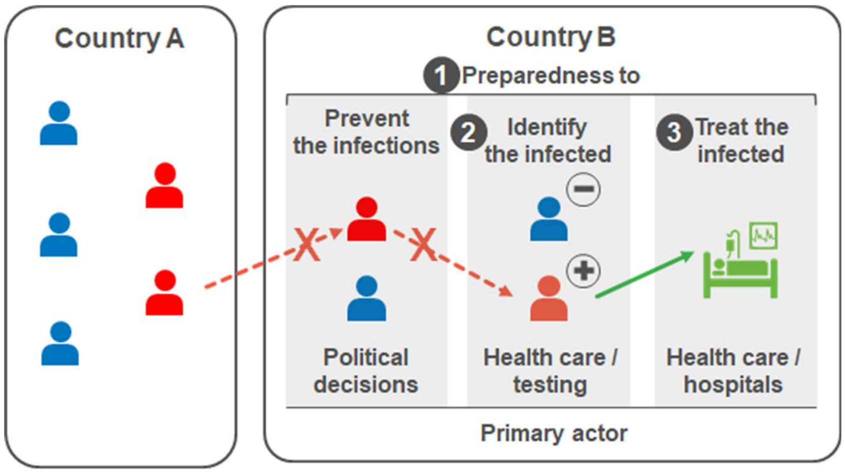
[50] The World Bank. World Development Indicators. https://databank.worldbank.org/reports.aspx?source=world-development-indicators

[51] Global Change Data Lab, 2020. Our World in Data. https://ourworldindata.org/grapher/healthcare-access-and-quality-index

[52] World Health Organization, 2020. The Global Health Observatory – Health Infrastructure. https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/health-infrastructure

measures into three categories: Measures to prevent the infections, measures to identify the infected and measures to treat the infected (see Figure 4). The categories are not completely separate from each other as, for example, testing can be a vital part of the prevention strategy of a country. However, this categorization supports us in analyzing the role of the healthcare system in the crisis.

Figure 4: Categorization of the measures to deal with COVID-19



In this chapter we analyze 1) the correlation of the expected preparedness and the empirical results from COVID-19, 2) the different testing strategies to identify the infected and the related COVID-19 mortality outcomes, and 3) the services required to treat the infected in hospitals. As the existing preparedness indices include very broad sets of government capabilities, the perspectives of the prevention, the identification and the treatment are assumed to be included in the indices. The identification and the treatment of the infected are also analyzed empirically as separate focus areas.

This chapter is structured so that the existing preparedness assessments, the testing and the hospital care are separate entities with separate introductions, methods and data and results. We consequently discuss our findings for the whole theme of responsiveness.

3.1 Existing preparedness assessments

In this focus area, we analyze how the health-related outcomes from the first wave compare to the expected preparedness measured by the existing preparedness indices on a country level.

3.1.1 Introduction

We examined four different indices which aim to rank countries based on preparedness or potential responsiveness to epidemics, pandemics or other healthcare crises. The four studied indices were GHSI

(Global Health Security Index)[53], EPI (Epidemic Preparedness Index)[54], INFORM Epidemic Risk Index[55] and IHR (International Health Regulations monitoring framework)[56].

All four indices aim to estimate the countries' capabilities to respond and function in case of unprecedented health issues:

- **GHSI** is designed to address the health security of a country. It is organized around 6 main themes: prevention, detection and reporting, rapid response, health system, compliance with international norms and risk environment.
- **EPI index** is developed to complement indices which focus merely on healthcare system capabilities and fail to consider other aspects which influence the pandemic outbreak. It consists of five main themes: economic resources, public health communications, infrastructure, public health systems and institutional capacity.
- **INFORM Epidemic Risk Index** on the other hand focuses on the risk of the nation to experience significant consequences in case of an epidemic instead of analysing the potential response.
- **IHR monitoring framework** has been developed to investigate the risks of countries and to encourage them to improve capabilities in the most problematic areas.

The purpose of each index and a short description of the main indicators is depicted in Table 6 below.

Table 5: Description of the healthcare system preparedness indices

	GHSI	**EPI**	**INFORM epidemic risk**	**IHR monitoring framework**
Purpose	GHSI assesses and benchmarks health security capabilities	The EPI measures a country's capacity to detect and respond to infectious disease events	Risk assessment tool for humanitarian crisis, disasters and epidemics	Set of legal instruments designed to ensure and improve the capacity to prevent, detect, assess, notify, and respond to public health risks and acute events
Indicators - theme	Prevention of the emergence, early detection and reporting, rapid response and mitigation of spread, sufficient and robust health sector, commitments to national improvements, overall risk environment	Public health infrastructure, physical infrastructure, institutional capacity, economic resources	Hazard and exposure, vulnerability, lack of coping capacity	Legislation, coordination, surveillance, response, preparedness, risk communication, human resources, laboratory, points of entry, zoonosis, food safety, chemical, radionuclear

[53] Nuclear Threat Initiative, Johns Hopkins Center for Health Security, The Economist Intelligence Unit, 2020. Global Health Security Index. https://www.ghsindex.org/
[54] Oppenheim, B., Gallivan, M., Madhav, N.K., Brown, N., Serhiyenko, V., Wolfe, N.D. and Ayscue, P., 2019. Assessing global preparedness for the next pandemic: development and application of an Epidemic Preparedness Index. *BMJ global health*, *4*(1).
[55] EU Science Hub, 2020. Inform epidemic risk index. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/inform-epidemic-risk-index-support-collaborative-risk-assessment-health-threats
[56] WHO, 2020. International Health Regulations monitoring framework. https://www.who.int/health-topics/international-health-regulations#tab=tab_1

Top performers	United States, UK, Netherland, Australia, Canada, Thailand, Scandinavia and South Korea	European countries, United States, Canada and Australia	Scandinavia, Benelux countries and UK, Singapore and Canada	North American countries, Singapore, Norway, Cuba, South Korea, Malaysia, Japan and China
Mediocre performers	Low and lower middle income countries	Low and lower middle income countries	Low and lower middle income countries	Low and lower middle income countries

The essential purpose of the indices is to describe the nations' capability to respond and survive in case of an epidemic or a pandemic. However, the indices are theoretical and have not been tested empirically as there has not been a major pandemic of the COVID-19's magnitude in the recent years. Thus, it is unclear whether the theoretical frameworks of the indices actually describe the real preparedness and can actually anticipate which countries succeed in treating a global pandemic.

3.1.2 Methods and data

To empirically study the relevance of the different indices, we compared countries ranking globally in indices to the number of COVID-19 deaths per capita. First, we analysed the index data and ranked all the countries based on the indicators. GHSI and INFORM had built-in rankings, in the case of the IHR we formed the ranking based on average of indicators scores (all indicators had values ranging from 0 to 100). We did not use the previously described EPI index in this comparison phase, as there was no raw data available and the model clustered countries into five groups which is not detailed enough for our ranking purposes. Finally, we performed a scatter plot analysis with the indices and COVID-19 mortality.

In Table 7 below, the top 40 performing countries of the indices are illustrated. The top 40 performing countries are here ranked by the sum of ranks from the three actual indices. In general, the countries seem to rank quite similarly within each index. However, some differences exist, e.g. with the United States, Japan, China, Luxembourg, Estonia and Saudi-Arabia.

Table 6: Ranking of countries based on three healthcare system preparedness indices

Rank	Continent	Country	GHSI	INFORM	IHR	Mean of ranks
1	Americas	Canada	5	14	1	7
2	Europe	Norway	16	2	3	7
3	Europe	Netherlands	3	8	17	9
4	Europe	Finland	10	1	20	10
5	Asia	Singapore	24	11	3	13
6	Oceania	Australia	4	27	12	14
7	Europe	Sweden	7	8	29	15
8	Asia	South Korea	9	29	8	16
9	Europe	Germany	14	14	20	16
10	Europe	United Kingdom	2	11	43	19
11	Europe	Denmark	8	4	46	19
12	Americas	United States	1	59	2	21
13	Europe	Switzerland	13	8	44	22
14	Oceania	New Zealand	35	20	12	22

15	Asia	Japan	21	48	9	26
16	Europe	Portugal	20	27	31	26
17	Asia	Malaysia	18	59	7	28
18	Europe	Czechia	42	14	34	30
19	Europe	Latvia	17	20	53	30
20	Europe	Spain	15	31	47	31
21	Europe	France	11	27	61	33
22	Europe	Belgium	19	21	67	36
23	Europe	Italy	31	41	36	36
24	Europe	Slovakia	52	35	27	38
25	Asia	United Arab Emirates	56	27	32	38
26	Europe	Slovenia	12	20	89	40
27	Asia	Saudi Arabia	47	71	6	41
28	Asia	Thailand	6	104	18	43
29	Europe	Lithuania	33	11	87	44
30	Europe	Luxembourg	67	8	56	44
31	Europe	Ireland	23	20	94	46
32	Asia	Cyprus	77	48	16	47
33	Asia	Mongolia	46	41	55	47
34	Europe	Russia	63	71	11	48
35	Americas	Chile	27	59	60	49
36	Asia	China	51	90	10	50
37	Europe	Estonia	29	4	121	51
38	Asia	Bahrain	88	31	37	52
39	Asia	Oman	73	41	42	52
40	Americas	Uruguay	81	27	48	52
Total number of countries included			181	179	180	177

In addition to the rankings, we used the COVID-19 mortality data to analyze the rankings against it. Mortality was chosen based on the reasoning discussed in chapter 2. Here, we applied the total COVID-19 deaths per million people. The data was downloaded 1 June 2020[57], so it reflects the COVID-19 situation in the spring of 2020. The time frame includes the first wave of the COVID-19 in most of the European countries. To improve the comparability of results, we analysed the total number of COVID-19 deaths 60 days after the first death. This approach balances the different stages of the pandemic and all studied countries are on the same line. Additionally, the approach excludes countries where not enough time has passed since the first death.

The final analyses were completed by plotting the mortality and index ranking datasets. First, we combined the mortality data and the index rankings for each country. Second, we created a scatter plot where the rankings were on y-axis and deaths per capita on x-axis. Third, to examine the significance of the correlation, we performed a Pearson correlation test and explored the resulting correlation coefficients and p-values.

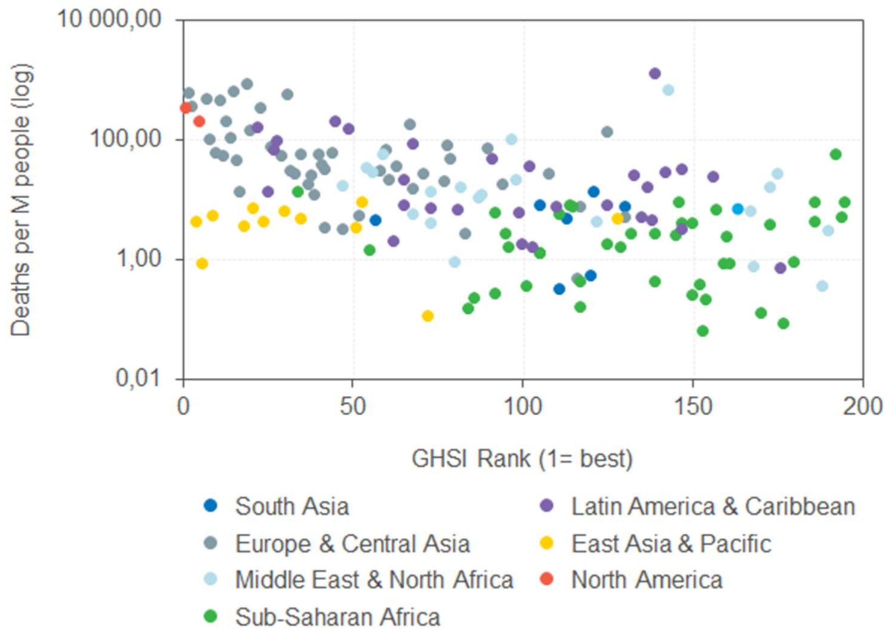
[57] Global Change Data Lab. 2020. Our world in data - Total cumulative number of covid-19 deaths per 1M people. https://ourworldindata.org/covid-deaths#what-is-the-total-number-of-confirmed-deaths

3.1.3 Results

In this section, we introduce the results of existing preparedness index analyses. First, we present the scatter plots of indices ranking against mortality. Second, we discuss the correlation between these two metrics.

The scatter plots for each index and mortality are presented in Figures 5-7 below. Different geographical areas of the countries are distinguished based on colour. With each index, the better ranked countries often have higher mortality rates than the countries with lower ranks. In addition, East Asia & Pacific deviates a bit from the pattern as the index ranks are comparable to e.g. European countries, but the mortality seems to be lower than in similar European countries. However, it is important to note that the data was extracted at the end of May and some of the regions had not peaked in terms of mortality at the time yet (e.g. Latin America).

Figure 5: GHSI index rank and deaths per 1M people



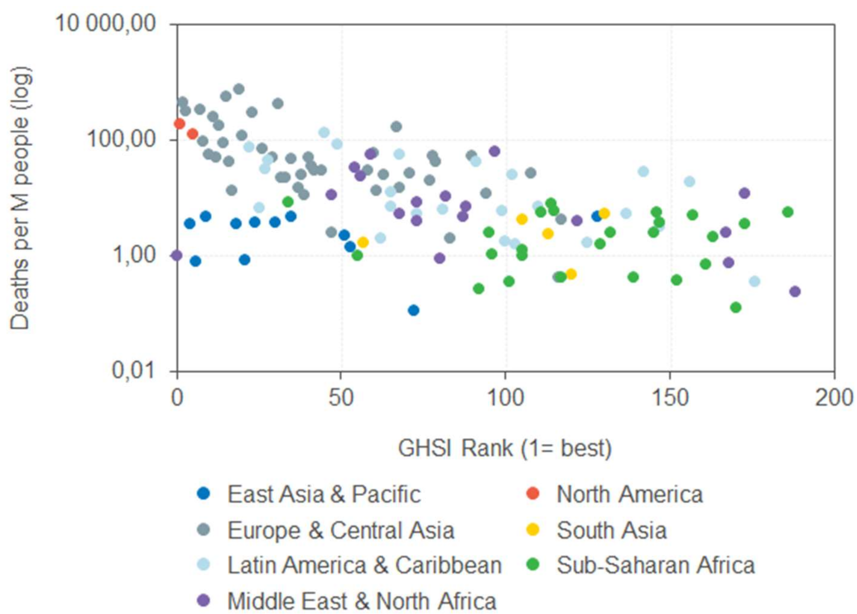


Figure 6: INFORM index rank and deaths per 1M people

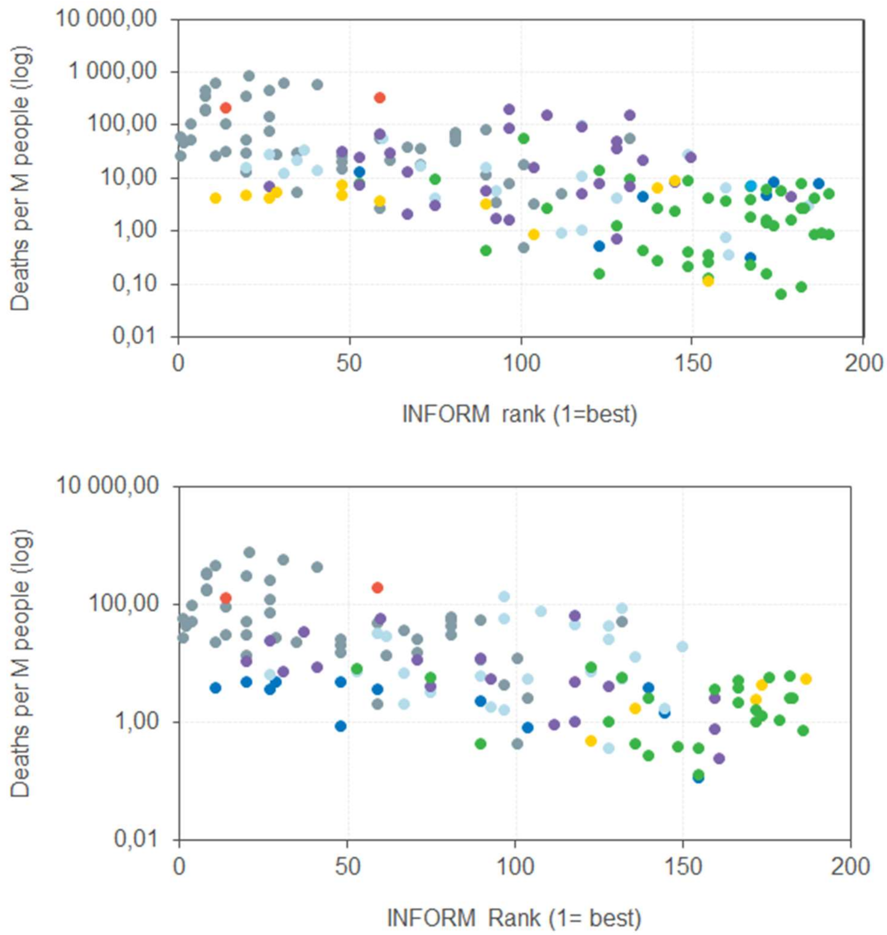
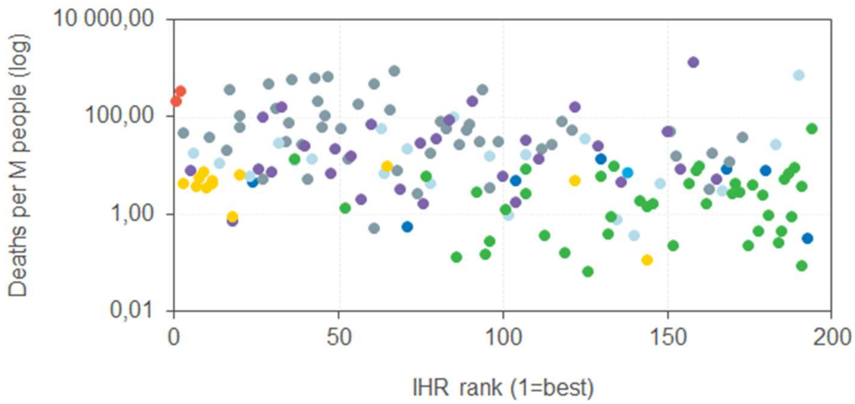
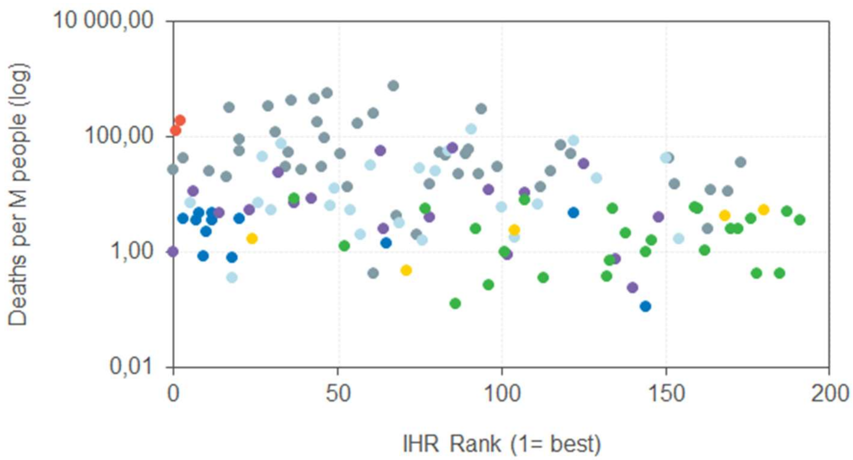


Figure 7: IHR index rank and deaths per 1M people





To test the hypothesis that better ranked countries also have higher mortality rates, we performed a Pearson correlation test (see Table 8). According to the test, both GHSI and INFORM indices had negative correlation with mortality ($p < 0.001$). IHR was also negatively correlated, but the p-value was above 0.1. As a summary, GHSI and INFORM indices had a statistically significant negative correlation with mortality.

Table 7: Correlation table for the preparedness indices

Significance at the 0.1 %, 1 % and 5 % level is indicated by ***, ** and *, respectively.

Preparedness Index	Correlation coefficient	P-value
GHSI	-0.407	< 0.001 ***
INFORM	-0.400	< 0.001 ***
IHR	-0.201	0.021 *

To summarize the results of this focus area, the health-related outcomes from the first wave were primarily negatively correlated with the expected preparedness measured by the existing preparedness indices on a country level. To simplify, the countries that were better well prepared in theory, suffered the worst outcomes in practice during the spring of 2020.

3.2 Diagnostics to identify the infected (testing)

In this focus area, we analyze what kind of diagnostic strategies can be recognized for diagnosing the potentially infected and how they are related to other interventions and the health-related outcomes on a country level.

3.2.1 Introduction

Diagnostics is arguably in a vital role in both containment and control strategies of pandemics[58]. Firstly, early detection of the disease and its spread helps to set other crucial measures which aim to contain the virus[59]. Further, early detection enables targeted quarantines which help to control the spread[60].

The benefits of diagnostics are enhanced if it is combined together with contact tracing and targeted quarantines. Rapid contact tracing after a positive test result can lead to significant decrease in the R-rate[61]. This accelerates the control and contamination of the virus. After tracing and testing the potentially exposed people, targeted quarantines help to limit the transmission further[62]. However, quarantines can be politically sensitive decisions, as they limit the freedom of people.

In case of COVID-19, countries seem to have adopted several strategies regarding testing, tracing and targeted quarantines. For instance, Iceland chose to test even asymptomatic people already in the early stages of the pandemic and has additionally managed to trace around 95 % of the transmissions[63]. Similarly, Taiwan managed to take control of the disease early on with the help of comprehensive testing, tracing and targeted quarantines[64]. Additionally, Vietnam responded rapidly to the threat of COVID-19 and issued mandatory quarantines for inbound travellers[65]. In comparison, the United States had problems in ramping up the testing capacity in the early stages of the pandemic[66].

There have been several different testing strategies around the globe during the COVID-19 pandemic. Moreover, many countries have altered their strategies during the progress of the epidemic[67]. The purpose of this chapter is to assess the countries' behaviour regarding testing and analyze whether the countries with different overall strategies have had different outcomes in terms of pandemic spread. In this study, the potential relationships between testing and mortality are explored together with other COVID-19 restrictive measures.

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[58] Kelly-Cirino, C.D., Nkengasong, J., Kettler, H., Tongio, I., Gay-Andrieu, F., Escadafal, C., Piot, P., Peeling, R.W., Gadde, R. and Boehme, C., 2019. Importance of diagnostics in epidemic and pandemic preparedness. *BMJ global health*, *4*(Suppl 2), p.e001179.

[59] Perkins, M.D., Dye, C., Balasegaram, M., Bréchot, C., Mombouli, J.V., Røttingen, J.A., Tanner, M. and Boehme, C.C., 2017. Diagnostic preparedness for infectious disease outbreaks. *The Lancet*, *390*(10108), pp.2211-2214.

[60] Rosenthal, P.J., 2020. The Importance of Diagnostic Testing during a Viral Pandemic: Early Lessons from Novel Coronavirus Disease (COVID-19). *The American Journal of Tropical Medicine and Hygiene*, *102*(5), p.915.

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[62] Tognotti, E., 2013. Lessons from the history of quarantine, from plague to influenza A. *Emerging infectious diseases*, *19*(2), p.254.

[63] John Hopkins Centre for Health Security. 2020. Lessons from Iceland. https://www.outbreakobservatory.org/outbreakthursday-1/4/16/2020/the-success-of-iceland

[64] John Hopkins Centre for Health Security. 2020. Taiwan's Covid-19 response. https://www.outbreakobservatory.org/outbreakthursday-1/4/30/2020/taiwans-covid-19-response

[65] John Hopkins Centre for Health Security. 2020. Zero covid-19 deaths in Vietnam. https://www.outbreakobservatory.org/outbreakthursday-1/7/9/2020/zero-covid-19-deaths-in-vietnam

[66] John Hopkins Centre for Health Security. 2020. An Overview of US Sars-Cov-2 testing and Surveillance. https://www.outbreakobservatory.org/outbreakthursday-1/3/5/2020/an-overview-of-us-sars-cov-2-testing-and-surveillance

[67] Ministry of Social Affairs and Health in Finland, *Krista Kiuru: Testing for coronavirus to be increased considerably in Finland.* 9 April 2020. https://valtioneuvosto.fi/en/-/1271139/krista-kiuru-suomi-lisaa-koronavirustestausta-merkittavasti

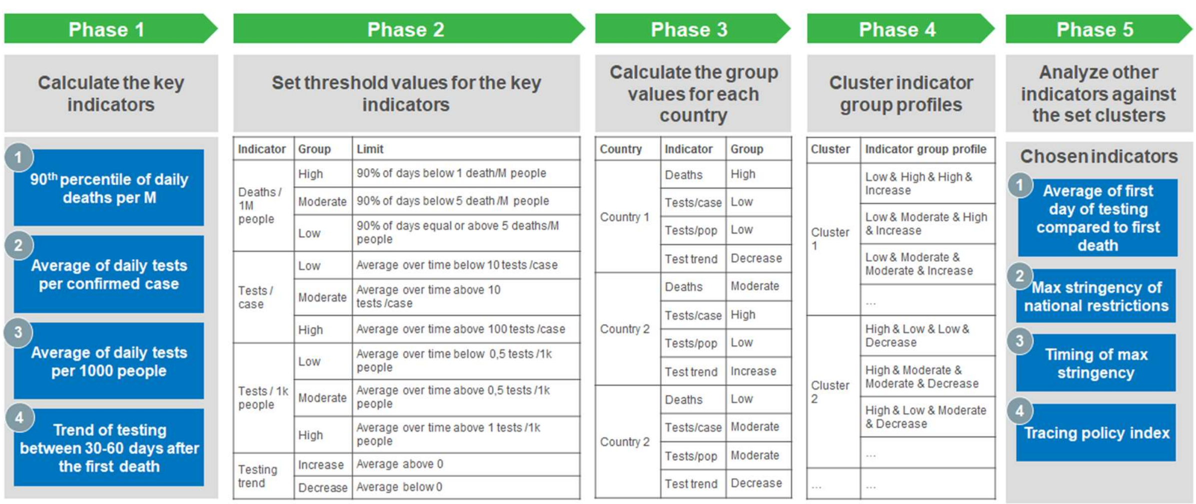
3.2.2 Methods and data

In this section, we describe the data and methods applied to analyze the different testing strategies and their outcomes. First, we introduce the raw data we used. Second, we describe the analysis process. Third, we discuss the division of countries into clusters based on the data. Finally, we introduce the additional analyses we have performed to understand other common factors between the formed clusters.

We used three main raw data sources to cluster the countries. All datasets were provided by Our World in Data[68] and consisted of daily data, which enabled the analysis of the evolution of strategies and outcomes. The data was downloaded 25 May 2020, and thus the analyses reflect the COVID-19 situation in the spring of 2020. The first indicator we applied was tests per confirmed case. Our hypothesis was that if the tests per confirmed case ratio is high, tests are more widely accessible. On the other hand, if the ratio is low, the hypothesis is that only those with more difficult symptoms or critical professions get tested. The second metric was the daily tests per 1 000 people. The aim was to determine whether testing was widely used in general regardless of the number of cases. The third and final indicator was daily deaths per million people. The objective of this metric is to be able to address the outcomes of COVID-19. The reasoning behind choosing this indicator and assessing its reliability has been discussed in chapter 2 more thoroughly.

After obtaining and combining the data, the next task was to form the clusters of countries. First, we created four key indicators (see phase 1 in Figure 8). The purpose was to summarize the daily data in a way that one country would only have four key indicators. These were the 90th percentile of daily deaths per 1M people, average tests per positive test result, average tests per 1k people and tests/positive result trend during 30-60 days after the first death. The purpose of the 90th percentile of daily deaths is to both capture the death peak and exclude outliers from the data. We want to analyse the death peak instead of total number of deaths as this mitigates the differences between countries in COVID-19 stages during the spring. Further, to analyze the peak in deaths, we take the 10 % of days with most deaths instead of maximum daily mortality. This still captures the peak mortality, but is less vulnerable to data errors. The reasoning behind these key indicators is described in Table 9 below.

Figure 8: Illustration of the analysis process



[68] Global Change Data Lab. 2020. Our World in Data - Coronavirus Pandemic datasets. https://ourworldindata.org/grapher/tests-per-confirmed-case-daily-smoothed

Table 8: Summarizing key indicators

Key indicator	Base indicator	Reasoning
90th percentile of daily deaths per 1M people	Deaths per M people	To exclude single outliers. These may be due to inconsistencies in recording the deaths from different sources
Average of daily tests per confirmed case	Tests per confirmed case	Depicts the general situation of testing capacity - if the ratio is high, it most likely means accessible diagnostics and vice versa
Average of daily tests per 1k people	Tests per 1k people	Describes the overall extent of testing despite the number of positive cases
Trend of testing between 30-60 days after the first death	Tests per confirmed case	Increasing tests per case ratio describes the reduction of positive cases or the increase of testing capacity and vice versa

The second phase was to determine the threshold values for the key indicators (see phase 2 in Figure 8). For each key indicator, we set limits in order to classify the countries into two or three categories. The limits are based on our qualitative assessment. The aim was to form as homogeneous groups as possible based on our best knowledge regarding the responses to the COVID-19 crisis. The number of groups was not determined beforehand, but the aim was to have a reasonable number of clusters, e.g. below 5. Finally, we ended up having three categories for the first three indicators and 2 categories for the last one.

In phase three of the analysis, the purpose was to determine to which group a certain country belonged to within each indicator. This was done by comparing the country's values against the limits and thus assigning a group value for each country and each indicator. For the visualization of this process step, see phase 3 in Figure 8.

After phase three, each country had a group value for each indicator. As a result, we had dozens of country profiles consisting of different group value combinations (e.g. significant number of deaths, moderate testing per case, low number of tests per capita and increasing number of tests per case). The purpose of phase four (see Figure 8) was to bundle these profiles into a more limited number of clusters. Again, the clustering was based on qualitative assessment about which profiles resemble each other enough. As a result, we were able to form six clusters and one cluster for countries lacking data.

The final step in our analysis was to examine whether the categories had other common factors apart from testing and mortality (see phase 5 in Figure 8). Again, we utilized data from Our World in Data[69]. Here, we investigated the correlation between clusters and the beginning of testing, maximum stringency index, the timing of maximum stringency index and tracing policies. Here, stringency refers to the magnitude of the national restrictions. The data is shortly explained in Table 10 below.

[69] Global Change Data Lab. 2020. Our World in Data - Coronavirus Pandemic datasets. https://ourworldindata.org/grapher/tests-per-confirmed-case-daily-smoothed

Table 9: Additional metrics used to compare testing clusters

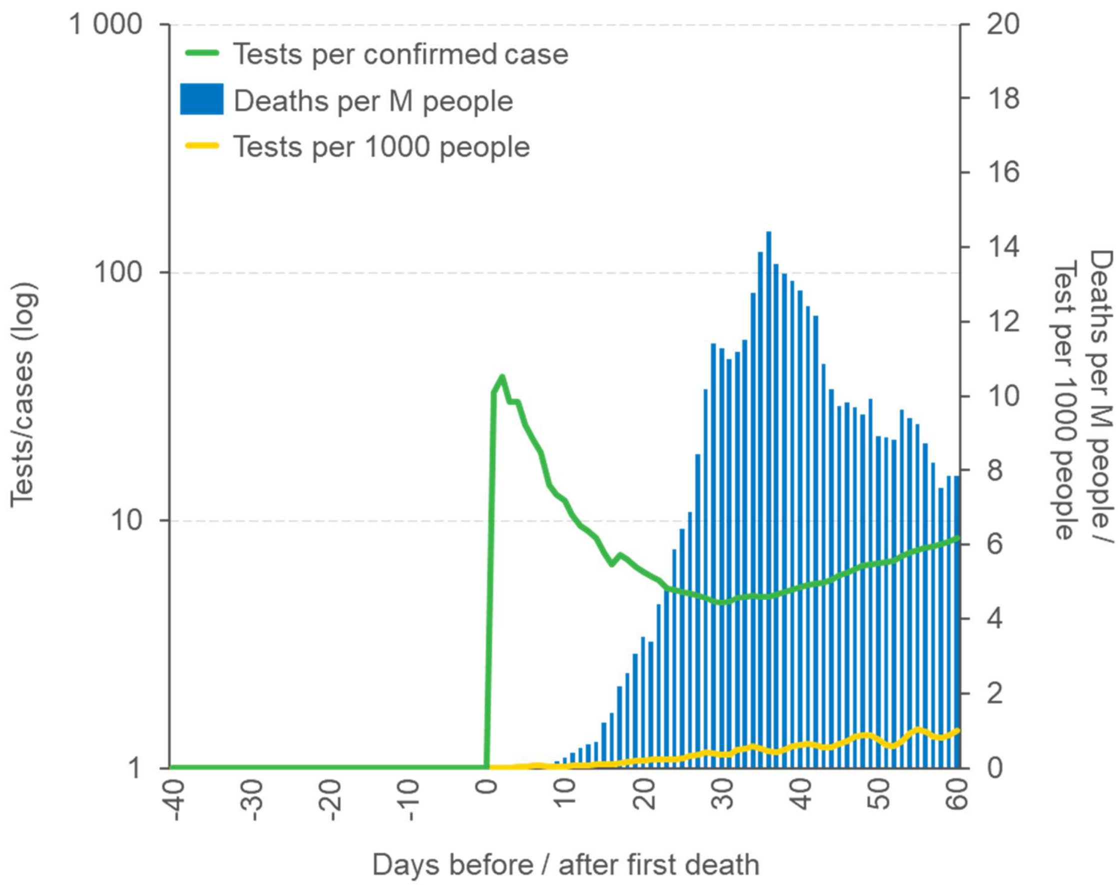
Indicator	Description	Data type	Purpose
Beginning of testing	The day of first test compared to the day of first death	Days compared to first death	If the cluster generally tests more, have the countries also begun the testing earlier?
Max of stringency index	Describes the magnitude of national restrictions	Index, continuous values between 0 and 100 (100=max)	Is the comprehensive testing related to heavy national restrictions as well?
Timing of max stringency	The day of maximum stringency compared to the day of first death	Days compared to first death	Differs the timing of more stringent restrictions between the clusters?
Tracing policy	Describes the policy limits for tracing, e.g. are all cases traces or only some	Index, categorical values between 0 and 2 (0=no tracing, 1= limited tracing, 2=comprehensive tracing)	Analyse the relationship between testing and tracing

3.2.3 Results

In this section, we introduce the results of analyses regarding testing strategies. First, we demonstrate an example of the visualization of the data. Second, we describe the clustering process and its results. Third, we illustrate the cross-analysis of clusters against other key indicators.

In Figure 9 below, one example country, Italy, is shown in terms of tests per confirmed case, deaths per 1M people and tests per 1 000 people. Here, the left y-axis stands for logarithmic tests per case and the right y-axis for deaths per 1M people and tests per 1 000 people. The x-axis is the days before or after the first COVID-19 death.

Figure 9: Tests per confirmed case, deaths per 1M people and tests per 1 000 people in Italy



As mentioned in the methodology section, we set limits in order to have categorical values for each indicator. The limits for each category were numerical and are presented in Table 11 below.

Table 10: Categorization of indicators and the limits for the categories

Original indicator	Key indicator	Group value	Limit
Deaths / 1M people	90th percentile of daily deaths per 1M people	Few deaths per capita	90 % of days below 1 death / 1M people
		Moderate number of deaths per capita	90 % of days below 5 deaths / 1M people
		Significant number of deaths per capita	90 % of days equal or above 5 deaths / 1M people
Tests / confirmed case	Average of daily tests per confirmed case	Few tests per case	Average below 10 tests / case
		Moderate number of tests per case	Average above 10 tests / case
		Significant number of tests per case	Average above 100 tests / case

Tests / 1k people	Average of daily tests per 1k people	Few tests per capita	Average below 0.5 tests / 1 000 people
		Moderate number of tests per capita	Average above 0.5 tests / 1 000 people
		Significant number of tests per capita	Average above 1 tests / 1 000 people
Tests / confirmed case	Trend of testing between 30-60 days after the first death	Increasing number of tests per case	During the last 30 days, the average of daily change is above 0
		Decreasing number of tests per case	During the last 30 days, the average of daily change is below 0

The next phase was to assign the above listed group values for each country. As an example, we describe the whole process for one country, Finland. In Finland, in 90 % of days the mortality rate was below 5 deaths per 1M people, thus the category for Finland would be a moderate number of deaths. As for the tests per confirmed case ratio, Finland was above 10 but below 100 on average, which places Finland in the moderate category. In the tests per capita, the average for Finland was below the limit of 0.5 and thus Finland received the category value few tests per capita. Finally, the testing trend value was positive, placing Finland in the increasing testing category. Thus, the final category for Finland would be "Moderate & Moderate & Few & Increasing". The key indicator values for Finland are presented in Table 12 below.

Table 11: Key indicator values and categories for Finland

Country	Key indicator	Key indicator value	Category value
Finland	90th percentile of daily deaths per 1M people	1.083	**Moderate** number of deaths per capita
	Average of daily tests per confirmed case	30.377	**Moderate** number of tests per case
	Average of daily tests per 1k people	0.280	**Few** tests per capita
	Trend of testing between 30-60 days after the first death	0.012	**Increasing** number of tests per case

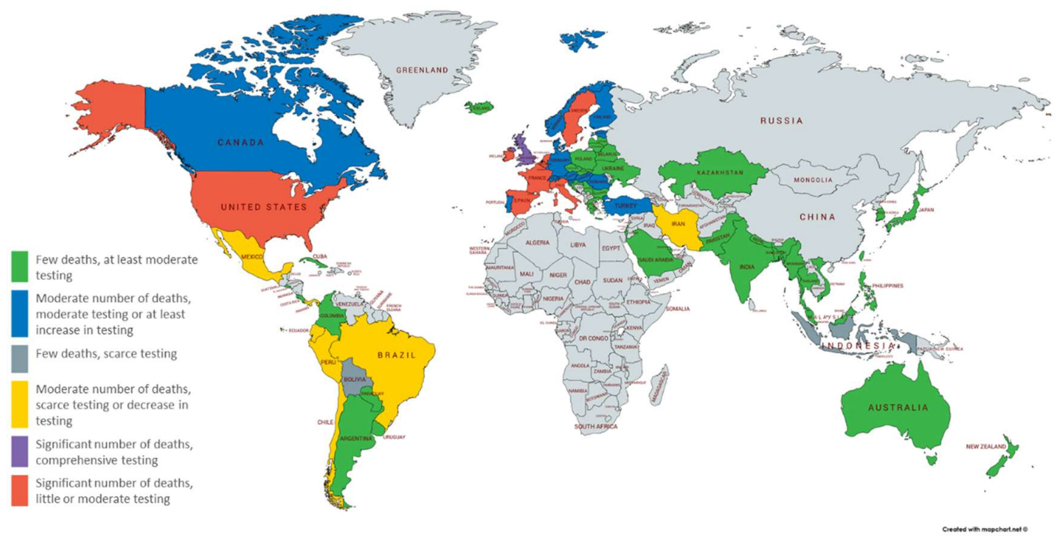
The next phase was to form the clusters of countries. As mentioned, numerous unique country profiles were identified, and thus our data required further clustering. The aim was to group countries with similar category values into the same cluster, and to have numerical criteria for each cluster. Table 13 below demonstrates the final clustering criteria. Based on the clustering criteria, Finland belongs to the Cluster 2, as the death rate is below 5, tests per case is above 10 and even though the test per population is below 0.5, the rate of tests per case is increasing.

Table 12: Cluster criteria

Cluster	Cluster description	Cluster criteria
Cluster 1	Few deaths, at least moderate testing	● 90 % of days below 1 death / 1M people ● Average number of tests per confirmed case over 10
Cluster 2	Moderate number of deaths, moderate testing or at least increase in testing	● 90 % of days below 5 deaths / 1M people ● Average number of tests per confirmed case over 10 ● If the average number of tests per population is below 0.5, the average number of tests per confirmed case has increased
Cluster 3	Few deaths, scarce testing	● 90 % of days below 1 deaths / 1M people ● Average number of tests per confirmed case below 10 ● Average number of tests per population below 0.5
Cluster 4	Moderate number of deaths, scarce testing or decrease in testing	● 90 % of days below 5 deaths / 1M people ● Average number of tests per confirmed case below 100 ● Average number of tests per population below 0.5 ● If the average number of tests per confirmed case is above 10, tests per confirmed case has decreased over the last 20 days
Cluster 5	Significant number of deaths, comprehensive testing	● 90 % of days over 5 deaths / 1M people ● Average number of tests per confirmed case over 100 ● Tests per population average per day below 0.5
Cluster 6	Significant number of deaths, little or moderate testing	● 90 % of days over 5 deaths / 1M people ● Average number of tests per confirmed case below 100

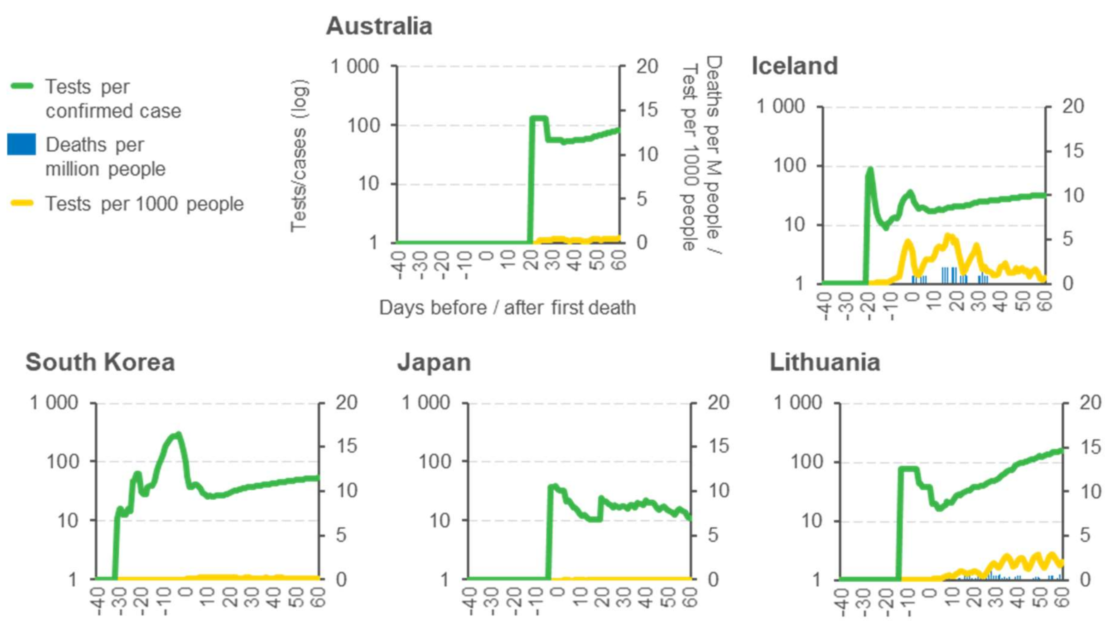
As a result, each country with sufficient data was assigned into a cluster. A world map with coloured country profiles is presented in Figure 10 below. Green represents Cluster 1, blue Cluster 2, dark grey Cluster 3, yellow Cluster 4, violet Cluster 5 and red Cluster 6. Countries with not enough data are coloured with light grey.

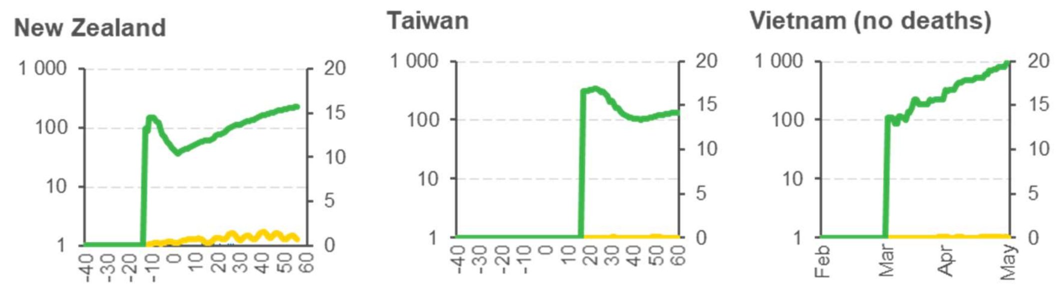
Figure 10: Map of clusters based on testing and mortality



Cluster 1 (Few deaths, at least moderate testing) includes countries such as Iceland, Lithuania, Japan, South Korea, New Zealand and Australia. The key indicators for some Cluster 1 countries are presented in Figures 11 below. As a reminder, this reflects the situation by the end of May 2020.

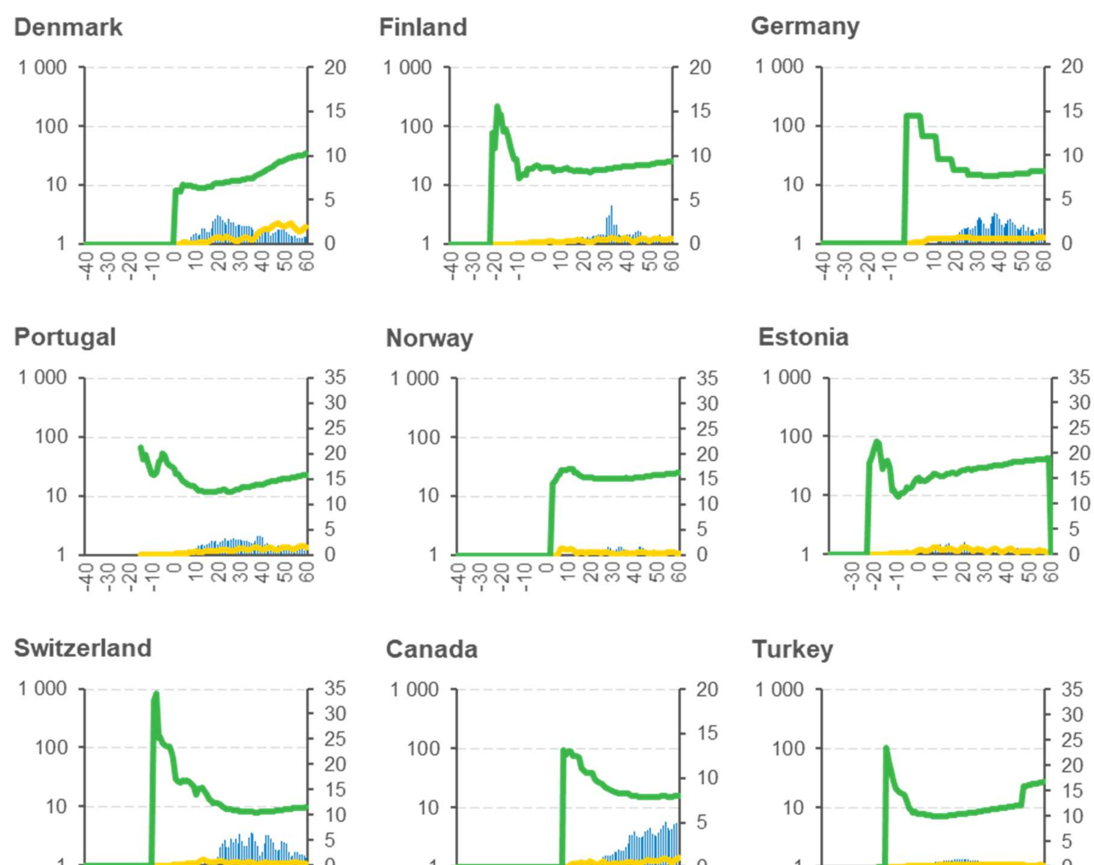
Figure 11: Illustrations of testing and mortality for Cluster 1 countries





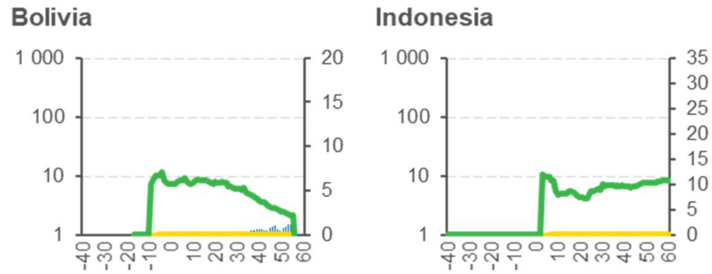
Cluster 2 (Moderate number of deaths, moderate testing or at least increase in testing) includes e.g. Norway, Finland, Germany, Switzerland, Portugal and Canada. The key indicators for some Cluster 2 countries are shown in Figures 12 below.

Figure 12: Illustrations of testing and mortality for Cluster 2 countries



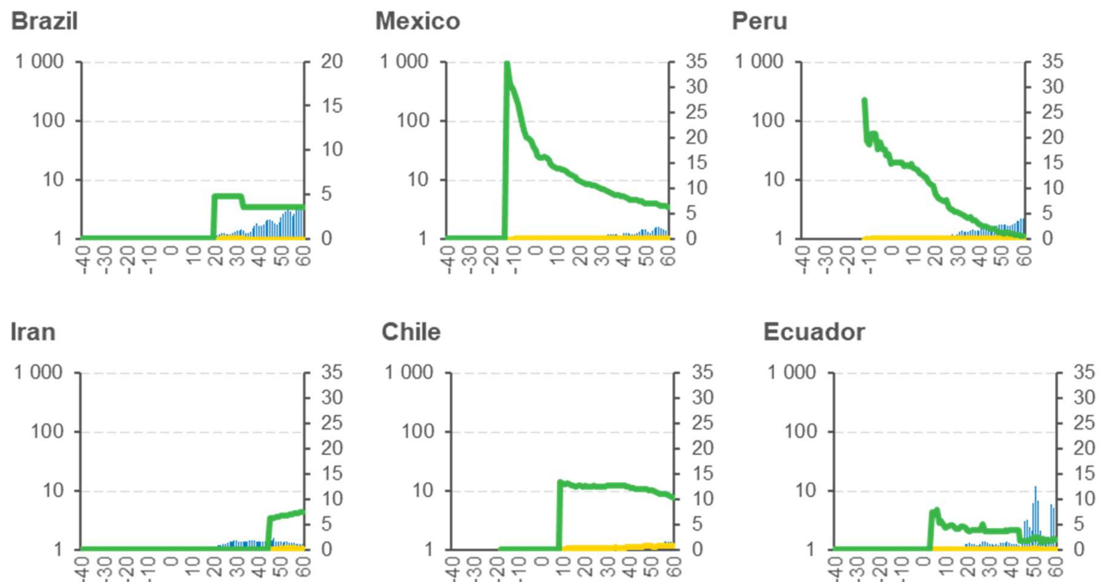
Cluster 3 (Few deaths, scarce testing) includes only Bolivia and Indonesia. The key indicators for these countries are presented in Figures 13 below.

Figure 13: Illustrations of testing and mortality for Cluster 3 countries



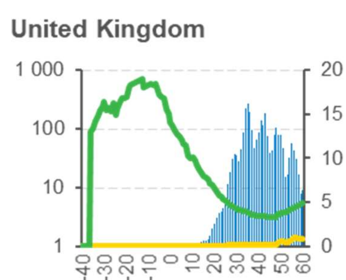
Cluster 4 (Moderate number of deaths, scarce testing or decrease in testing) comprises countries like Brazil, Mexico, Peru and Iran. The key indicators for some of the Cluster 4 countries are presented in Figures 14 below.

Figure 14: Illustrations of testing and mortality for Cluster 4 countries



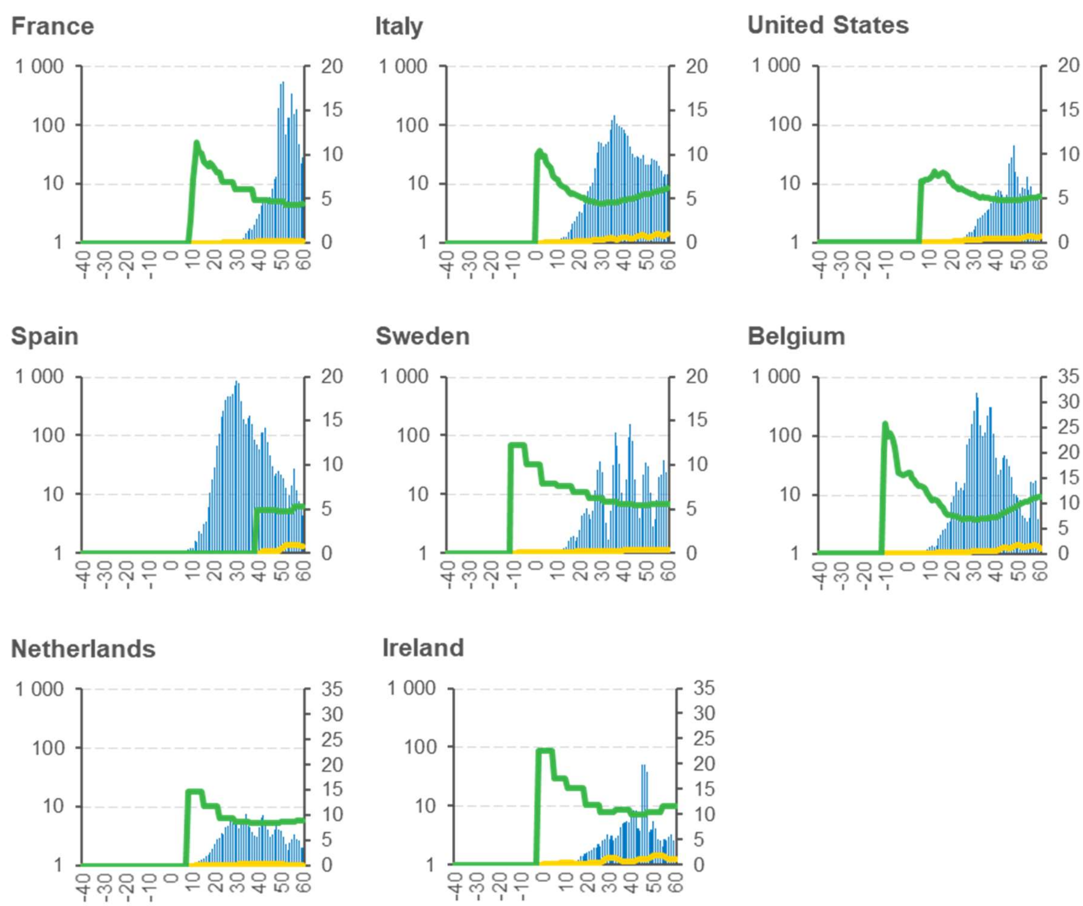
Cluster 5 (Significant number of deaths, comprehensive testing) includes only Great Britain. The indicators for the UK are presented in Figure 15 below.

Figure 15: Illustrations of testing and mortality for Cluster 5 countries



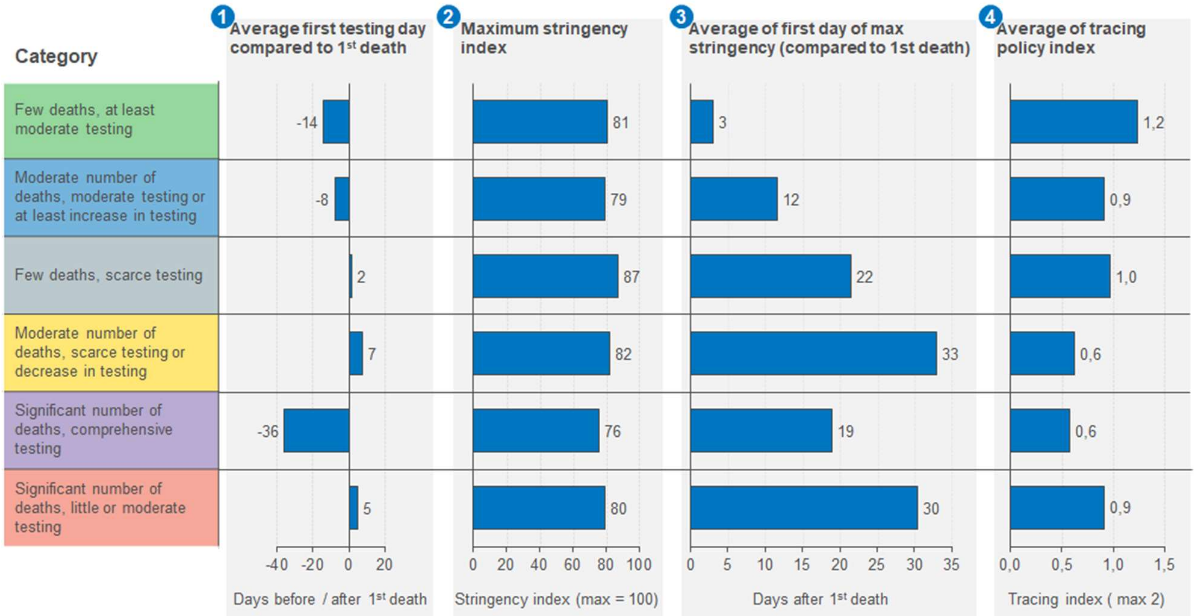
Finally, **Cluster 6** (Significant number of deaths, little or moderate testing) consists of countries such as the United States, Sweden, Italy, Spain, France and Ireland. The key indicators for some of the Cluster 6 countries are presented in Figures 16 below.

Figure 16: Illustrations of testing and mortality for Cluster 6 countries



The final stage of our testing analysis was cross-checking the clusters with additional indicators. The results are illustrated in the first graph in Figure 17.

Figure 17: Results of additional metric analyses for each cluster



First, we explored the average beginning date of testing in relation to the day of first COVID-19 death. Clusters with less deaths and more comprehensive testing (clusters 1-2) had started the testing earlier than the other clusters. Only exception is the cluster 5 (including only the UK), where the testing had begun very early. However, the UK actually seemed to change the testing strategy as can be seen in Figure 20 above, where the tests per confirmed case drops significantly after the first death.

The second and third additional indicators are related to the government issued restrictions. The average of maximum stringency indices are quite similar across the clusters. However, there is variation in timing of the restrictions. The clusters with less deaths and more testing issued the restriction policies earlier than the other clusters on average. Finally, the fourth graph illustrates the differences in tracing policy. Here, the cluster with the least deaths and very comprehensive testing had stricter tracing policies. The clusters 4 and 5, on the other hand, had less strict tracing policies.

To summarize the results of this focus area, we recognized a wide variety of numerically different strategies for diagnosing the potentially infected and categorized them into six different clusters. There were also patterns related to other interventions between the different clusters. The cluster with few deaths and at least moderate testing was associated with early start of testing, early increase in the stringency index and high tracing policy index. On the other hand, most of the countries with significant amounts of deaths were associated with little or moderate testing, late first testing day and late increase in the stringency index with the UK being one exception.

3.3 Hospital intensive care units

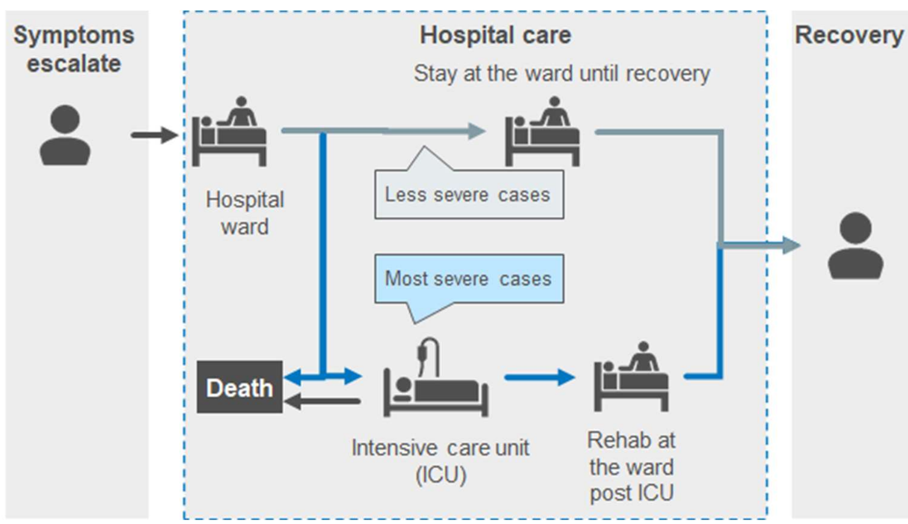
In this focus area, we analyse if there was sufficient healthcare service capacity to treat the infected who required the hospital services in different phases of the crisis on a country and regional level.

3.3.1 Introduction

As there is no direct treatment to cure the COVID-19 disease, the COVID-19 patients with a severe clinical picture may require secondary care services that support patients' own body organ systems and keep the patients alive so that the patients' immune systems get more time to activate and start fighting against the virus.[70] In fact, most of the infected have only less severe symptoms or are asymptomatic and do not require any kind of treatment by the healthcare system[71] [72].

The general COVID-19 patient's process in hospitals is quite straightforward. When the symptoms of an infected person escalate, the patient is admitted to a hospital ward. If the symptoms do not escalate further, the patient recovers in the ward care until the patient is discharged from the hospital. If the symptoms escalate further while at the ward care and the patient is evaluated to benefit from intensive care, the patient is transferred to an intensive care unit (ICU). Patients may also have severe enough symptoms outside the hospital to be taken directly to the ICU when admitted to the hospital. If there is progress with the patient's recovery at the ICU and the symptoms ease, the patients in the ICU are transferred back to the ward care for a period of rehabilitation before being discharged. The symptoms can also escalate into a stage that causes the death of the patient during either the stay at the ward or at the ICU.[73] The general COVID-19 patient's process at the hospital is described visually in Figure 18.

Figure 18: The general COVID-19 patient's process at the hospital



The general patient process indicates that the hospital service capacities the COVID-19 patients require are the capacity at the ward care and the capacity at the ICU. The correlation between ward care peak capacity utilization and ICU capacity peak utilization varied in different example countries where reliable national COVID-19 hospitalization data on both ward patients and ICU patients, as well as national long-term ward

[70] The Guardian. *Intensive care units: 'The point is to keep people alive'*. 7 April 2020. https://www.theguardian.com/world/2020/apr/07/coronavirus-uk-intensive-care-units-the-point-is-to-keep-people-alive

[71] Day, Michael. Covid-19: four fifths of cases are asymptomatic, China figures indicate. 2020.

[72] Mizumoto, Kenji, et al. "Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020." Eurosurveillance 25.10 (2020): 2000180.

[73] Centers for Disease Control and Prevention. Interim Clinical Guidance for Management of Patients with Confirmed Coronavirus Disease (COVID-19). 30 June 2020. https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-guidance-management-patients.html

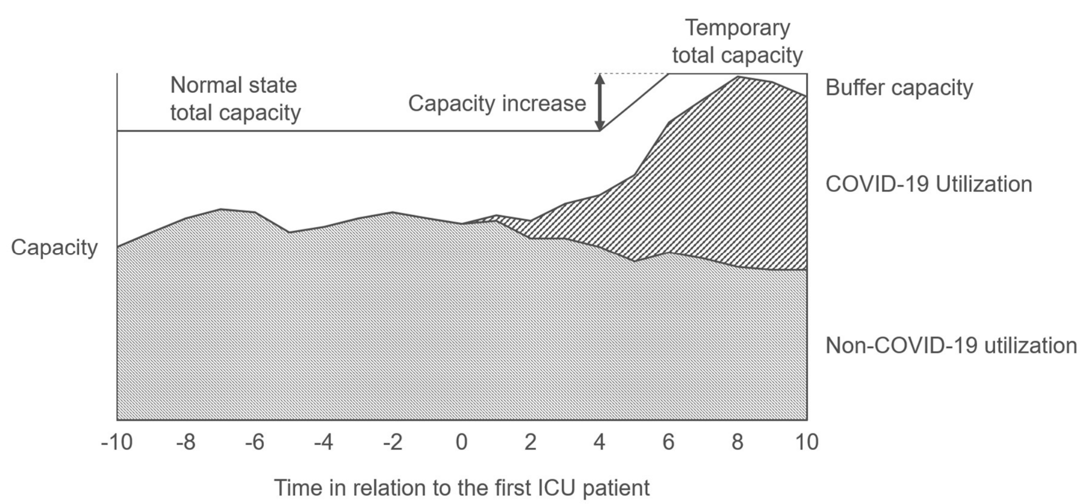
and ICU capacity was available (see Table 14). However, as illustrated also in our data sample, the ICU capacity utilization rates have been remarkably higher than the ward care capacity utilization rates, and the ICU capacity has proved to be the critical bottleneck service in the treatment of the COVID-19 patients[74]. Thus, we focus our capacity analysis on the ICU capacity.

Table 13: Ward and ICU capacity and utilization

	Finland	Austria	France
Ward patients at peak	162 (9 April 2020)	~900 (31 March 2020)	~25 000 (14 April 2020)
Ward capacity	~24 000	~66 000	~435 000
Ward utilization	< 1 %	~2 %	~7 %
ICU patients at peak	83 (7 April 2020)	267 (8 April 2020)	7 019 (8 April 2020)
Normal state ICU capacity	~350	~1 900	~7 800
ICU utilization	24 %	14 %	89 %
ICU patients per ward patients at peaks	0.51	0.24	0.22

Estimating the utilization of the ICU capacity in different countries and regions during the COVID-19 crisis in the spring of 2020 turned out challenging. Data regarding the utilization of COVID-19 patients and normal state total capacity was often available. However, data regarding the temporary capacity increases, non-COVID-19 utilization or buffer capacities was not available. Different elements of ICU utilization during the COVID-19 crisis are also illustrated in Figure 19 below.

Figure 19: Illustration of the dynamics of ICU utilization during the COVID-19 crisis



[74] Rodriguez-Llanes JM, Castro Delgado R, Pedersen MG, Arcos González P & Meneghini M. *Confronting COVID-19: Surging critical care capacity in Italy*. [Preprint]. Bull World Health Organ. E-pub: 6 April 2020. doi: http://dx.doi.org/10.2471/BLT.20.257766

The normal state ICU capacity per population varies across countries[75]. The ICU units consist generally of the beds and the equipment related to each bed and the personnel to treat the patients. During the normal state, the number of ICU units and the capacity of the specific units is estimated as the number of beds. This normal state capacity can be considered as fixed in the short term.

During the crisis there were **temporary increases in the supply of ICU capacity**[76] [77]. Data regarding this increase is, however, very difficult to take into account due to several reasons. Firstly, the data regarding the current total capacity or added capacity proved to be difficult to obtain. Secondly, the situation seemed to change rapidly so cross-sectional data from single points in time would not be useful for our purposes. Thirdly, the definition of capacity became somewhat flexible. In addition to the normal state ICU units, there was 1) already utilized temporary capacity, 2) ramped up spare capacity with no utilization yet and 3) the planned extra capacity above the already ramped-up units. When capacities were increased and communicated to the public during the crisis, there was often no way to be sure what sorts of capacity it included.

The ICU utilization by the COVID-19 patients was mainly driven by the pace of the spread of the virus, which can be seen especially in different statistical estimates for the ICU capacity demand, which often assume the relation between the number of infected and the number of patients requiring ICU treatment as a constant[78]. However, there has been also progress in adjusting the clinical admission criteria into the ICU[79] and adjusting the clinical treatment to the patients[80] which may have also affected the length of stay in the ICU and thus the capacity demand.

The ICU capacity utilization related to other than COVID-19 patients may have differed from the normal state during the COVID-19 crisis. At the hospitals some elective operations were scaled down in order to ensure sufficient capacity and resources for the COVID-19 patients[81]. Also, the patients themselves have been reluctant to seek care even in emergencies.[82]

The hospital units are also designed to have **buffer capacity**. For example, in Finland the ICU units have a 60-70 % utilization rate on average according to the chairman of the intensive care association in Finland[83]. This suggests that a buffer capacity of 30-40 % is in reserve for the demand peaks. The relative and absolute sizes of these buffer capacities have not been directly taken into account in the analyses due to their poor availability. However, there is little reason to suspect that countries especially with similar capacities relative to their population should have completely different utilization rates.

In conclusion, the demand of the ICU capacity, the supply of ICU capacity and the balance between these two were constantly changing during the COVID-19 crisis in the spring of 2020. As a result, we are bound to

[75] A. Rhodes, P. Ferdinande, H. Flaatten, B. Guidet, P. G. Metnitz & R. P. Moreno. The variability of critical care bed numbers in Europe. Intensive Care Medicine volume 38, pages 1647–1653(2012)
[76] The Local. The biggest challenge of our time': How Sweden doubled intensive care capacity amid Covid-19 pandemic. 23 June 2020. https://www.thelocal.com/20200623/how-sweden-doubled-intensive-care-capacity-to-treat-coronavirus-patients
[77] Toikkanen U, Keränen T. "Tuhat tehohoitopaikkaa saadaan kasaan". Finnish Medical Journal 13/2020 edition 75 p. 795
[78] Finnish Institute for Health and Welfare. *Parameters of corona modelling. 7* May 2020. https://thl.fi/documents/533963/5860112/Parametrin-arvot-THL-070520.pdf/20cbe6af-9f0e-3575-426b-15cf5e9a7908?t=1588916468977
[79] Azoulay, É., Beloucif, S., Guidet, B. et al. Admission decisions to intensive care units in the context of the major COVID-19 outbreak: local guidance from the COVID-19 Paris-region area. Crit Care 24, 293 (2020). https://doi.org/10.1186/s13054-020-03021-2
[80] Phua J, Weng L, Ling L, et al. Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations. Lancet Respir Med. 2020; 8: 506-517.
[81] Jain A.,Dai T.,Bibee K. and Myers C.G. Covid-19 Created an Elective Surgery Backlog. How Can Hospitals Get Back on Track?. Harvard business review. https://hbr.org/2020/08/covid-19-created-an-elective-surgery-backlog-how-can-hospitals-get-back-on-track
[82] Wong L., Hawkins J., Langness S., Murrell K., Iris P., Sammann A. Where Are All the Patients? Addressing Covid-19 Fear to Encourage Sick Patients to Seek Emergency Care. NECM Catalyst. https://catalyst.nejm.org/doi/full/10.1056/CAT.20.0193
[83] MTV news. Kaikilla Suomen teho-osastoilla loppuvat joskus paikat – hoito silti korkeatasoista. 29 July 2018. https://www.mtvuutiset.fi/artikkeli/kaikilla-suomen-teho-osastoilla-loppuvat-joskus-paikat-suomen-hoito-silti-korkeatasoista/7011450#gs.e0yhat

analyze the balance of COVID-19 patients' utilization of the ICUs compared to the normal state capacities in different areas. Thus, the end results of this focus area will not be exact figures of utilization rates but rather the magnitudes of the different utilization situations in relation to the normal state capacities.

3.3.2 Methods and data

We analysed hospital intensive care unit utilization with descriptive methods utilizing especially geographical visualizations of the COVID-19 patients' ICU utilization and normal state capacities. For these purposes, we gathered the available data of both the utilization of ICU beds by COVID-19 patients and the normal state ICU capacities.

The daily ICU utilization data was gathered from publicly available secondary sources. Most of the utilized sources were national health authorities. Data was gathered at the beginning of May 2020 so the data starts from the country-specific day with the first COVID-19 patients in the ICU and ends 1 May 2020. The data was available on country level from most of the EU countries with a population of at least 1 million people. We also included the data of selected countries essentially located close to the EU countries. In addition to country level data, we gathered regional data from the countries where it was available from public sources. The full list of included countries and data regarding the ICU utilization is described below in Table 15. The full list of sources can be found in the Annexes.

Table 14: Countries included into the ICU analysis

Country	Country level	Regional level		Country	Country level	Regional level
Austria	Included	Included		Liechtenstein	Not included	Not included
Belgium	Included	Not available		Lithuania	Not available	Not available
Bulgaria	Included	Not available		Luxembourg	Not included	Not included
Croatia	Not available	Not available		Malta	Not included	Not included
Cyprus	Not available	Not available		Netherlands	Included	Not available
Czechia	Included	Not available		Norway	Included	Not available
Denmark	Included	Included		Poland	Not available	Not available
Estonia	Included	Not available		Portugal	Included	Not available
Finland	Included	Included		Romania	Included	Not available
France	Included	Included		Serbia	Included	Not available
Germany	Included	Not available		Slovakia	Not available	Not available
Greece	Included	Not available		Slovenia	Not available	Not available
Hungary	Included	Not available		Spain	Included	Included
Iceland	Not included	Not included		Sweden	Included	Included
Ireland	Included	Not available		Switzerland	Not available	Not available
Italy	Included	Included		United Kingdom	Included	Not available
Latvia	Not available	Not available				

As for the country level normal state capacities, comprehensive current data was found to be poorly available and thus we utilized the figures from previous research. The normal state capacity we used was gathered by Rhodes et al. during 2010-2011 and it is illustrated in Table 16 below [50]. The authors also noted that it was not always possible to distinguish the intensive care and intermediate care beds. As the capacity data is both outdated and has been subject to interpretations, the capacities should be considered as indicative figures, where phenomena of large magnitudes can be identified.

Table 15: ICU capacity in the countries analysed

Country	ICU capacity (beds) per 100k inhabitants		Country	ICU capacity (beds) per 100k inhabitants
Germany	29.2		Norway	8.0
Austria	21.8		Denmark	6.7
Romania	21.4		United Kingdom	6.6
Belgium	15.9		Ireland	6.5
Estonia	14.6		Netherlands	6.4
Hungary	13.8		Finland	6.1
Italy	12.5		Greece	6.0
Bulgaria	12.2		Sweden	5.8
France	11.6		Serbia	5.2
Czechia	11.6		Portugal	4.2
Spain	9.7			

We estimated the regional ICU capacities for each region in order to conduct the regional analyses. . The assumption is that the regional distribution of the total national ICU bed capacity follows the distribution of population in regions: for example, if a country has two regions with populations of 500 and 1 000 respectively, then the regions' ICU capacities should be one third and two thirds of the total ICU capacity. Reliable data on regional ICU capacities is challenging to gather , and we could only interpret Finnish data with the level of reliability that we can be sure that we understand the data and that the data is sufficiently up to date. Therefore, we tested our assumption (See Table 17) with the data from Finland[84] and proceeded with the assumption of population-based distribution as there were no significant outliers with the ICU beds / 100k population.

Table 16: Example of regional differences in ICU beds per 100k population

Region	# of ICU beds, spring of 2020	Share of ICU beds	Population December 2019	Share of population	ICU beds / 100k
HYKS (Helsinki)	167	40 %	2 188 253	40 %	7.6
TAYS (Tampere)	61	15 %	901 358	16 %	6.8
TYKS (Turku)	54	13 %	868 416	16 %	6.2
KYS Kuopio)	58	14 %	800 498	15 %	7.2
OYS (Oulu)	76	18 %	736 883	13 %	10.3
Total	**416**	**100 %**	**5 495 408**	**100 %**	**7.6**

[84] Association of Intensive Care in Finland (Suomen tehohoitoyhdistys). ICU wards in Finland (Suomen teho-osastot). Withdrawn 22 April 2020. https://sthy.fi/suomen-teho-osastot/

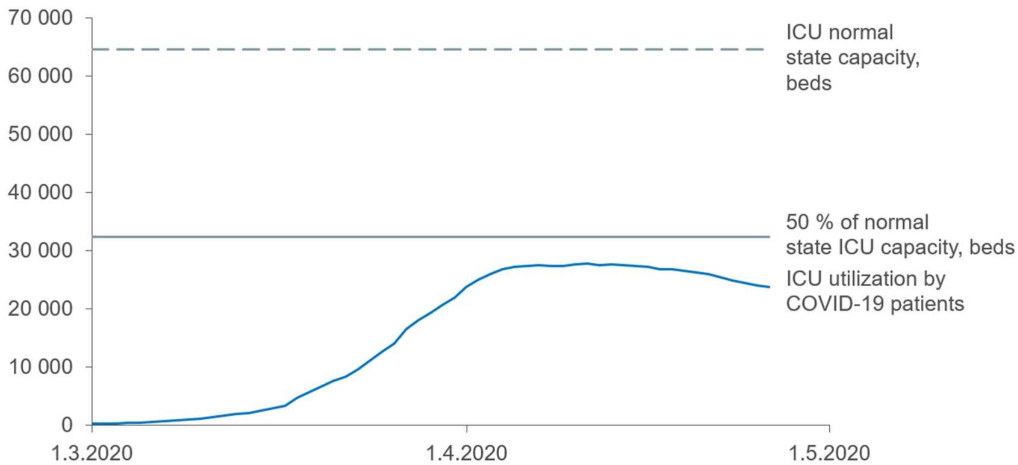
We then joined the data on COVID-19 ICU utilization and the normal state ICU capacity in order to see what share of the normal state capacity was occupied by the COVID-19 patients and what share of the capacity was left for other patients or as a buffer capacity. These analyses were conducted both on the level of all mentioned countries combined, countries individually and, where the utilization data was available, also on the regional level. Graphs for the capacity utilization over time were drawn for each country and region. In addition, geographical visualizations illustrating the cross-sectional capacity utilization in different locations at a certain period of time were drawn. For the purposes of the geographical visualizations, we compared the number of COVID-19 patients against the expected free ICU normal state capacity.

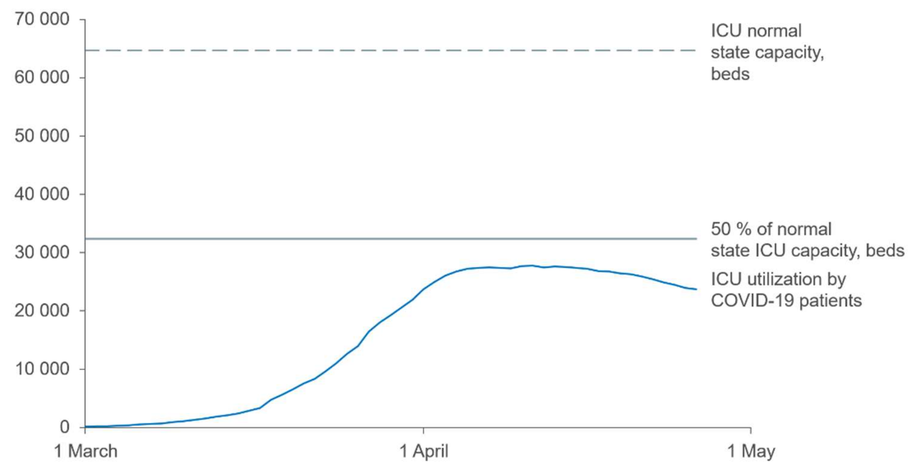
3.3.3 Results

In this section we present the different utilization figures and geographical visualizations. We begin with the time series graphs of the countries combined and countries individually. Then we proceed to the geographical visualizations of the peak days on a country level. We end the results part with the regional graphs and visualizations regional of Italy and Spain.

At the combined level, the included countries (see Figure 20) had a normal state ICU capacity of ~64 700 ICU beds. For the illustrative purposes, we have also drawn the line of 50 % of the normal state capacity for each graph. In the included countries combined, the number of ICU utilization by COVID-19 patients peaked at ~27 700 on 11 April which is 43 % of the total normal state capacity.

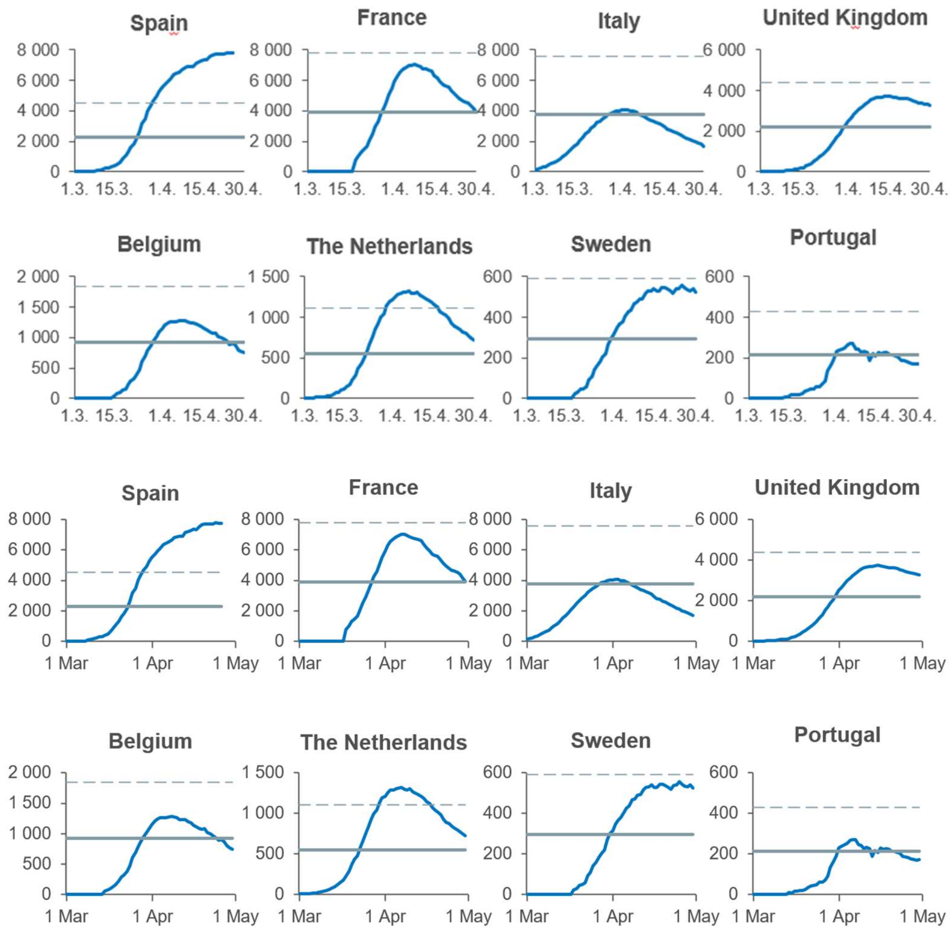
Figure 20: Utilization of ICU capacity by the COVID-19 patients in selected European countries





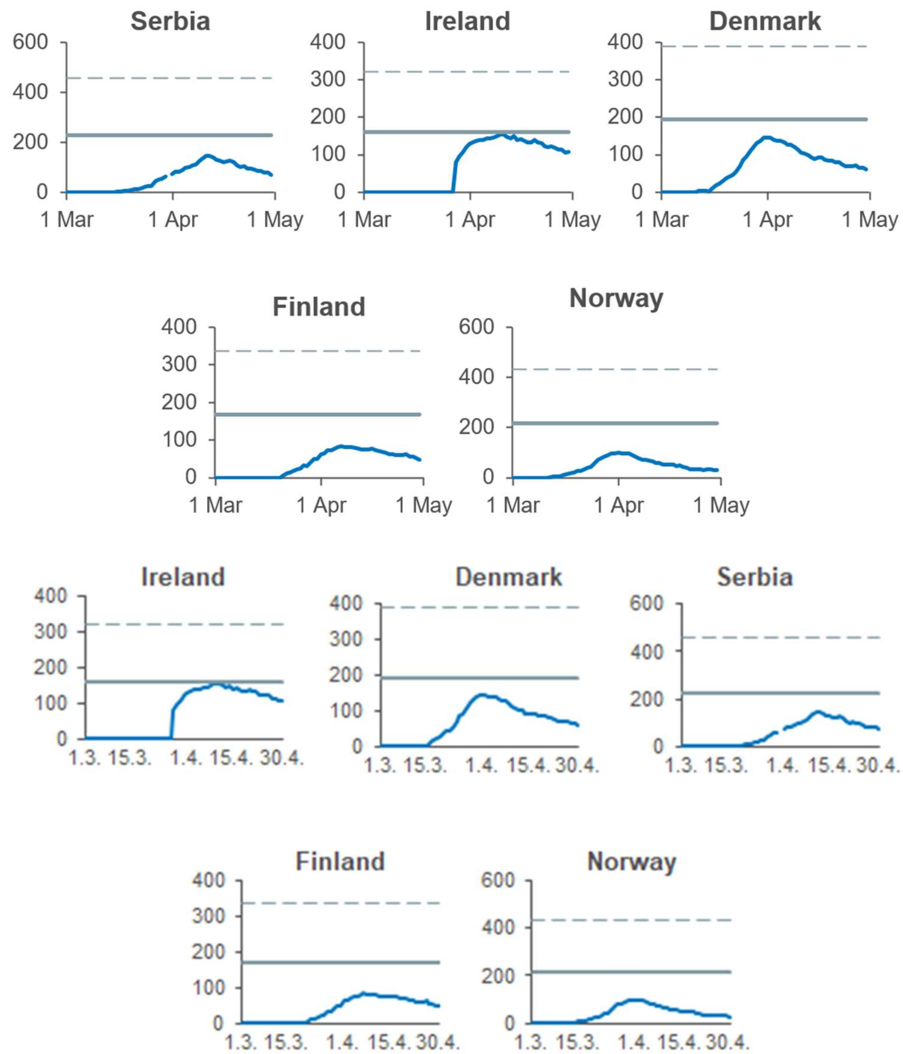
On the country level, the countries where the utilization by the COVID-19 patients peaked at more than 50 % of the normal state capacity were Belgium, France, Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom (see Figure 21 below).

Figure 21: Countries where the utilization by the COVID-19 patients exceeded more than 50 % of normal state ICU capacity



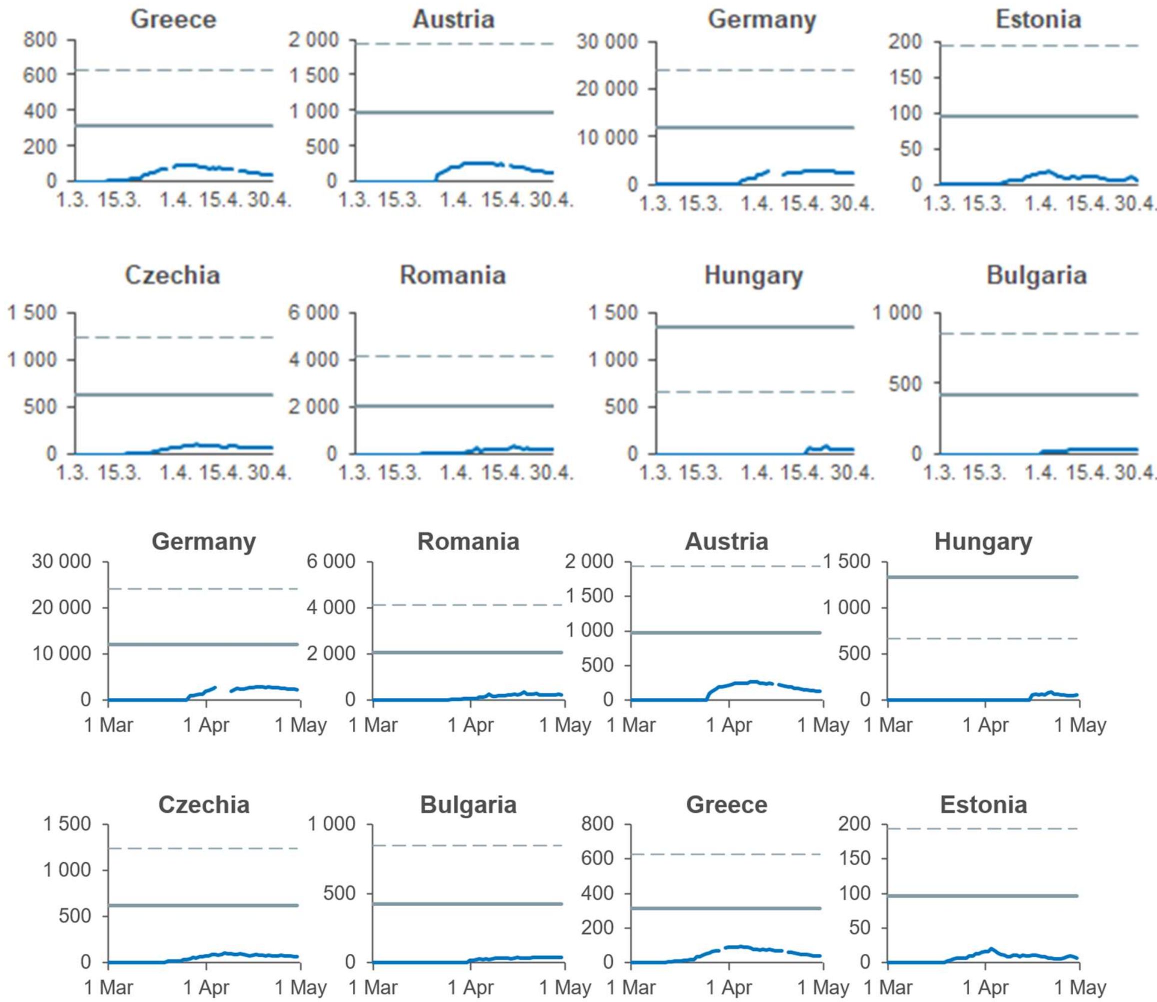
The countries where the utilization by the COVID-19 patients peaked at more than 20 % but at less than 50 % of the normal state capacity were Denmark, Finland, Ireland, Norway, Serbia (see Figure 22 below).

Figure 22: Countries where the utilization by the COVID-19 patients exceeded more than 20 % but was less than 50 % of normal state ICU capacity



The countries where the utilization by the COVID-19 patients peaked at less than 20 % of the normal state capacity were Austria, Bulgaria, Czechia, Estonia, Germany, Greece, Hungary, Romania (see Figure 23 below).

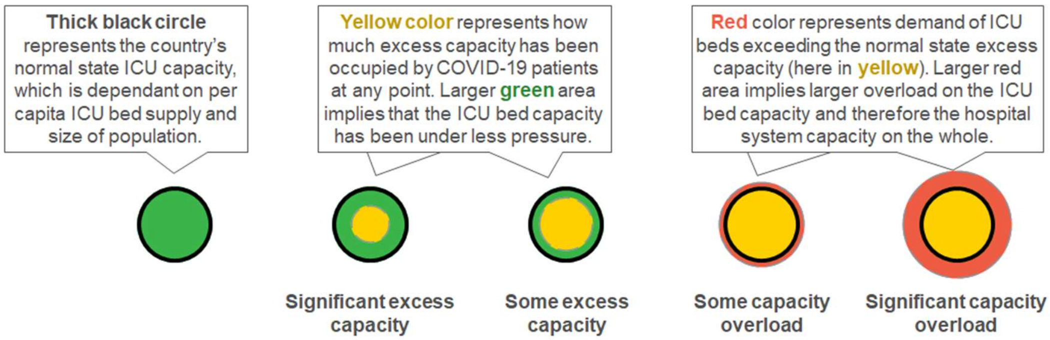
Figure 23: Countries where the utilization by the COVID-19 patients was less than 20 % of normal state ICU capacity



As a conclusion from the country level utilization analyses, the utilization levels varied significantly between the different countries. There is also some variation in timing of the first patients in the ICUs. However, the timing of the peaks in different countries seem to be quite close to each other.

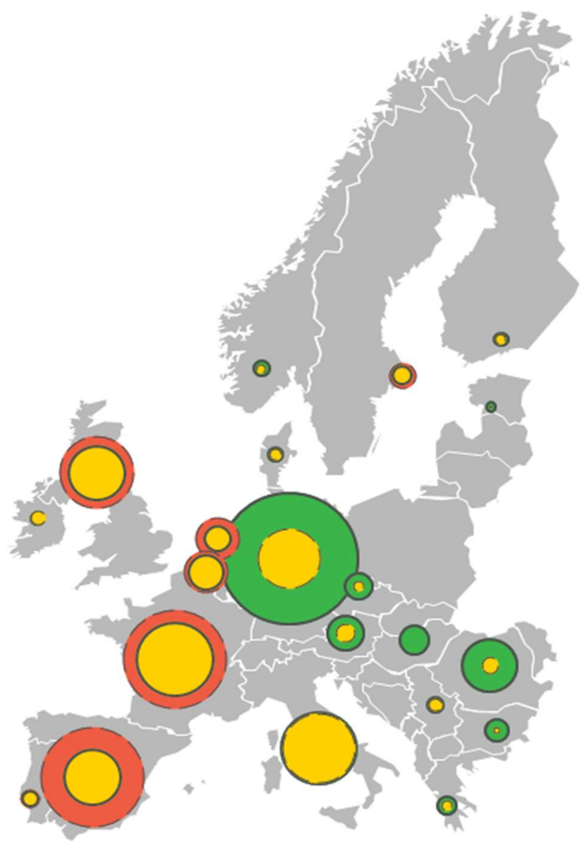
The geographical visualizations are designed to depict the magnitude of the capacity demand caused by the COVID-19 patients in relation to the normal state capacity. The majority of the normal state capacity is normally utilized by the non-COVID-19 patients and only a certain share of the normal state capacity is available for the COVID-19 patients. Thus, in the visualizations, we use 50 % of the normal state capacity as the limit for overload. In the visualizations, the area inside the unbroken circle depicts the 50 % of the normal capacity. The dotted circle, on the other hand, depicts the utilization by the COVID-19 patients. The green colour (the unbroken circle minus the dotted circle) describes the proportion of the 50 % of the normal capacity not used by the COVID-19 patients. The yellow colour describes the utilization of COVID-19 patients under 50 % of the normal state capacity. The red colour describes the utilization of COVID-19 patients over 50 % of the normal state capacity. The visualizations are illustrated in Figure 24 below.

Figure 24: Geographical visualizations' legend



The utilization related to the normal state capacity varied across Europe during the combined peak as Figure 25 illustrates. The utilization rates were significantly high in the Western Europe whereas the countries of the Eastern Europe had significantly lower utilization rates.

Figure 25: Overview of patients in intensive care due to COVID-19 in Europe by country, relative to ICU capacity: April 11 (European Utilization peak)



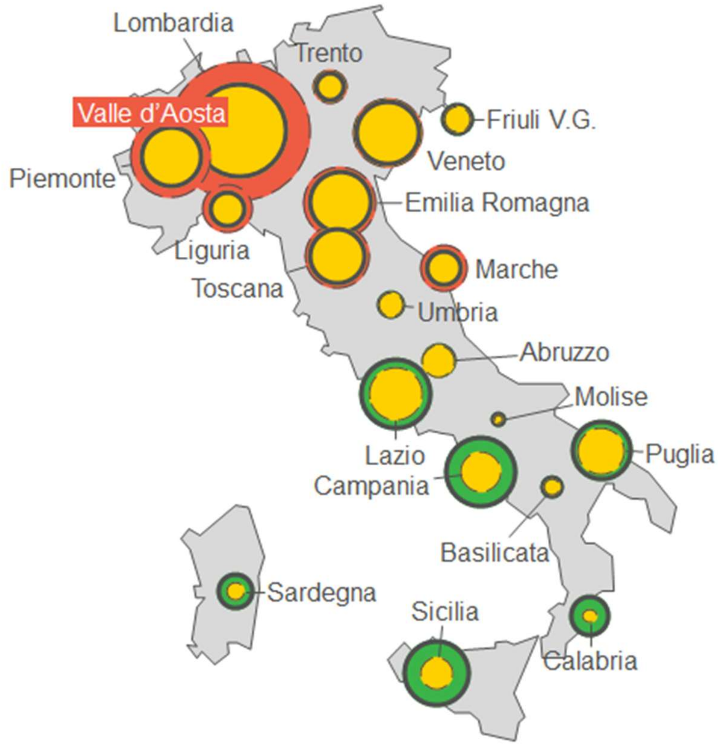
For the region-level analyses within countries we selected Italy and Spain. Italy was selected as it was the first country in Europe where the utilization of COVID-19 patients at the ICUs became significant. Spain was selected as the ICU utilization peak in relation to the normal state capacity was the highest of the analysed countries.

The regional utilization in Italy varied significantly (see Figure 26). Of the 20 regions in Italy, in 6 regions the normal state ICU capacity was exceeded by the COVID-19 patients. In 7 regions the COVID-19 patients utilized less than the normal state capacity but more than 50 % of the normal state capacity. In the remaining 7 regions the utilization by COVID-19 patients was lower than 50 % of the normal state capacity.

Figure 26: Utilization of the ICU capacity by the COVID-19 patients in Italy by region

In the cross-sectional geographical visualization (see Figure 27), we see clearly that the regions where the 50 % of the normal state capacity was significantly exceeded by the COVID-19 patients during the first wave of the COVID-19 crisis were the regions in North-Western Italy. At the same time, the utilization of COVID-19 patients related to the normal state capacities in the southern and even the middle of Italy was significantly lower.

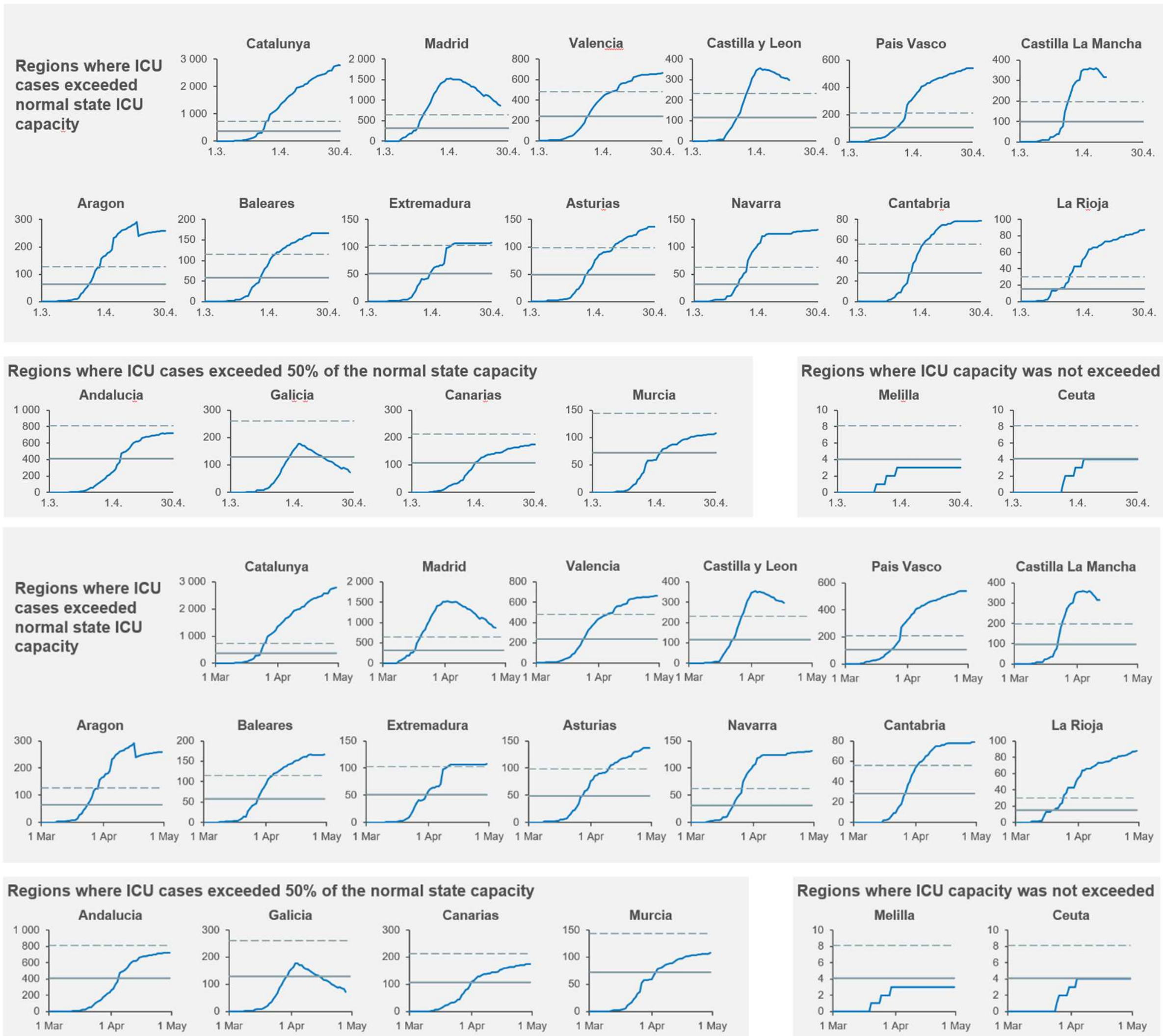
Figure 27: Overview of patients in intensive care due to COVID-19 in Italy by region, relative to regional ICU bed capacity: April 4 (Italy utilization peak)



There was less variation in utilization in relation to the normal state capacity in different regions in Spain compared to Italy (see Figure 28). Of the 19 regions in Spain, in 13 regions the normal state ICU capacity was exceeded by the COVID-19 patients. In 4 regions the COVID-19 patients occupied less than the normal state capacity but more than 50 % of the normal state capacity. The remaining 2 regions had a lower utilization of ICU beds by the COVID-19 patients than 50 % of the normal state capacity. Of the 20 regions in Italy, in 6 regions the normal state ICU capacity was exceeded by the COVID-19 patients. In 7 regions the COVID-19 patients utilized less than the normal state capacity but more than 50 % of the normal state capacity. In the remaining 7 regions the utilization by COVID-19 patients was lower than 50 % of the normal state capacity. The major regions measured by population and correspondingly distributed ICU capacities (Madrid, Catalunya, Valencia), had utilization by the COVID-19 patients higher than the normal state ICU capacity. The Spanish hospitalization figures should be interpreted with caution because the tracking policy of occupied beds seems to have varied regionally during the spring: some regions reported cumulative numbers of hospitalized patients whereas others reported daily currently hospitalized patients.[85]

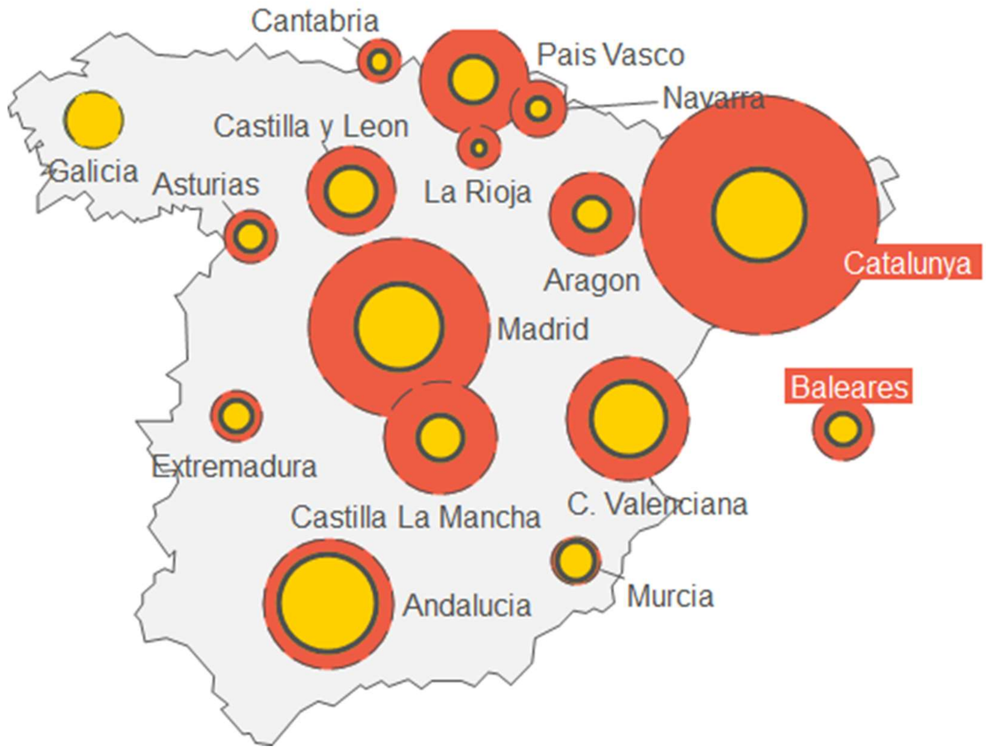
[85] Details: "The problems Spain's outdated data methods have caused during a 21st-century pandemic" (https://english.elpais.com/society/2020-06-24/the-problems-spains-outdated-data-methods-have-caused-during-a-21st-century-pandemic.html) and GitHub issue discussion on the topic of hospitalizations in e.g. https://github.com/neherlab/covid19_scenarios/issues/595.

Figure 28: Utilization of the ICU capacity by the COVID-19 patients in Spain by region



The cross-sectional geographical visualization shows that within Spain, the capacity utilization by the COVID-19 patients was more evenly distributed than in Italy (see Figure 29).

Figure 29: overview of patients in intensive care due to COVID-19 in Spain by region, relative to regional ICU bed capacity: April 15 (Spain utilization peak)



To summarize, there was significant variation in the ICU capacity utilization between both European countries and the country-specific regions that were analyzed. There were many regions and even whole countries where the ICU capacity utilization increased to levels exceeding the normal state ICU capacity.

3.4 Discussion

Countries that were assumed to be well prepared for a health crisis based on the preparedness indices were actually hit the hardest measured by mortality during the spring of 2020. This could be because the preparedness indices may have been constructed based on the previous epidemics which have either been suppressed (e.g. SARS), have had a lower mortality (e.g. H1N1 of 2009) or have transmitted with a slower pace (e.g. HIV). In addition, the fact that the pandemic is still advancing with differing phases in the analysed countries, have an affect on the results.

In chapter 2.4 we identified government interventions which reduce social interactions as the most efficient way to reduce the spread of the virus and decrease mortality. On the other hand, the amount of travel, especially international, increased the pace of the spread. These perspectives have not been included with their proper weight in the existing preparedness indices. Especially willingness to implement different restrictions is very difficult, if not impossible, to estimate beforehand as the implementation of interventions are political decisions. However, information about the social activity, both domestic and international, in a country could bring value to future indices as it seems to increase the risk of a spread of a pandemic.

Even if the theoretical preparedness did not save the European countries from severe outcomes, this does not mean that we should or could not improve the preparedness of the healthcare systems for the possible future pandemics.

Comprehensive testing of the potentially infected appeared to be a part of successful strategies to reduce the spread of the virus during the first wave of the COVID-19. According to the findings of chapter 2.4 and the testing focus area in this section, the low mortality rates are correlated with interventions especially in categories of cancelling public events and controlling international travel. Testing and the related contact tracing seem to be one part of the intervention repertoire utilized by the countries with low mortality rates after the first wave. This could be one factor explaining why the spread of the virus was so much slower in many countries in the East Asia and the Pacific compared to the also more developed countries in Europe.

Analysing the shortcomings in diagnostic capacity in the beginning of the crisis is difficult because several countries chose a strategy where identification of the infected was not one of the key elements. It is not clear whether the small scale of testing was actually a result of the chosen strategy or vice versa. Different testing strategies were thus not actually decisions whether to test the potentially infected or not, but rather whether to invest in increasing the testing capacity or not.

Intensive care provided by the hospital ICUs was identified to have the most critical capacity constraints within the treatment of the infected. The conducted comparison between the normal state capacities and the COVID-19 utilization do not take into account several variables and thus do not give the exact figures of the ICU utilization rates during the spring of 2020. However, they do depict the magnitude of the burden brought by COVID-19 patients in relation to the normal state capacity. This is quite relevant as the quality of the ICU treatment may decrease in situations where the normal state capacity is exceeded.

The geographical visualizations reveal that there were different utilization situations even within relatively short distances. Especially in central Europe, some areas, be they countries or regions, seemed to have severely burdened healthcare systems with more COVID-19 patients than their whole normal state capacity. At the same time, their neighbouring areas, be they countries or regions, seemed to have significantly less strain on their ICUs.

With regards to improving and maintaining quality of the care at the ICU, the key three areas of focus are the organisational aspects of the ICU, medical and non-medical processes in the ICU and outcomes (such as mortality rate, length of stay and utilization of resources)[86]. During the COVID-19 crisis in the spring of 2020, the ICU capacity was increased temporarily in several countries, which means taking more equipment into use and either running the higher capacity with the same number of ICU professionals or bringing temporary professionals in[87]. From the personnel perspective, these both options may pose a risk to the quality of care in ICUs. If the same personnel treat more patients than planned for extended periods of time, risk of malpractice may increase. If new personnel with less ICU training is brought in, the risk of malpractice may increase.[84] If the utilization of COVID-19 patients at the ICUs reaches the normal state buffer capacities, the situation can be assumed to be suboptimal.[84] In our graphs and visualizations, we showed a utilization threshold of 50 %. If the sudden utilization of COVID-19 patients reaches 50 % of the normal state capacity, we have assumed that this is already a suboptimal situation in most countries and regions with normal buffer capacities of 30-40 % of the capacity.

[86] Thijs, L. G. "Continuous quality improvement in the ICU: general guidelines." Intensive care medicine 23.1 (1997): 125.
[87] Phua, Jason, et al. "Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations." The Lancet Respiratory Medicine (2020).

As a conclusion, there may have been possibilities to decrease mortality by distributing the load on ICUs in different areas. There are examples of redistribution being done even across country borders[88]. The idea is not original as it has been suggested by other authors as well[89]. The contribution of this study was that there appeared to be instances where the distribution of COVID-19 patients would have been feasible in Europe taking into account the distances between the areas with different utilizations.

Improved preparedness and distribution of demand according to available capacities in intensive care would not have slowed the pandemic down as the interventions decreasing the social activity did. However, having sufficient capacity is needed to save lives if efforts to contain the spread of the disease fail. Also, the treatment of the infected is one of the few measures without negative impact on the other parts of society. Whereas the interventions often limit the social and financial activity or the freedom of the individuals, treatment of the infected and increasing the healthcare system preparedness does not have such opportunity costs as the interventions to stop the spread of the virus.

[88] Reuters. *Germany treats first Italians as coronavirus care crosses borders.* 24 March 2020. https://www.reuters.com/article/us-health-coronavirus-germany-italy/germany-treats-first-italians-as-coronavirus-care-crosses-borders-idUSKBN21B2GL

[89] Harvard Business Review. *We Need to Relocate ICU Patients Out of Covid-19 Hotspots.* 23 June 2020. https://hbr.org/2020/06/we-need-to-relocate-icu-patients-out-of-covid-19-hotspots

4 Healthcare professionals

In the previous chapters we discussed the factors affecting the spread of COVID-19 and the responsiveness of healthcare systems with the focus areas of theoretical preparedness, testing during the crisis and ICU capacity utilization during the crisis. In this chapter, we analyse how the crisis affected the behaviour of the healthcare professionals responsible for provision of services for the COVID-19 patients in hospitals.

4.1 Introduction

In chapter 3, we concluded that the secondary healthcare services that COVID-19 patients require are the ward care and the ICU. We also observed that in the case of the hospitalized COVID-19 patients, the ICU utilization was significantly higher than the ward care utilization. Previous chapters have focused on examining the utilization rates and the stress of the ICU capacity during the first wave of COVID-19 epidemic at the hospital system level.

In this chapter, we examine the experiences of the healthcare professionals who worked at the ICUs and treated COVID-19 patients during the first wave of the pandemic in selected European countries. Our objective is to understand what kinds of behavioural phenomena and tendencies occurred at the grass-root level of the hospital system and the challenges that surfaced under these exceptional circumstances. The circumstances during the first wave of the pandemic have been exceptional not only at the hospital management level but also for the doctors and nurses working in intensive care. This can be seen especially in European countries, with no near experienced of large-scale pandemics that would have required nation-wide contingency plans to be activated.

Traditionally the European healthcare professionals who have been working in different crisis situations have worked in different rapid response collectives in organizations such as the Red Cross and the Red Crescent[90]. Emergency scenario training and simulations are an integral part of the specialization process of the ICU professionals, but simulation-based training taking place during the normal state does not guarantee preparedness for when an actual pandemic takes place. Understanding the perspective of the healthcare professionals widens our understanding of the challenges of the first wave of the pandemic, of the level of preparedness and of mechanisms that could support hospital system experts in the future.

The behaviour and motivation of healthcare professionals under crisis conditions has been discussed extensively in academia. Literature review by Valdez and Nichols (2013)[91] indicates that a significant and potentially crippling shortage of healthcare providers is likely to occur in the event of a large-scale public health crisis, and that healthcare organizations cannot rely on obligations alone to ensure the healthcare professionals report for work. According to them, the first conclusion is that the internal needs of the professionals are satisfied, i.e. ensuring sufficient facilities for rest during breaks and in-between shifts. Second, behaviour is highly influenced by the need of safety: strategies to ensure healthcare professionals with preventative medications, PPE (personal protective equipment) and supervisory care for dependent children or adults of employees are highly recommended. Third, in order to support healthcare professionals to feel a sense of belonging to something larger than them during a crisis, establishing a continuing psychological support network to prevent the feeling of isolation and even stigmatization due

[90] See e.g. "Health in emergencies" (https://www.ifrc.org/en/what-we-do/health/health-in-emergencies/). IFRC.
[91] Valdez, Christine D., and Thomas W. Nichols. "Motivating healthcare workers to work during a crisis: A literature review." Journal of Management Policy and Practice 14.4 (2013): 43-51.

to the high-risk nature of their jobs. Fourth, financial reward or "hazard pay" systems might help healthcare professionals to report to work since they might be required to work extended hours in a high-risk environment. Fifth, education on emergency preparedness and how an individual employee's role is communicated to him or her play an instrumental role in ensuring healthcare workforce readiness.

We developed these conclusions further into four main themes based on existing literature regarding the questions that are crucial for the behaviour of healthcare professionals during a healthcare crisis: preparedness of the hospitals, stress of the healthcare professionals, challenges in management and leadership, and sufficiency of resources. Under these themes, we proposed the following questions:

1) **Preparedness of the hospitals**[92]
   a) Were the existing preparation plans put to a serious test? Were they applicable for the COVID-19 pandemic?
   b) What kind of changes had to be done to the ICU wards? If the wards were split into COVID-19 cohorts and "other patients" cohorts, how were the cohorts different?
2) **Stress of the healthcare professionals**[89]
   a) Were the normal working hours exceeded during the first wave? Did the rhythm of the workday change otherwise?
   b) Was the workload spread equally among the professionals?
   c) Were there shortages of staff?
   d) Is there a risk for mass resignations of ICU professionals due to the exhausting pandemic?
3) **Challenges in management and leadership** [89]
   a) Was the communication from the management sufficient and successful?
   b) Were the onboarding processes of new employees shorter than usual?
4) **Sufficiency of resources**[93]
   a) Were there shortages of ICU beds and medical equipment required at the stations?
   b) Were there shortages of personal protective equipment (PPE)?
   c) Were there shortages of medicines?

Of particular interest are the comparisons between the experiences from the ICU professionals working in different countries and healthcare systems, which faced very different demand situations. There are some phenomena and experiences that surface for all ICU professionals regardless of nationality or experience level, especially regarding the general uncertainty revolving around a pandemic caused by a novel coronavirus.

4.2 Methods and data

We conducted interviews with ICU professionals who treated COVID-19 patients during the first wave of the epidemic. The interviewees (see Table 18) were from selected European countries and had different professional backgrounds to take into account the complexity of the COVID-19 epidemic. We conducted open-ended interviews to analyse the behaviour of professionals.

[92] Griffin, Kelly M., et al. "Hospital preparedness for COVID-19: a practical guide from a critical care perspective." American journal of respiratory and critical care medicine ja (2020).
[93] Dewey, C., Hingle, S., Goelz, E., & Linzer, M. (2020). Supporting clinicians during the COVID-19 pandemic.

In general, behavioural (experience-based or patterned behavioural) interviews focus on the past. The respondents were asked to relate what they did in the past on their actions now in the present.[94] [95] Behavioural interview questions are utilized especially in job interviews: they are used based on the hypothesis that past behaviour predicts future behaviour and work as a proxy for the performance in similar future situations.

Interviews were conducted with healthcare professionals who worked in Finland, Italy or Sweden during the spring of 2020. The professional background of the interviewees included doctors and nurses, whose roles varied between grass-root level professionals primarily treating patients and professionals on a managerial level who had also other duties at the ICUs (such as senior doctors of the ICU ward, head nurses managing the shift rosters, nurses and doctors responsible for trainings etc.). The majority of the interviewees worked daily at the ICU and therefore were experienced in the traditional intensive level care and its practices. However, some interviewees worked mainly in other fields of the healthcare sector (such as elderly services) but worked temporarily at the ICU treating COVID-19 patients during the spring of 2020. The total number of interviews was 16 (9 from Finland, 3 from Italy and 4 from Sweden). Other case interview countries we considered included Spain, the United Kingdom and the Netherlands, but scheduling interviews with professionals from these countries could not be done under the time constraints of our analysis.

We collected primary data in the form of notes, recordings and transcripts from interviews in order to understand the behaviour of the healthcare professionals during the crisis. For the purposes of this study, data was collected from Finland, Italy and Sweden respecting the hectic working schedules of the healthcare personnel in hospitals treating the COVID-19 patients. Due to travel restrictions and social distancing practices, instead of conducting face-to-face interviews, we carried out all interviews online via Microsoft Teams, Google Meet and Zoom. Interviews were recorded with the consent of the interviewees, and the interview recordings will be maintained strictly for the purposes of writing the transcripts and main conclusions of the interviews after which they will be deleted. All data is managed according to HERoS data management plan.

The main objective of the behavioural interview structure was to understand the behaviour of the ICU professionals during the first wave of the COVID-19 epidemic. Our open-ended question approach allowed for the interviewees to reflect on the response for the first wave of the COVID-19 crisis from their point of view and talk about their personal experiences both at the workplace and outside of it. With the open-ended approach we were able to identify a variety of phenomena and tendencies, which might be challenging to ensure using a more close-ended, pre-specified and detailed question structure (interview question structure included in Appendix 5).

The qualitative interview data was then analysed in conjunction with the main set of hypotheses in section 5.1, and the interview outputs categorized roughly under the four main categories of 1) preparations for the surge of COVID-19 patients, 2) stress and load on the healthcare professionals, 3) management and leadership and 4) resources. This categorization of observations allowed us to determine the common phenomena across the different professional groups and countries, as well as determine the key differences in the characteristics of behaviour of ICU professionals in different professional groups and countries.

[94] Janz, T. (1982). Initial comparisons of patterned behavior description interviews versus unstructured interviews. Journal of Applied Psychology, 67(5), 577–580. https://doi.org/10.1037/0021-9010.67.5.577
[95] Motowidlo, S. J., Carter, G. W., Dunnette, M. D., Tippins, N., Werner, S., Burnett, J. R., & Vaughan, M. J. (1992). Studies of the structured behavioral interview. Journal of Applied Psychology, 77(5), 571–587. https://doi.org/10.1037/0021-9010.77.5.571

Table 17: The respondents of the interviews and relevant background information

Respondent	Nationality	Occupation	Experience
Respondent A	Finland	Doctor	15 years
Respondent B	Finland	Nurse	25 years
Respondent C	Finland	Doctor	18 years
Respondent D	Finland	Doctor	7 years
Respondent E	Finland	Nurse	5 years
Respondent F	Finland	Nurse	17 years
Respondent G	Finland	Nurse	33 years
Respondent H	Finland	Nurse	13 years
Respondent I	Finland	Doctor	6 years
Respondent J	Italy	Doctor	not specified
Respondent K	Italy	Doctor	not specified
Respondent L	Italy	Nurse	not specified
Respondent M	Sweden	Nurse	17 years
Respondent N	Sweden	Nurse	26 years
Respondent O	Sweden	Doctor	1 year
Respondent P	Sweden	Doctor	4 years

4.3 Results

We firstly review some of the most important findings of previous sections regarding the countries where we had interviewees from: Finland, Italy and Sweden. Due to the different situations in each of these countries, it is important to first understand the context of the interviews. Secondly, we present the findings of the interviews per each category of hypotheses.

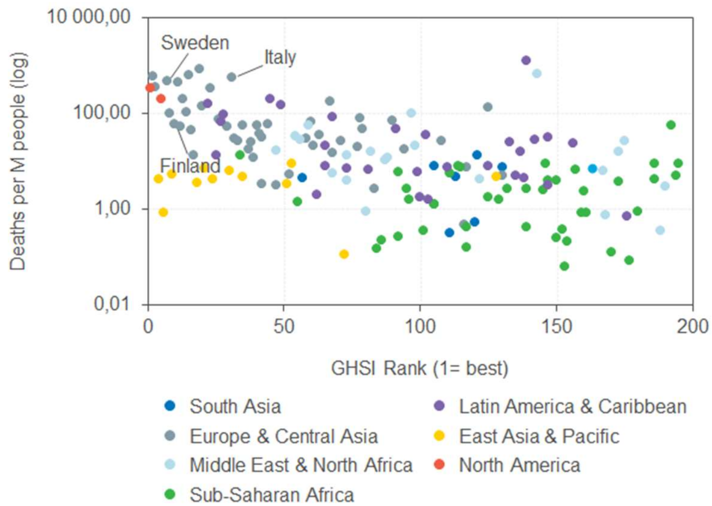
4.3.1 Overview of country-specific situations

Preparedness

In section 3.1 we analysed how the health-related outcomes from the first wave compare to the expected preparedness measured by the existing preparedness indices on a country level. We examined four different indices which aim to rank countries based on preparedness or potential responsiveness to epidemics, pandemics or other healthcare crises.

We found that the health-related outcomes from the first wave were primarily negatively correlated with the expected preparedness measured by the existing preparedness indices on a country level. To simplify, the countries with better preparedness did not have necessarily better health outcomes in the first wave. Finland, Italy and Sweden all seem to position in the same corner with high preparedness and high number of deaths per capita on a global scale (Figure 30). However, the number of deaths is roughly ten times higher in Italy (556 deaths per million people) and Sweden (450 deaths per million people) compared to Finland (58 deaths per million people). Regarding the rankings, Finland and Sweden placed in the ten best prepared countries in every index whereas Italy's rankings ranged from 11th to 27th.

Figure 30: GHSI index rank and deaths per 1M people

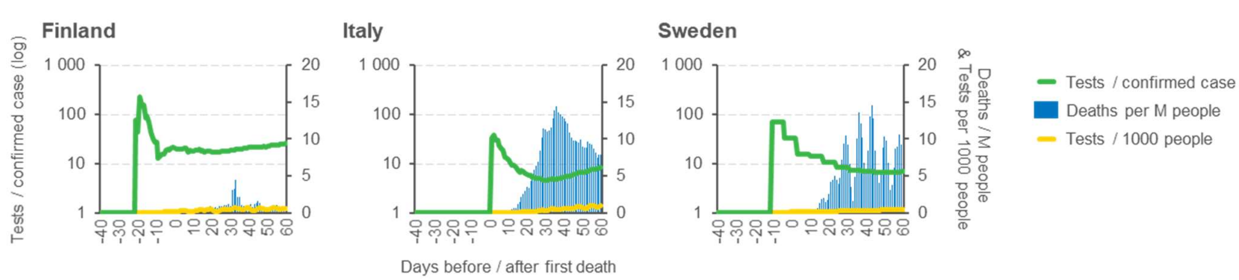


Testing

In section 3.2, we analysed what kind of diagnostic strategies can be recognized for diagnosing the potentially infected and how they are related to other interventions and the health-related outcomes on a country level. As we discussed earlier, there have been several different testing strategies used during the COVID-19 pandemic and many countries have altered their strategies during the progress of the epidemic. As the testing strategies are very versatile, it is important to understand the different approaches and potential connections between strategies and outcomes.

Finland was clustered into the Cluster 2 which includes countries with moderate number of deaths, moderate testing or at least increase in testing. Italy and Sweden were clustered into the Cluster 6 with significant numbers of deaths and little or moderate testing. We observed that the cluster with few deaths and at least moderate testing was associated with early start of testing, early increase in the stringency index and high tracing policy index. Most of the countries with high numbers of deaths were associated with little or moderate testing, late first testing day and late increase in the stringency index. Compared to Sweden and Italy, Finland started testing earlier relative to first death and increased stringency policies early on the first wave than the other two case countries (Figure 31). Sweden appeared to have an exceptionally low stringency index compared to Finland, Italy and most of the other countries.

Figure 31: Illustrations of testing and mortality for case countries



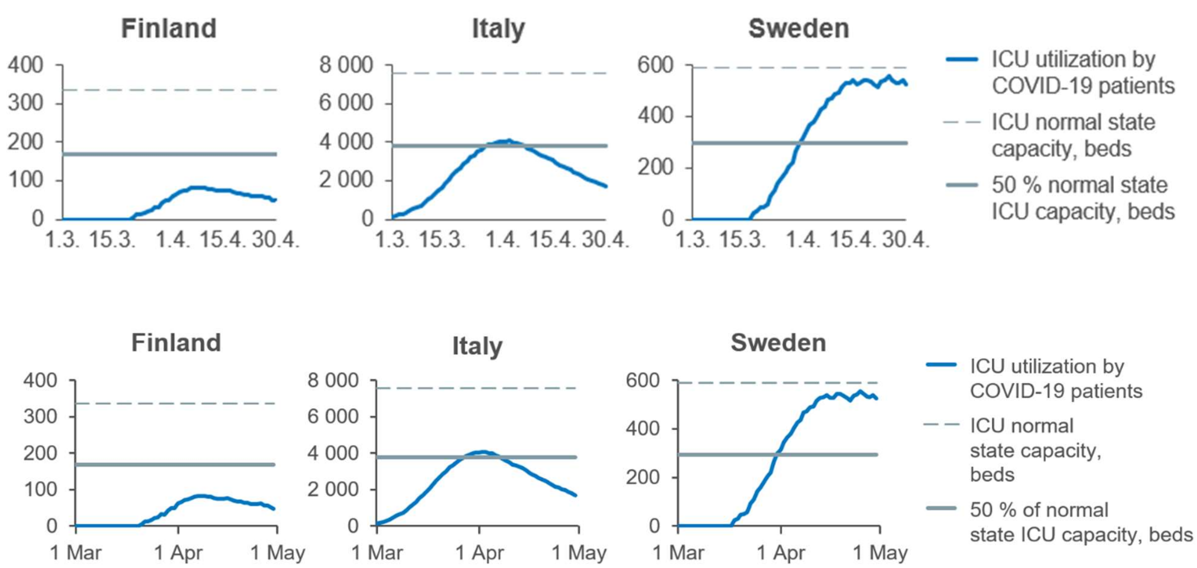
Intensive care

In section 3.2, we analysed the healthcare service capacity to treat the patients requiring hospital level care and services. We focused our analysis on the ICU capacity, since the ICU capacity utilization rates have been remarkably higher than the ward care capacity utilization rates. We concluded that the demand of the ICU capacity, the supply of ICU capacity and the balance between these two were constantly changing during the COVID-19 crisis in the spring of 2020. As a result, we were bound to analyse the balance of COVID-19 patients' utilization of the ICUs compared to the normal state capacities in different areas.

We analysed the ICU-related utilization figures per country using the number of patients at the ICU and the normal state ICU capacity as the baseline. As a conclusion, we derived that the utilization levels varied significantly between the different countries and the timing of the first patients at the ICU varied as well. However, the timing of the peaks in different countries seem to be quite close to each other.

The utilization graphs for the case countries are presented in Figure 32. The utilization of ICU capacity by the COVID-19 patients peaked first in Italy at 54 % utilization of 4 068 COVID-19 patients at the ICU on 3 April, after which the utilization started to decrease over the course of April. Finland peaked at 83 COVID-19 patients at the ICU on 7 April, which was 25 % of the normal state ICU capacity; after that COVID-19 hospitalizations started to decrease in Finland as well. Of the three countries, Sweden peaked the latest on April 25 with 556 COVID-19 patients at the ICU corresponding to 94 % utilization of normal state ICU capacity). Sweden's utilization peak was not only the highest of the three countries, but it also lasted longer and the COVID-19 hospitalizations decreased at a slower rate than in Finland and Italy.

Figure 32: Utilization of ICU capacity by the COVID-19 patients in the case countries



For all three case countries, regional variations in utilization and epidemic situation in general were large. Majority of Italy's cases and hospitalizations were situated in Northern Italy, while the situation in the southern parts of the country was less critical. In Finland's case, approximately three fourths of the hospitalizations occurred in the Helsinki metropolitan area. In Sweden, almost half of ICU patients at the peak were situated in the capital region of Stockholm.

4.3.2 Results from the interviews

Regarding the **preparation for the pandemic**, the healthcare professionals in general were initially surprised and overwhelmed at the severity of the early outbreak in Italy, especially the interviewees from Italy. The common sentiment initially was that the news from Wuhan, China indicated that the COVID-19 epidemic would remain a localized pandemic and the disease would not spread globally, in a similar manner to SARS and Ebola. Finnish healthcare professionals' view shifted drastically by the time COVID-19 case numbers had started to escalate in Northern Italy and the epidemic started to spread to other European countries as well. In Sweden, the interviewed healthcare professionals' threat assessment of COVID-19 was not completely unified; some interviewees had personally voiced their concerns to the hospital administration as early as in January 2020.

The spread of the epidemic really seemed to surprise the hospital management according to professionals in each country. They felt as if the hospital management did not take the threat of the epidemic reaching their countries as seriously as they could have. The interviewees emphasized how some preparations in the ICUs were done early and efficiently, but it was the hospital-level decision making and especially communication of the preparatory measures that was lacking: the preparatory measures include e.g. the implementation strategy of the use of PPE and providing general guidelines for the hospital-level first response. In Sweden specifically, the concerns voiced in January by the professionals were not taken seriously because they did not witness a response from the administration at the time. However, this was not a unified opinion amongst the Swedish interviewees: others thought that the hospitals reacted early and had a pandemic plan successfully in place.

In the case of the three countries, even though disaster plans existed, healthcare professionals reflected they were not applicable in the context of COVID-19. For example, Finnish interviewees thought that the existing preparation plan designed around an influenza breakout was helpful in setting the general processes and practices, but the detailed execution had to be conceived in the weeks before the first patients came in. There was also ongoing discussion regarding the use of personal protective equipment (PPE). Based on the interviews, it was imminent that effectively communicating the constantly changing practices and protocols was a problem point in the communication between the upper management and ICU wards also in Italy and Sweden.

ICU ward spaces were redesigned to accommodate the need to treat two kinds of patients at the hospital in all three countries: the COVID-19 patients and the other patients requiring intensive care. The ICUs were essentially divided into two separate cohorts to minimize the risk of the COVID-19 spreading from the infected patients to the non-infected and hospital staff, as well as to lower the risk of infections between staff members. In Finland, the ICU professionals spent a lot of time moving around treatment equipment, resources and even furniture, which was physically demanding. Mundane workday conduct was affected: inside the COVID-19 cohort one could not e.g. casually drink water, use the bathroom or take a break due to the isolation protocols and protective gear.

In all three countries, the physical ward capacity was increased space-wise by allocating other units to ICU use. ICU capacity was increased to accommodate the expected growth of patients needing ICU-level care in Finland, Sweden and Italy. Elective surgeries were cancelled or rescheduled. The COVID-19 cohort was treated at the ICU whereas other patients needing ICU-level care were treated elsewhere. In Italy, new ICU tents were established outside of major hospitals to meet the initial surge in demand in COVID-19 patients. There was initial confusion from both patients and professionals as to where to send patients who needed non-COVID-19-related intensive care.

On the topic of **the stress of the healthcare professionals**, healthcare professionals reported to have worked overtime in at least some points of the pandemic. At the beginning of the first wave of the epidemic in Finland, there was much work to be done with regards to preparing the required increase in ICU capacity, and respondents reported that the majority of the ICU workforce worked overtime hours, even at night. All interviewees reported that in the first weeks of preparing for the pandemic, they had seen more overtime hours being made than that they had ever seen at the ICU. Healthcare professionals in Italy worked extremely long hours seven days a week, as there was simply not enough staff to meet the massive demand. Despite the need for staff, initially healthcare institutions (in this case, hospitals and elderly care homes) rejected help from medical professionals who were differently qualified, such as sports doctors, despite many of them being temporarily out of work due to the pandemic.

The ICU professionals in Finland reported that their calendars changed significantly in just a few weeks due to the preparation work and increased need of staffing in general. Non-COVID-19 related trainings were cancelled or postponed in Finland, Italy and Sweden. The healthcare professionals in managing roles saw an increase in the length of shifts in Sweden, even though they did not necessarily need to pick up extra shifts. Other healthcare professionals also reported working longer shifts and taking more shifts per week than normally. Holidays were postponed, conferences and off-site trainings cancelled and doctors specializing in intensive care and anaesthesiology were called back from their off-site postings in other specialties.

The workload and stress of the professionals was not spread out equally: respondents in all countries reported that especially the employees in manager positions worked extensive overtime. For example, in Finland, after the first patients arrived at the ICUs, most of the nurses and doctors handling the treatment of the patients said that the workdays were not drastically different compared to the normal state. The same cannot be said of the managers, senior doctors and head nurses with responsibilities: their workdays were consistently longer. Main sources of the increased load were organizing trainings, onboarding of the new employees and preparing guidelines for the treatment of COVID-19 patients.

The ICU professionals from the case countries agreed that the group spirit was higher than normal in the beginning of the pandemic with people trying to help each other and carry the extra load together while leaning on each other. This changed somewhat after it dawned as imminent that the pandemic and the elevated number of ICU patients it brought along was not going to be over in weeks but instead maybe months. Morale started to weaken as people grew tired in each case country. The professionals described how they were happy to do the extra work and it was self-evident for them to push through during this unforeseen crisis, but some interviewees perceived the reaction and response from the hospital management after the worst part of the crisis was over as lacking empathy and respect for the professionals' efforts. The nurses especially described how it made them feel irrelevant that they were praised for their successful efforts in fighting the pandemic but simultaneously their summer vacations were cut short and not all overtime was compensated.

Outside of the workplace, healthcare professionals acted like any other citizens in general. Nurses and doctors from each case country said that they started working remotely whenever possible, including a shift in their behaviour outside of work, reporting that they spent less time in public places, cancelled non-work-related plans and experienced stress and worry about infecting others with COVID-19 both inside and outside of the hospital. For the professionals having family members who are either elderly or belong in other risk groups, the spring was an especially challenging time and choosing to not spend time with family members in risk groups affected their own well-being psychologically. This was the case especially in Italy, where multi-generational households are more common. This led to a widespread fear amongst healthcare professionals of spreading the disease to their parents or grandparents at home. In Italy, there was a general feeling of tiredness from the overwork and the high stress level.

Professionals in each country felt there may be risk for mass resignations at some point in the future, however the perceived risk was different in each country. Especially our respondents from Sweden expressed a fear of mass resignations among ICU staff in the future. Longer than normal work hours, the extra stress that came with the unique differences of treating COVID-19 patients when compared to other ICU-patients (such as having to be meticulous with the use of PPE, COVID-19 patients' exceptionally long treatment periods and the concern regarding having a sufficient storage of PPE) and the lack of work-life balance resulting from practising social distancing all accounted for the exacerbated strain they endured during the spring. Majority of Swedish respondents voiced their concern for the potential second wave of COVID-19 and how difficult it would be to manage if key personnel would decide to change jobs as a response to the aftermath of the first infection wave. It is also interesting that while the interviewees in Sweden said that they managed the spring quite well considering how challenging it was, many of them are considering a career elsewhere or even a change to a different field altogether. In Finland and Italy, the risk appears to be less prevalent: most of the interviewees felt the staff have had to recover from the exhausting first wave over the course of summer and they felt leaving the hospital setting was unlikely. However, at least in Finland a few of the professionals said they know of colleagues who are considering leaving the hospital setting.

From the perspective of **management and leadership during a pandemic**, the perceived confusion and the spread of the pandemic taking the hospital management by surprise manifested itself in miscommunication or lack of communication at the beginning. The challenges in communication seemed to manifest itself mainly in two ways in all case countries. Firstly, there seemed to be noticeable hesitation regarding the decisions on PPE protocols for professionals. Secondly, communication between ICU wards and between different personnel groups was perceived slow and dysfunctional at the start of preparations: e.g. some nurses felt like there was an asymmetry of information regarding how severe the disease is or what the national epidemiological situation is. At the same time, the healthcare professionals all said that they understood the realities of working in large communities and during exceptional, quickly evolving situations like the COVID-19 pandemic, effective communication will always be difficult and the risk for information changing between transmitters increases.

It surprised some interviewed professionals in Italy that they were turned away after offering their help. Despite being a qualified doctor, albeit in sports medicine, they resorted to volunteering with paramedics and later assisting at care homes. A high level of frustration was felt at not being permitted to assist in the way that they felt matched their abilities. This, combined with mixed and contradictory communications from management, fuelled stress levels evermore.

ICU professionals thought there could be ways to improve the ways in which knowledge is shared within the hospital in pandemic scenarios. As mentioned before, management from a communication point of view is difficult in a quickly developing epidemic scenario. However, it was at times challenging to keep up with the continuously changing recommendations and communications between the management and the staff. Professionals in all countries brought up an elevated need for straightforward communication in the midst of constant changes to strategies and protocols. At the same time, interviewees felt that the organization cannot communicate “too much” in these kinds of situations and there should be enough resources reserved for sharing information. The interviewees in management roles in Sweden were privy to this information because they attended daily COVID-19 meetings yet voiced out how they did their best in communicating the current strategy and practices to their colleagues but found keeping everyone aligned challenging.

Temporary personnel, students and previous personnel were hired to support core ICU staff with the growing number of patients in all case countries. Anaesthesiology nurses were trained for ICU, and the anaesthesiology and intensive care double certified physicians that had been previously working as anaesthesiologists were quickly onboarded to work in an ICU setting.

Finnish and Swedish ICU professionals unanimously agreed that there were enough nurses and doctors arranged for the first wave of the COVID-19 pandemic at their ICU wards. However, Swedish professionals also emphasized that this was not the case in all Swedish hospitals since some areas and hospitals were much more strained resource-wise. The situation in Finland and Sweden was in stark contrast to the case in Italy, where interviewees reported that a shortage of staff was a severe problem at many medical centres in the beginning of the pandemic. As a result, healthcare professionals flew from many different parts of the country, mostly volunteering and paying for their own flights, in order to help the northern Italy when the crisis was at its worst. While generally the number of staff was sufficient after the beginning of the first wave in Italy and the volunteer professionals came in, the staff felt extremely overworked and exhausted over the course of the first wave despite staff increases. There was a feeling amongst the professionals that they could do this for a month, but after that everyone would be completely burned out.

The extra personnel provided much needed help to manage the growing number of patients, but at the same time brought up at least three challenges different from the normal ICU state. First, the general onboarding process was shortened, for example in the case of ICU nurses from three months to two weeks, increasing their need for support from more experienced colleagues. Organizing trainings and treatment simulations was challenging due to the fact that the entire workforce needed to be taught new skills and qualifications, so the traditional scope and scale of trainings with long-term capacity of the ICU workforce was smaller than what it was at the first wave of the epidemic. Second, there is usually more time for managers to get to know their new employees on an individual level and learn their existing skillset, allowing them to tailor their training even down to an individual level and provide more personal guidance. At the beginning of the first wave, getting to know the new doctors and nurses along with their skillset was close to impossible in the short term, especially when the experienced professionals had to be taught new qualifications as well. Third, handling the practical matters of the new staff caused a lot of work for shift managers and head nurses. The temporary personnel needed clearance passes, dressing room spaces, authorizations and user accounts for IT systems, which are the responsibility of the professionals in managing roles to take care of for the new employees.

In general, the professionals believed that hospital management genuinely tried to support them as well as they could, but at the same time they wished for more frequent and concrete actions of gratitude and support in future crisis situations. They reflected on how even small gestures of support impacting everyday work routines could be extremely helpful in enduring stress and working overtime. One Finnish professional gave an example on commuting: the preferred way of arriving at the workplace would be via car in order to minimize human contact. However, the use of their own cars was on a personal level disincentivized by the fact that the hospital parking lot comes at a cost for the hospital staff as well. On the other hand, using public transport was risky because the trains and trams were available less often and had a decreased passenger capacity, which made it difficult to maintain social distancing with other passengers. Therefore, social distancing in smaller commuter trains was harder to maintain. Arranging for extra public transportation or removing staff parking fees are just some of the examples how the management could have been able to ease the stress experienced by the professionals.

The availability of ICU resources and equipment, and the challenges the lack of those caused, varied between the case countries. Regarding the ICU treatment machinery, medicinal equipment and drugs needed in the ICU, in Finland the interviewees were largely unanimous in their views that there was close to no worry whether there would be sufficient resources and equipment. Compared to face masks, the public discussion regarding the sufficiency of equipment was practically non-existent in Finland, and it seemed like the ICU professionals shared this sentiment. However, there were a few specific pieces of equipment that had to be rationed at least in some wards during the first wave of COVID-19 pandemic. These included e.g. rectal filters, catheters and surgical suction pumps.

A second challenge in Finland regarded the ventilators and other machinery required in treating the COVID-19 patients: across ICU wards, the machinery differed in many ways (age, manufacturer, model etc.) which meant that the specific setups the COVID-19 patients required had to be done separately for each type of machine. Some of the Finnish professionals said that this caused challenges: if the hospital district owned the machinery instead of utilizing alternative supply methods such as leasing, the setup work and updates had to be done by the nurses on-site. According to the healthcare professionals, standard machinery between all ICU wards would make onboarding and daily work easier. In addition, if the machines would have been leased instead of owned, this would have allowed for the professionals to use their time more efficiently as the manufacturers would be responsible for adjusting the settings and providing technical support. Finally, leased machinery tends to be renewed more often which decreases the risk for malfunction at critical times.

In Italy, there was a shortage of breathing machines initially. In addition, basic medicines such as saline drips ran low due to inoperative distribution channels. However, it should be noted that the vast shortage of PPE and initial shortage of staff was a much larger issue. Also, the lack of COVID-19 tests was very visible, causing a lot of frustration amongst the medical staff. Healthcare professionals who tested positive or showed symptoms needed to quarantine for two weeks, and could only return to work upon testing negative *twice.* There were simply not enough tests for this, causing shortages of healthcare professionals.

In Sweden the ICU professionals reported that they did not experience a shortage of ventilators because those were moved to ICUs from other wards and a backup supply of old ventilators was collected (those never had to be used, though). However, there was a shortage of medicines such as propofol, oxycodone and multiple muscle relaxants that resulted in the usage of alternative medications. The interviewees emphasized the elevated need for muscle relaxant usage with the intubated COVID-19 patients compared to the other intubated ICU-patients, causing pressure on the supply of these drugs.

Regarding personal protective equipment (PPE), there were **shortages of face masks and protective suits**, especially in the beginning of the pandemic. Of different types of PPE, face masks were usually the most problematic equipment to procure.

The ICUs made their own calculations at the beginning of the first wave of the pandemic regarding the theoretical daily usage of face masks. The calculated demand for masks was remarkably higher compared to normal days at the ICU, and at some point, the professionals felt rationing and re-using face masks would become necessary. There were problems procuring PPE in Finland, and the quality of face masks was a common topic in the public discussion. Yet, according to the professionals, in the end, there were always enough masks, and most importantly masks of sufficient quality.

Again, in Italy the situation was very different. In northern Italy medical facilities ran out of masks or were on the verge of running out of masks during the initial wave. In the first month, before additional help came, some nurses and doctors would wear the same, normally single-usable and disposable, PPE for an entire week. The Italian respondents believed it was caused by problems in distribution: mask deliveries were delayed or stored in unsuitable places which caused massive delays further down the distribution channel. Some healthcare professionals ended up browsing online for masks, but the prices were seen as extortionate. An interviewee reported hearing that masks (as well as staff) had been brought to Italy from Germany, in addition to a delivery of masks arriving from China.

According to our Swedish interviewees, in Sweden the situation with PPE was at least satisfactory. The interviewees acknowledged that they were very low on protective gear supply, but since the ICU was prioritized over other wards (many of which also treated COVID-19 patients), there was never a situation where they were completely out of PPE. At some point the ICU personnel were handed personal gas masks by the Swedish military when the FFP-3 mask supply started running low. On the other hand, they reported that the protective visors and long-armed single use gowns were short at times. Additionally, the supply ran very low on protective gloves, hand sanitizer and sterilized water especially early on in the epidemic. But when the extra orders started coming in, this shortage was alleviated.

4.4 Discussion

The COVID-19 crisis in general **seemed to surprise the hospital management,** and the healthcare professionals felt that the hospital management did not take the threat of the epidemic reaching their countries as seriously as they could have. The interviewees emphasized how some preparations in the ICUs were done early and efficiently, but it was the hospital-level decision making and especially communication of the preparatory measures that was lacking. Even though epidemic outbreak plans were in place even before COVID-19, they seemed to have been insufficient in scope in the case of a novel virus with little to no information being available from the onset.

Two most important conclusions that can be drawn from the first wave of the COVID-19 pandemic from the perspective of healthcare professionals' stress and experiences relate to **communication** and **paying attention to the sources of perceived stress** of the healthcare professionals and how to mitigate it. These results follow findings from previous studies specifying the importance of timely and relevant communication in crises, and of the importance of trust in the information shared [96][97]. First, sufficient and uniform communication within organizations is of utmost importance during exceptional circumstances. New knowledge about the disease, its spread and new guidelines related to handling the disease emerges daily especially at the beginning of the pandemic. Based on the interviews, it is extremely stressful and difficult to keep up with the latest, up-to-date information. The hospitals might not have the resources to have constantly up-to-date data and information ready for communication, which implies that (e.g. national) support by providing more specific, up-to-date information to hospitals could be of use in the

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future. Second, it is extremely important to show support, understanding and appreciation to staff working under high stress and workload. Professionals experience stress and worry outside of the workplace and they were worried that they would spread the disease either at home or during commute. During the first wave of the COVID-19 pandemic, there was significant voluntary overtime and the professionals relied on the workplace community and team spirit to push through stress, even though overtime was not always compensated for and vacations were postponed or cancelled. The risk for mass resignations is relevant according to the respondents, especially in countries with the most patients, longest peaks of ICU utilization and longest first wave in general.

Increasing ICU capacity was not an easy task during the first wave of the COVID-19 pandemic from the perspective of how the preparations and capacity increase procedures affected the work of the healthcare professionals. Traditionally months long specialization and extended onboarding process was sped up in order to ensure sufficient staffing resources, which meant that the professionals in managing roles were under extensive stress. The differences between countries in availability of protective gear and other resources were apparent, and further increased the stress experienced by the professionals to varying degrees depending on the country.

5 Conclusions and discussion

In this chapter, we summarize the findings from the different focus areas and make policy recommendations based on the findings.

5.1 Conclusions

When comparing the effects of government interventions and the country features in **the statistical model for the outcome of COVID-19**, in all settings the interventions seemed to have larger effects on the daily change in COVID-19 mortality over the demographic, cultural or healthcare system characteristics of the countries. Thus, our findings suggest that interventions affecting the actions of the citizens had a central role in fighting the first wave of the pandemic. The results show that requiring all school levels to close, either recommending or requiring public events to be cancelled, recommending closing internal movement or restricting international travel, all had an effect to reduce mortality. That being said, it has to be noted that many of the interventions started and were in action at the same time, which causes the effects of distinct interventions to be difficult to separate. Furthermore, the model proved sensitive to a selection of country level features. Of the studied country level features, diabetes prevalence in the population and Geert Hofstede's masculinity index correlated with higher daily mortality change.

Regarding the **theoretical preparedness** of different countries, the countries that were better prepared in theory, suffered the worst outcomes in practice with two out of the three assessed preparedness indices. Thus, the theoretical preparedness to face sudden global health crises as we have previously understood them does not seem to be relevant in the case of a global pandemic such as COVID-19. This could be explained by the preparedness indices having been constructed based on the previous epidemics which have been either suppressed (e.g. SARS), have had a lower mortality (e.g. H1N1 of 2009) or have transmitted with a slower pace (e.g. HIV).

Comprehensive **testing of the potentially infected** and the related contact tracing for the infected appeared to be a part of successful strategies to reduce the spread of the virus during the first wave of the COVID-19. Countries seemed to apply different testing strategies over the spring of 2020: both the scale of testing (tests per population and tests per positive test result) and timing of intensive testing in relation to the first COVID-19 related death in the country. It would seem that countries that managed to control the spread of the virus employed more extensive testing strategies earlier on in the epidemic than other countries. However, when analysing the testing strategies, we should remember to consider the shortages in testing capacity. Different testing strategies were not actually decisions whether to test the potentially infected or not, but rather whether to invest in increasing the testing capacity or not.

Within the most critical **intensive care** treatment for the infected, there was significant variation in the ICU capacity utilization between both the European countries and some country-specific regions that were analysed. There were many regions and even whole countries where the ICU capacity utilization increased to levels exceeding the total normal state ICU capacity. Such overload situations may increase mortality when sufficient life support equipment is not available, and the risk for malpractice incidents increases as especially the strain on the personnel with ICU expertise increases remarkably. It remains uncertain whether there were situations where patients who would benefit from the intensive care but could not be admitted to ICUs, or not.

To mitigate the risk of the overload situations and the increasing risk of malpractices, there may have been possibilities to decrease mortality by distributing the load on ICUs in different areas. The findings of this study indicate that there appeared to be instances where either the COVID-19 patients or ICU personnel and capacity could have been shared across regional or national borders.

In order to support **healthcare professionals** in times of crisis, the two most important conclusions relate to communication and acts of understanding and appreciation of their stress. First, the importance of sufficient and uniform communication within organizations cannot be understated. Especially in case of quickly escalating outbreak caused by a novel virus, the emergence of new knowledge about the disease and its spread as well as guidelines for professionals takes place on a daily basis, making it hard to keep up with the latest information. Second, it is extremely important to show support, understanding and appreciation to staff working under high stress and workload. Professionals experience stress and worry outside of the workplace and they were worried that they would spread the disease either at home or during commute.

From the perspective of healthcare professionals and their daily work, increasing ICU capacity is not easy. Training and onboarding of new staff takes normally several months, but this process was sped up in order to ensure sufficient staffing resources. Ramping up increased the workload for nurses and doctors in managing roles. Also, specifically in Italy there was some frustration among healthcare professionals volunteering for a rapid response workforce that their help was not accepted since their field of specialty was not directly related. Finally, there were differences between countries in availability of protective gear.

5.2 Policy recommendations

According to a generally recognized dynamic within the social and healthcare sector, prevention is more powerful than treatment[98]. Based on the results from this study, **interventions designed to prevent the spread of the virus did seem to have an effect on the mortality change**. Social distancing interventions seemed to be more effective in preventing COVID-19 deaths than country characteristics and healthcare system responsiveness.

Most of the country features, on the other hand, be it demographic, cultural or healthcare system specific, did not seem to have an effect on the mortality change, at least in this country level study. Even good preparedness for pandemics did not always protect from the impact of COVID-19.

Intervention decisions by the governments undoubtedly saved lives, but also led to economic and social problems, which were not analysed in this study. In addition, interventions differed from one country to another, resulting in questions about the suitability and the timing of the choices made in respective countries. Closing borders has been a widely utilized action by the governments to restrict movement, violating the freedom of movement within the EU and constitutional rights of people in many countries. To lift the containment measures, a European roadmap was created to enable a coordinated way to enter the recovery phase.[99] But, in case COVID-19 spreads further and governments face pressure to reinstate social distancing measures, the EU could devise a common framework for interventions in a similar way it has done with lifting the containment measures.

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The COVID-19 pandemic also showed that the healthcare systems of European countries were ill equipped to manage the different effects of the pandemic regardless of having ample healthcare resources and ranking high in preparedness indices. Clearly, systems were slow to ramp up capacity required to test and treat COVID-19 patients. **More cooperation across regional and national borders could have helped the areas worst affected by the pandemic**. This includes sharing materials, professionals and even patients. Some patients were in fact transferred within countries and even cross borders, but only to a limited extent. One reason for limited cross-border cooperation may have been the lack of information regarding the situations across the border.

Improving the access, reliability, precision and timeliness of the pandemic related data would help the decision-makers with a wide spectrum of decisions. The situations where better data would improve the decisions are numerous: decisions regarding the travel restrictions, decisions regarding the internal social distancing interventions and decisions regarding the redistribution of patients for example. Some of the decisions are required to prevent the virus from spreading whereas some decisions are required to keep healthcare service utilization rates feasible. These decisions may have a significant effect not only on the health outcomes of a pandemic but also on the economic and the social outcomes resulting from the different decisions.

Improved access to data, e.g. open access to relevant information from different primary sources in different countries on a single portal or platform. Since the pandemic started, the numbers of confirmed COVID-19 infections and deaths were quickly found from different web portals. However, the data could be supplemented from the very beginning with new kinds of data such as utilization and available capacities in health care or amounts of tests conducted. This kind of data is already partly available on, for example, websites of the national healthcare institutions.

The improved reliability of data relates mainly to the different biases in the numbers of positive test results reported. During the spring of 2020, experts and policy-makers had data available of both the absolute number of positives and relative number of positives per population. These figures often failed to describe the situation equally as the testing criteria varied significantly between countries and over time. The figures appear different whether the testing was available for the whole population or whether the limited testing capacity was targeted only to specific groups such as the elderly. The equality failed both between countries with different criteria and also within a certain country over time if the country changed its testing criteria. As the testing coverages varied significantly in the early days of the pandemic estimating the pace of the spread of the virus was very open to misinterpretations.

With improved precision and timeliness, the processes to gather and combine data from bottom-up should be streamlined as early as possible. During the spring of 2020, there were numerous inconsistencies in the data due to the different data gathering cycles and late additions of data. This, again, may easily lead to misinterpretations.

Paying attention to the stress and workload of the professionals after the initial first wave should be a high priority for the hospital management. The professionals should be compensated for their efforts during the stressful periods by allowing them to have the chance for sufficient recovery from the intense preparation and increased workload; also, monetary compensations and other forms of compensation should be utilized if at all possible. In the case of COVID-19, the first wave was mostly handled with voluntary overtime, pushing through utilizing the high team spirit and working for the greater good, even though overtime was not always compensated for and vacations were postponed or cancelled. The risk for mass resignations certainly exists based on the interviews, especially in areas and professional groups where the stress and workload were the most extreme. Based on the interviews, the risk is the highest especially if the second wave of the local pandemic starts and when it starts to fiddle out (which is when professionals considering a change of field could leave the hospital setting with a “good conscience”).

In order to support hospital management in communicating uniform, sufficient information, **policymakers** (such as the European Union) **should consider looking into the possibility of providing more or more specific guidelines and recommendations** to pandemic management at the hospital level decision-making. The healthcare professionals as well as hospital management could evaluate different scenarios related to e.g. pandemic preparation, epidemiological overview both on a local and global level, treatment requirements and treatment processes more accurately qualitatively or quantitatively, if the hospitals had more reliable data or more information in general available.

Regarding the future, the indirect harm to the well-being of EU citizens due to COVID-19 certainly needs to be studied in detail. Issues include for example increase in untreated diseases, increase in deaths due other causes than COVID-19, increase in marginalization and decrease in the financial standing of countries.

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Annexes

Annex 1: Descriptive statistics of the country features

	AUT	BEL	BGR	HRV	CZE	DNK	EST	FIN	FRA	DEU	GRC
alcohol	11.60	12.10	12.70	8.90	14.40	10.40	11.60	10.70	12.60	13.40	10.40
arrivals	29 460 000	8 385 000	8 883 000	15 593 000	10 160 000	11 743 000	3 245 000	3 180 000	86 861 000	37 452 000	27 194 000
atms	168.89	87.45	92.89	147.65	57.09	47.90	68.14	34.84	98.30	118.22	62.34
blood_a_minus	0.07	0.06	0.07	0.06	0.06	0.07	0.05	0.06	0.07	0.06	0.05
blood_a_plus	0.37	0.34	0.37	0.36	0.36	0.37	0.31	0.35	0.37	0.37	0.33
blood_ab_minus	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
blood_ab_plus	0.05	0.04	0.07	0.05	0.07	0.04	0.06	0.07	0.03	0.04	0.04
blood_b_minus	0.02	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.01	0.02	0.02
blood_b_plus	0.12	0.09	0.13	0.15	0.15	0.08	0.21	0.16	0.09	0.09	0.11
blood_o_minus	0.06	0.07	0.05	0.05	0.05	0.06	0.04	0.05	0.06	0.06	0.07
blood_o_plus	0.30	0.38	0.28	0.29	0.27	0.35	0.30	0.28	0.36	0.35	0.37
blood_pressure	21.00	17.50	28.40	32.40	27.90	20.60	27.40	19.40	22.00	19.90	19.10
bmi	25.60	26.10	26.40	27.40	27.10	25.30	26.40	25.90	25.00	26.60	27.10
cholesterol	59.70	62.40	49.90	49.80	53.90	65.20	56.70	59.00	62.00	65.60	48.20
corruption	77.00	75.00	43.00	47.00	56.00	87.00	74.00	86.00	69.00	80.00	48.00
diabetes	6.60	4.60	6.00	5.40	7.00	8.30	4.20	5.60	4.80	10.40	4.70
gdp	51 462	47 519	9 273	14 910	23 079	61 350	23 266	50 152	41 464	47 603	20 324
gini	29.70	27.40	40.40	30.40	24.90	28.70	30.40	27.40	31.60	31.90	34.40
gov_eff	1.45	1.17	0.27	0.46	0.92	1.87	1.19	1.98	1.48	1.62	0.34
hc_costs	4 688	4 149	612	884	1 322	5 566	1 185	4 117	4 263	4 714	1 511
hc_costs_of_gdp	10.44	10.04	8.23	7.18	7.15	10.35	6.68	9.49	11.54	11.14	8.45
hci	0.79	0.76	0.68	0.72	0.78	0.77	0.75	0.81	0.77	0.80	0.68
hdi	0.91	0.92	0.82	0.84	0.89	0.93	0.88	0.93	0.89	0.94	0.87
hofstede_pdi	11.0	65.0	70.0	73.0	57.0	18.0	40.0	33.0	68.0	35.0	60.0
hofstede_idv	55.0	75.0	30.0	33.0	58.0	74.0	60.0	63.0	71.0	67.0	35.0
hofstede_mas	79.0	54.0	40.0	40.0	57.0	16.0	30.0	26.0	43.0	66.0	57.0
hofstede_uai	70.0	94.0	85.0	80.0	74.0	23.0	60.0	59.0	86.0	65.0	112.0
hofstede_ltowvs	60.0	82.0	69.0	58.0	70.0	35.0	82.0	38.0	63.0	83.0	45.0
hospital_beds	7.60	6.20	6.80	5.60	6.50	2.50	5.00	4.40	6.50	8.30	4.30
household	2.27	2.36	2.34	2.80	2.40	2.10	2.30	2.07	2.26	2.14	2.56
illnesses	11.40	11.40	23.60	16.70	15.00	11.30	17.00	10.20	10.60	12.10	12.40
internet	87.94	87.68	63.41	67.10	78.72	97.10	88.10	80.50	48.05	34.67	55.86
life_exp	81.64	81.44	74.81	77.83	79.48	81.00	77.64	81.43	82.52	80.99	81.39
mobile_subs	123.54	99.70	118.94	105.58	119.11	125.12	145.44	129.47	108.36	129.32	115.67
nurses	8.18	11.10	5.30	8.11	8.41	10.30	6.45	14.72	9.69	13.20	3.37
oop_hc	18.92	15.86	47.95	15.36	15.02	13.71	22.69	20.35	9.76	12.41	34.34
physicians	5.14	3.32	3.99	3.00	4.31	4.46	3.47	3.81	3.23	4.21	4.59
pollution	12.48	12.89	19.15	17.90	16.07	10.03	6.73	5.86	11.81	12.03	16.22
pop_density	107.21	377.21	64.70	73.08	137.60	138.07	30.39	18.16	122.34	237.37	83.22
pop_gender	1.06	1.05	1.06	1.06	1.06	1.06	1.07	1.05	1.05	1.05	1.07
pop_tot	8 847 037	11 422 068	7 024 216	4 089 400	10 625 695	5 797 446	1 320 884	5 518 050	66 987 244	82 927 922	10 727 668
pop_urban	58.30	98.00	75.01	56.95	73.79	87.87	68.88	85.38	80.44	77.31	79.06
priv_share	27.49	15.89	49.44	21.75	18.12	15.88	24.37	22.64	17.10	15.33	39.00
services_of_gdp	71.67	78.40	63.44	67.02	59.58	79.37	66.91	74.50	77.28	71.86	72.88
smoking	29.60	28.20	37.00	37.00	34.30	19.10	31.30	20.40	32.70	30.60	43.40
unemployment	4.64	6.44	4.82	7.77	2.47	4.83	5.88	7.25	9.10	3.20	18.08
vaccine_dpt	85.00	98.00	92.00	93.00	96.00	97.00	92.00	91.00	96.00	93.00	99.00
vaccine_measles	94.00	96.00	93.00	93.00	96.00	95.00	87.00	96.00	90.00	97.00	97.00
women_labour	83.39	81.64	80.37	78.81	76.86	88.07	80.49	88.51	84.10	83.65	74.82

	HUN	IRL	ISR	ITA	JPN	LUX	NLD	NZL	NOR	POL	PRT
alcohol	11.40	13.00	3.80	7.50	8.00	13.00	8.70	10.70	7.50	11.60	12.30
arrivals	5 650 000	10 338 000	3 613 000	58 253 000	28 691 000	1 046 000	17 924 000	3 555 000	6 252 000	18 258 000	15 432 000
atms	60.52	79.14	128.07	91.14	127.59	117.40	41.15	64.66	34.55	70.78	165.69
blood_a_minus	0.07	0.05	0.04	0.06	0.00	0.06	0.07	0.06	0.07	0.06	0.07
blood_a_plus	0.33	0.26	0.34	0.36	0.40	0.37	0.35	0.32	0.42	0.32	0.40
blood_ab_minus	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
blood_ab_plus	0.08	0.02	0.07	0.03	0.10	0.04	0.03	0.03	0.03	0.07	0.03
blood_b_minus	0.03	0.02	0.02	0.02	0.00	0.02	0.01	0.02	0.01	0.02	0.01
blood_b_plus	0.16	0.09	0.17	0.08	0.20	0.09	0.07	0.09	0.07	0.15	0.07
blood_o_minus	0.05	0.08	0.03	0.07	0.00	0.06	0.08	0.09	0.06	0.06	0.06
blood_o_plus	0.27	0.47	0.32	0.39	0.30	0.35	0.40	0.38	0.33	0.31	0.36
blood_pressure	30.00	19.70	16.60	21.20	17.60	21.90	18.70	16.20	19.70	28.70	24.40
bmi	27.30	27.50	27.30	25.60	22.70	26.30	25.60	28.00	26.70	26.70	25.60
cholesterol	55.20	62.60	53.50	62.20	57.10	66.90	60.50	56.20	61.90	57.10	55.90
corruption	44.00	74.00	60.00	53.00	73.00	80.00	82.00	87.00	84.00	58.00	62.00
diabetes	6.90	3.20	9.70	5.00	5.60	5.00	5.40	6.20	5.30	6.10	9.80
gdp	16 162	78 806	41 715	34 483	39 290	116 640	53 024	41 945	81 697	15 421	23 408
gini	30.60	32.80	39.00	35.90	32.90	34.90	28.50	34.90	27.00	29.70	33.80
gov_eff	0.49	1.42	1.21	0.41	1.68	1.78	1.85	1.67	1.89	0.66	1.21
hc_costs	943	4 759	2 837	2 739	4 233	6 271	4 742	3 745	7 478	809	1 801
hc_costs_of_gdp	7.36	7.38	7.31	8.94	10.93	6.16	10.36	9.22	10.50	6.52	9.08
hci	0.70	0.81	0.76	0.77	0.84	0.69	0.80	0.77	0.77	0.75	0.78
hdi	0.84	0.94	0.91	0.88	0.91	0.91	0.93	0.92	0.95	0.87	0.85
hofstede_pdi	46.0	28.0	13.0	50.0	54.0	40.0	38.0	22.0	31.0	68.0	63.0
hofstede_idv	80.0	70.0	54.0	76.0	46.0	60.0	80.0	79.0	69.0	60.0	27.0
hofstede_mas	88.0	68.0	47.0	70.0	95.0	50.0	14.0	58.0	8.0	64.0	31.0
hofstede_uai	82.0	35.0	81.0	75.0	92.0	70.0	53.0	49.0	50.0	93.0	104.0
hofstede_ltowvs	58.0	24.0	38.0	61.0	88.0	64.0	67.0	33.0	35.0	38.0	28.0
hospital_beds	7.00	2.80	3.10	3.40	13.40	4.80	4.70	2.80	3.90	6.50	3.40
household	2.60	2.81	3.14	2.40	2.42	2.41	2.23	2.70	2.22	2.82	2.66
illnesses	23.00	10.30	9.60	9.50	8.40	10.00	11.20	10.10	9.20	18.70	11.10
internet	98.24	81.58	61.30	44.37	62.30	9.80	88.47	24.57	15.51	94.29	63.75
life_exp	76.06	81.96	82.60	83.24	84.10	82.69	81.56	81.66	82.51	77.85	81.12
mobile_subs	103.45	103.17	127.66	137.47	141.41	132.16	123.73	134.93	107.17	134.75	115.63
nurses	6.64	14.29	5.20	5.87	11.52	12.35	11.10	10.96	18.12	5.72	6.37
oop_hc	29.70	12.99	22.97	23.11	13.45	11.23	11.45	13.58	14.52	22.94	27.75
physicians	3.23	3.09	3.22	4.09	2.41	3.03	3.51	3.03	4.63	2.40	3.34
pollution	15.93	8.21	21.38	16.75	11.70	10.36	12.03	5.96	6.96	20.88	8.16
pop_density	107.91	70.45	410.53	205.45	347.07	250.09	511.46	18.55	14.55	124.04	112.24
pop_gender	1.06	1.06	1.05	1.06	1.06	1.05	1.05	1.06	1.06	1.06	1.06
pop_tot	9 768 785	4 853 506	8 883 800	60 431 283	126 529 100	607 728	17 231 017	4 885 500	5 314 336	37 978 548	10 281 762
pop_urban	71.35	63.17	92.42	70.44	91.62	90.98	91.49	86.54	82.25	60.06	65.21
priv_share	34.14	27.93	35.97	25.54	16.41	17.63	19.02	21.35	14.87	30.12	33.65
services_of_gdp	63.89	76.75	81.81	70.66	72.24	88.24	81.63	73.50	78.89	58.61	69.32
smoking	30.60	24.30	25.20	23.70	22.10	23.50	25.80	16.00	20.20	28.00	22.70
unemployment	3.46	5.28	3.93	9.22	2.41	5.41	3.76	4.81	3.97	3.27	6.13
vaccine_dpt	99.00	94.00	98.00	95.00	99.00	99.00	93.00	93.00	96.00	95.00	99.00
vaccine_measles	99.00	92.00	98.00	93.00	97.00	99.00	93.00	92.00	96.00	93.00	99.00
women_labour	74.54	81.16	85.84	68.71	72.96	85.54	84.43	85.37	90.52	74.68	83.98

	ROU	SRB	SGP	SVN	ZAF	KOR	ESP	SWE	CHE	UKR	GBR
alcohol	12.70	11.10	2.00	12.60	9.30	10.20	10.00	9.20	11.50	8.60	11.50
arrivals	10 926 000	1 497 000	13 903 000	3 586 000	10 285 000	13 336 000	81 786 000	7 054 000	9 889 000	14 230 000	37 651 000
atms	64.49	48.75	66.46	90.03	66.66	272.82	108.58	32.01	99.19	97.36	115.67
blood_a_minus	0.07	0.07	0.00	0.07	0.05	0.00	0.07	0.07	0.07	0.06	0.07
blood_a_plus	0.37	0.35	0.24	0.33	0.32	0.34	0.36	0.37	0.38	0.34	0.32
blood_ab_minus	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
blood_ab_plus	0.07	0.04	0.06	0.06	0.03	0.11	0.03	0.05	0.04	0.05	0.03
blood_b_minus	0.02	0.02	0.00	0.03	0.02	0.00	0.02	0.02	0.01	0.02	0.02
blood_b_plus	0.14	0.13	0.25	0.12	0.12	0.27	0.08	0.10	0.08	0.15	0.08
blood_o_minus	0.05	0.06	0.01	0.07	0.06	0.00	0.09	0.06	0.06	0.05	0.09
blood_o_plus	0.28	0.32	0.45	0.31	0.39	0.28	0.35	0.32	0.35	0.32	0.38
blood_pressure	30.00	29.50	14.60	30.50	26.90	11.00	19.20	19.30	18.00	27.10	15.20
bmi	26.90	26.10	23.60	26.60	27.30	23.80	25.90	26.00	25.20	26.60	27.10
cholesterol	45.80	49.80	57.50	56.30	35.50	42.50	56.10	51.80	59.20	44.40	63.40
corruption	44.00	39.00	85.00	60.00	44.00	59.00	62.00	85.00	85.00	30.00	77.00
diabetes	6.90	9.00	5.50	5.90	12.70	6.90	6.90	4.80	5.70	6.10	3.90
gdp	12 301	7 247	64 582	26 124	6 374	31 363	30 371	54 608	82 797	3 095	42 944
gini	36.00	36.20	45.90	24.20	63.00	31.60	34.70	28.80	32.70	26.10	34.80
gov_eff	-0.25	0.11	2.23	1.13	0.34	1.18	1.00	1.83	2.04	-0.42	1.34
hc_costs	476	494	2 462	1 834	428	2 044	2 390	5 711	9 836	141	3 958
hc_costs_of_gdp	4.98	9.14	4.47	8.47	8.11	7.34	8.97	10.93	12.25	6.73	9.76
hci	0.60	0.76	0.88	0.79	0.41	0.85	0.74	0.80	0.77	0.65	0.78
hdi	0.82	0.80	0.93	0.90	0.70	0.91	0.89	0.94	0.95	0.75	0.92
hofstede_pdi	90.0	86.0	74.0	71.0	49.0	60.0	57.0	31.0	34.0	92.0	35.0
hofstede_idv	30.0	25.0	20.0	27.0	65.0	18.0	51.0	71.0	68.0	25.0	89.0
hofstede_mas	42.0	43.0	48.0	19.0	63.0	39.0	42.0	5.0	70.0	27.0	66.0
hofstede_uai	90.0	92.0	8.0	88.0	49.0	85.0	86.0	29.0	58.0	95.0	35.0
hofstede_ltowvs	52.0	52.0	72.0	49.0	34.0	100.0	48.0	53.0	74.0	86.0	51.0
hospital_beds	6.30	5.70	2.40	4.60	2.80	11.50	3.00	2.60	4.70	8.80	2.80
household	2.88	2.88	3.29	2.47	3.38	3.90	2.69	2.20	2.20	2.46	2.35
illnesses	21.40	19.10	9.30	12.70	26.20	7.80	9.90	9.10	8.60	24.70	10.90
internet	20.00	11.77	78.89	1.88	84.60	98.00	28.00	93.71	31.87	53.00	94.78
life_exp	75.31	76.09	82.90	81.18	63.54	82.63	83.33	82.31	83.60	71.78	81.16
mobile_subs	116.25	95.78	148.82	118.67	159.93	129.67	115.99	126.83	126.77	127.75	118.37
nurses	6.10	6.12	7.21	9.68	3.52	6.97	5.53	11.54	17.28	7.06	8.29
oop_hc	20.75	40.50	31.17	12.00	7.75	33.31	23.83	15.24	29.56	54.34	15.12
physicians	2.26	3.13	2.31	3.00	0.91	2.37	4.07	5.40	4.24	3.01	2.81
pollution	14.61	24.73	19.08	16.02	25.10	25.04	9.70	6.18	10.30	20.31	10.47
pop_density	84.64	79.83	7 953.00	102.64	47.63	529.65	93.53	25.00	215.52	77.03	274.83
pop_gender	1.06	1.07	1.07	1.06	1.03	1.06	1.06	1.06	1.05	1.06	1.05
pop_tot	19 473 936	6 982 084	5 638 676	2 067 372	57 779 622	51 635 256	46 723 749	10 183 175	8 516 543	44 622 516	66 488 991
pop_urban	54.00	56.09	100.00	54.54	66.36	81.46	80.32	87.43	73.80	69.35	83.40
priv_share	21.81	41.85	45.47	27.71	44.27	40.85	28.76	16.49	37.22	56.76	19.76
services_of_gdp	47.55	57.96	83.02	61.68	71.73	70.48	76.02	80.39	76.80	60.53	80.89
smoking	29.70	38.90	16.50	22.50	20.30	23.30	29.30	18.80	25.70	28.90	22.30
unemployment	4.16	13.51	3.62	5.50	27.32	3.71	14.70	6.84	4.87	9.31	3.81
vaccine_dpt	86.00	96.00	96.00	93.00	74.00	98.00	93.00	97.00	96.00	50.00	94.00
vaccine_measles	90.00	92.00	95.00	93.00	70.00	98.00	97.00	97.00	96.00	91.00	92.00
women_labour	70.75	75.34	79.34	85.30	77.92	71.94	81.79	90.53	84.78	74.20	84.39

Annex 2: Correlation table of selected country features

	blood_ab_plus	blood_o_plus	corruption	diabetes	gini	hci	hofstede_mas	life_exp	nurses	pollution	priv_share	unemployment	vaccine_dpt
blood_ab_plus	1.00												
blood_o_plus	-0.72	1.00											
corruption	-0.21	0.34	1.00										
diabetes	0.04	-0.13	-0.29	1.00									
gini	-0.15	0.36	-0.22	0.49	1.00								
hci	0.17	0.07	0.58	-0.42	-0.56	1.00							
hofstede_mas	0.13	0.09	-0.13	0.05	0.28	-0.06	1.00						
life_exp	-0.04	0.18	0.65	-0.48	-0.50	0.85	-0.01	1.00					
nurses	-0.17	0.14	0.71	-0.33	-0.43	0.42	-0.14	0.47	1.00				
pollution	0.35	-0.16	-0.72	0.42	0.42	-0.35	0.18	-0.51	-0.63	1.00			
priv_share	0.17	0.01	-0.60	0.27	0.44	-0.33	0.07	-0.49	-0.52	0.66	1.00		
unemployment	-0.39	0.23	-0.42	0.36	0.59	-0.68	0.00	-0.54	-0.43	0.31	0.37	1.00	
vaccine_dpt	0.09	0.05	0.42	-0.18	-0.14	0.53	0.11	0.65	0.19	-0.26	-0.47	-0.34	1.00
vaccine_measles	0.24	-0.19	0.28	-0.29	-0.62	0.70	-0.03	0.76	0.30	-0.29	-0.23	-0.62	0.53

Annex 3: Days between first start of different interventions, in categories

	Intervention	N	Avg. 1st executed	1	2	3	4	5	6	7	8	9	10
1	c1_school_any_mes	33	11 March										
2	c2_work_any_mes	33	14 March	-3									
3	c3_events_any_mes	33	7 March	4	7								
4	c4_gatherings_any_mes	32	15 March	-4	-1	-8							
5	c5_transport_any_mes	23	19 March	-8	-6	-13	-4						
6	c6_curfew_any_mes	31	17 March	-6	-3	-10	-2	3					
7	c7_movement_any_mes	33	15 March	-4	-1	-8	0	5	2				
8	c8_travelctrl_any_mes	32	24 February	16	19	12	20	24	22	20			
9	h1_campaigns_any_mes	33	11 February	29	32	25	33	37	35	33	13		
10	h2_testing_any_policy	33	18 February	22	25	18	26	30	28	26	6	-7	
11	h3_tracing_any_tracing	32	26 February	15	17	10	19	23	20	18	-2	-15	-8

Annex 4: Days between first start of different interventions, independently

	Intervention	N	Avg. 1st executed	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	c1_school_rec	12	29 May																												
2	c1_shool_req_some	28	7 May	21																											
3	c1_school_req_all	29	14 March	75	54																										
4	c2_work_rec	25	14 April	45	23	-31																									
5	c2_work_req_some	29	7 April	52	30	-24	7																								
6	c2_work_req_all	20	22 March	68	47	-8	23	16																							
7	c3_events_rec	20	23 April	36	14	-40	-9	-16	-32																						
8	c3_events_req	30	11 March	78	57	3	34	27	10	43																					
9	c4_gatherings_1000plus	9	20 April	39	17	-37	-6	-13	-29	3	-40																				
10	c4_gatherings_100_1000	23	23 April	36	15	-40	-9	-16	-32	0	-42	-3																			
11	c4_gatherings_10_100	23	29 April	30	9	-46	-15	-22	-38	-6	-48	-9	-6																		
12	c4_gatherings_10minus	27	20 March	69	48	-6	25	18	2	34	-9	31	33	39																	
13	c5_transport_rec	19	28 March	61	40	-14	17	9	-7	25	-17	22	25	31	-8																
14	c5_transport_req	7	24 March	65	44	-10	21	14	-2	30	-13	27	30	35	-4	4															
15	c6_curfew_rec	28	11 April	48	26	-28	3	-4	-20	12	-31	9	12	18	-22	-13	-18														
16	c6_curfew_req_loose	23	22 March	68	47	-8	23	16	0	32	-10	29	32	38	-1	7	3	20													
17	c7_movement_rec	26	31 March	58	37	-17	14	7	-9	23	-20	20	22	28	-11	-3	-7	11	-10												
18	c7_movement_req	21	23 March	66	45	-9	22	15	-2	31	-12	28	30	36	-3	5	1	19	-2	8											
19	c8_travelctrl_screening	17	29 February	89	68	14	45	37	21	53	11	51	53	59	20	28	24	41	21	31	23										
20	c8_travelctrl_quarantine	15	15 April	44	23	-32	-1	-8	-24	8	-34	5	8	14	-26	-17	-22	-4	-24	-14	-22	-45									
21	c8_travelctrl_ban_high_risk	29	15 March	75	54	-1	30	23	7	39	-3	36	39	45	6	14	9	27	7	17	9	-14	31								
22	c8_travelctrl_total_closure	18	20 March	70	49	-6	25	18	2	34	-8	31	34	40	1	9	4	22	2	12	4	-19	26	-5							
23	h1_campaigns_individual	11	3 February	115	94	40	71	64	48	80	37	77	80	85	46	54	50	68	48	57	49	26	72	41	46						
24	h1_campaigns_coordinated	33	18 February	100	79	25	56	48	32	64	22	62	64	70	31	39	35	53	32	42	34	11	56	25	30	-15					
25	h2_testing_criteria	31	18 February	101	80	25	56	49	33	65	23	62	65	71	32	40	36	53	33	43	35	12	57	26	31	-15	1				
26	h2_testing_symptoms	27	12 April	46	25	-29	2	-5	-21	11	-32	8	11	16	-23	-15	-19	-1	-21	-12	-20	-43	3	-28	-23	-69	-54	-54			
27	h2_testing_open	11	6 May	23	2	-53	-22	-29	-45	-13	-55	-16	-13	-7	-46	-38	-43	-25	-45	-35	-43	-66	-21	-52	-47	-93	-77	-78	-24		
28	h3_tracing_limited	19	7 March	83	62	7	38	31	15	47	5	44	47	53	13	22	17	35	15	24	16	-6	39	8	13	-33	-17	-18	36	60	
29	h3_tracing_comprehensive	29	13 March	77	56	1	32	25	9	41	-1	38	41	47	8	16	11	29	9	19	11	-12	33	2	7	-39	-23	-24	30	54	-6

Annex 5: Interview guide for professional interviews

Questions

0. **Background**: duration of employment, profession, experience
1. **At the start:** Things that are easy to talk about
    a. Describe briefly a regular day at work in general terms
    b. What tasks fill up your workday?
    c. Did you have any plans for the past spring, e.g. vacation?
    d. What went through your head when you first heard about the first COVID-19 case in your country?
    e. What was the COVID-19 situation at your hospital?
2. **The core questions related to the themes**
    a. Changes at the hospital caused by the epidemic
    b. General feelings and emotions of a HC professional in a crisis
    c. Management and leadership under a crisis and demand surge
    d. Changes in the behavior of a HC professional outside of work
    e. Questions related to resources and equipment:
        i. Have they faced any shortage of personal protective equipments?
        ii. Have they faced any shortage of ventilators and other medical equipments?
        iii. Have they faced any shortage of medicines to fight COVID-19?
        iv. What are the measures to mitigate the challenges related to the medical supplies?
3. **Future**
    a. How do you feel about the future at work?
    b. Worries related to COVID-19?
    c. Do you feel like continuing at your current position in the future?
    d. How could the hospital, the community and the government prepare better for possible second wave of infections?
4. **Final five minutes**
    a. Summarizing the output of the interview in general
    b. Some spare time for final questions
    c. Before the end: asking for permission to get back to the interviewee at later point IF any need for clarifications come up

<u>Supplementary list of questions</u>

Changes at the hospital caused by the epidemic

- Has the treatment of patients changed during the pandemic?
- What have been the strengths of your process? What are the development areas?
- What could be learned from other cities, areas or countries?
- Have the customers / patients been happy with the treatment and processes?
- Is it feasible to transfer patients with respiratory diseases requiring ICU level care from one country to another? If yes, is there an upper limit and how should it be done?
- Would it have been feasible for your hospital to receive hospital from farther reaches of the country or Europe? Why or why not?

General feelings and emotions of a HC professional in a crisis

- How did you and your colleagues feel about the epidemic on a personal level and how did it effect on your work? How do you feel about it now?
- Has the work been manageable over the course of the epidemic?
- When was the worst time at the front line?

Management and leadership under a crisis and demand surge

- Has the hospital management responded well to the epidemic?
- Have the professionals at the ward been heard in strategic decision-making, w.r.t. The COVID-19 pandemic management?
- Has the leadership and management been effective?
- Has the capacity been adequate from the personnel and equipment standpoint?
- Have the instructions and guidelines on treatment been communicated clearly?
- Has the resourcing been challenging? Why or why not?

Changes in the behavior of a HC professional outside of work

- How did the epidemic change your behavior outside of work?
- In what ways the epidemic has been stressful? What were the reasons for it?