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Visualization and Analysis of data related to Government Restrictive Measures on COVID-19

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VISUALIZATION AND ANALYSIS OF DATA RELATED TO GOVERNMENT RESTRICTIVE MEASURES ON COVID-19

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Abstract

From January 2020 onward, many countries around the world adopted government measures with the purpose of restricting the COVID-19 pandemic. In this thesis, initially a dashboard has been developed which provides interactive visualisations of the data related to the COVID-19 government measures. Subsequently, a number of analyses were carried out to find out whether the Greek government was taking measures in relation to the COVID-19 positive test rate and at what distance of days, using the cross-correlation method. For some selected European countries (Cyprus, France, Greece, Ireland, Malta and Norway), their correlation with regard to their government measures is first estimated to determine how similarly they reacted to the tightening and the relaxing of measures and, secondly, at which distance of days their measures had the highest cross-correlation. The Greek government's measures showed a high correlation with the COVID-19 positive test rate, at a distance of +13 days. This behavior is explained by the fixed weekly-based reassessment of the COVID-19 situation in that country. Mediterranean countries were found to demonstrate similar behavior, a finding attributed to the fact that their economies are mainly driven by the tourist sector.

Keywords: Dashboard, COVID-19 Positive Test Rate, COVID-19 Related Government Measures, Correlation, Cross-Correlation

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Chapter 1

Introduction

In December 2019 an epidemic of pneumonia emerged in Wuhan, China (1). The virus began to spread to the rest of the world, with France being the European country to report the first positive cases on January 24, 2020 (2).

On March 12, 2020 the World Health Organization declared COVID-19 as a global pandemic (3). Many governments around the world, with the purpose of restricting the COVID-19 pandemic and preserving lives, adopted measures such as lock-downs, travel restrictions, quarantines and use of face masks.

Data mining and machine learning algorithms have been widely used to early detect infected individuals, which is essential to combat this pandemic, for example by studying chest X-ray images (4), and to analyze epidemiological data and forecast the pandemic (5; 6; 7). Other studies focused on finding the main characteristics of severely affected patients by COVID-19, such as age, gender, etc., and the epidemic patterns that can be used in the decision-making of measures to reduce the spread of the virus (8).

The restrictions that have been imposed to contain the pandemic have many implications in other areas, that various researchers have shown great interest in studying. The pandemic measures had mainly negative impact, especially on the economy, where there was a strong correlation between COVID-19 and gross domestic product (GDP), due to low economic growth rates, stock market and tax revenues (9). In addition, the mental health of many people appeared to be affected, with health-care workers showing higher rates of anxiety and depression (10). Also, the lock-down reduced mental health and increased the gender gap in mental health (11).

Despite the negative effects of the pandemic, there were also positive environmental and political impacts. Lock-down measures have been observed to significantly improve air quality by reducing the concentration of air pollutants (12; 13), and there has been a high level of trust in government and satisfaction with democracy (14).

In this thesis, initially a dashboard was developed in the R programming language, which provides interactive maps and bar plots to aid in the analysis and inference of data related to the COVID-19 government measures. Subsequently, a number of analyses were carried out and the focus is on the government measures taken at the beginning of the pandemic, with the purpose of restricting it. The aim is to explore the existence of similarities between different countries and whether epidemiological data may indeed have influenced the decisions of governments. Specifically, two analyses were carried out for the year 2020. The first analysis concerns Greece, which confirmed the first positive case on February 26, 2020 (15), and explores whether there is a correlation between the measures taken by the government and the COVID-19 positive test rate (PTR) observed and at which distance of days the highest correlation is found.

The second analysis examines for some selected European countries (Cyprus, France, Greece, Ireland, Malta and Norway) whether (a) their governments reacted similarly to the tightening and relaxation of the measures, and, (b) at which distance of days their measures had the highest cross-correlation.

The Greek government's measures showed a high correlation with COVID-19 PTR, at a distance of +13 days, due to the fact that the measures were usually taken for a period of week(s), until the next reassessment of the COVID-19 situation. Cyprus, France, Greece and Malta showed high correlation values without large daily shifts, a behavior that can be attributed to the influence of tourism on their economies. On the other hand, Ireland and Norway showed no correlation with any other country.

The structure of this thesis is the following:

- Chapter 2 reviews the relevant literature.
- Chapter 3 presents other dashboards that provide visualizations relevant to covid-19.
- Chapter 4 describes in detail the data and the sources used for this study, the pre-processing applied on it, and, the rationale behind the choice of the analysis methods.
- Chapter 5 presents the interactive visualisations developed for the dashboard.

- Chapter 6 presents all the analyses performed on the collected data and the respective findings.
- Chapter 7 discusses the findings and gives pointers for further research on the subject.

Chapter 2

Literature review

An extensive search on the literature using the keywords "covid", "government" and "measure or policy" did not identify other similar studies to this thesis. This thesis examines the relationship between government measures and the COVID-19 epidemiological data and compares some selected European countries (Cyprus, France, Greece, Ireland, Malta and Norway) on the basis of government measures taken before any immediate treatment such as vaccination of the population took place. Additionally, it uses different data than previous studies, namely, the Oxford COVID-19 government response tracker (16) for measures and numerical data ranges.

For example, the study (17) used the above response data for some selected countries (China, Germany, Austria and the USA) and compared the effectiveness of the two COVID-19 lockdowns on virus spread and changing infection dynamics based on time discontinuity and earlyR epidemic regression models. The analyses carried out showed that the timing and strictness of measures, the cultural and economic background of each country and people's perception of risk influence the effectiveness of measures and the authors suggests that lockdowns applied by state governments, should be strict and brief because on the other hand long period or reintroduced late in the pandemic would exert, at best, a weaker, attenuated effect on the circulation of the virus and the number of casualties.

The development of technology, with the population's access to the internet and especially social media, has obviously contributed to raising awareness of COVID-19 and assessing how governments have responded to the pandemic. Relevant studies conducted to find relationships between COVID-19 measures and social media responses are as follows:

The public sentiment on governmental COVID-19 measures in Dutch social media (Twitter, Reddit and Nu.nl) from February to September 2020, appears in the study

(18). The authors applied sentiment analysis methods in order to analyze polarity and determine Dutch attitudes towards social distancing and the use of face masks measures. The analysis showed that the polarity of comments related to COVID-19 was negative. Regarding the two measures, the Dutch appeared positive on social distancing when the measure was announced in March and then support declined until June. On the use of face masks, attitudes were positive regarding their use, but not to the government measure.

Another interesting study is the (19), which tries to link government performance to people's political expression on social media during the pandemic. The author, with the help of a machine learning neural network model, classified over 8 million tweets addressed to the governors of US states as civil or uncivil. The analysis showed that there is an increase in uncivil tweets against state governors due to the increase in COVID-19 cases. The study then discusses the implications of the findings from two perspectives, the non-institutionalized political participation and the importance of elections in democracies.

A similar study, investigates the perception of the Brazilian federal government through a quantitative and qualitative analysis of 3,756 tweets of users to a time window of 30 days before and 30 days after a tweet about a family member of them that victimized by COVID-19. The study found subtle changes in the perceptions of people who approve or disapprove of the federal government. In an analysis of the word clouds it was noticed an increasing in the size of the words "pandemic", "protest", "hate", "death", "hunger" and "shit". In addition, new concerns for example for hunger emerged after the base tweet (20).

However, technology was not only a tool for citizens to criticise the measures taken by governments during the pandemic. It was also an opportunity to modernise the services provided to them. Study (21) examines the implementation of best practices of digital transformation that were used by governments globally and, more specifically, in the case of Greece. The analysis with the statistical program PSPP of the 150 usable questionnaires answered showed that the majority of the practices used by the government were well communicated, as most digital services were acknowledged by the participants even if they had not used them. After a thorough examination, the authors concluded that more or less all of the measures taken around the world followed similar patterns, but in each case all governments showed tremendous improvement in order to meet the needs of citizens. In the case of Greece, e-government practices were well acknowledged by the public in relation to the haste with which they were implemented.

Many countries are considered to have many political and cultural similarities. An example is the Scandinavian countries (Denmark, Norway and Sweden). Study (22) examines how similarly they acted to contain the COVID-19 pandemic. However, there are striking differences in the way these countries approached the pandemic. Quantitative-ethnographic (QE) by the use of nCoder tools and ENA methodologies aimed to understand similarities and differences in the four areas of reorganization of population behavior, containment of viral transmission, preparation of health systems, and management of socioeconomic impacts. According to the survey, Sweden differed from Denmark and Norway, which followed a stronger discourse around the Health System along with accumulated information on statistics, symptoms and characteristics of the virus, quickly adopted restrictive measures and held national speeches to enforce isolation.

To best limit the spread of a pandemic, it is necessary to look in depth at previous pandemics in order to choose the best policies and actions to be imposed by the government and regions to safeguard the population and health. Most of the existing literature on the COVID-19 pandemic deals with this, providing a different perspective and analysis and trying to find ways to better predict the evolution of the pandemic in order to better prepare humanity for a future similar situation. Some examples of such research are presented below:

A preliminary data analysis to understand the rules followed by the virus during its spread in Italy and the Region of Lombardy, through the investigation of the possible correlation between the goods and transport routes and the citizen travels with the spread of COVID-19 from a geographical perspective, and an empirical discussion on how actions and decrees imposed by the Italian government over time have impacted on the spread of COVID-19 are presented in (23). These analyses explained why Codogno was the first site of the outbreak in Italy, due to the interpersonal distribution of goods taking place in Lombard territory, as south of Lodi are located the largest logistics and distribution hubs in Italy and among the largest in Europe.

Study (24), with survey data from 705 respondents in Indonesia, attempts to understand how the quality of government information and citizens' partisanship affect citizens' well-being in terms of life satisfaction and stress during COVID-19. The analyses conducted showed that the quality of government information is crucial to help citizens prepare for the pandemic, and a reduction in the quality of their anxiety leads to a greater ability to respond quickly to the crisis, as well as a reduced level of information overload. While partisanship is an important predictor of information overload, it did not have a significant effect on perceived ability to respond quickly. Quick reaction ability and information overload, in turn, predicted stress and life satisfaction.

(25) tries to identify the most important strategy against the COVID-19 pandemic that governments should implement. For this purpose, orthopathic q-rung fuzzy sets (q-ROFSs) are used because this decision making process is considered a multiple criteria decision making problem (MCDM) and it is necessary to allow decision makers to make their judgments in a wider space and to better deal with ambiguous information. The results of the two different TOPSIS methods based on q-ROFS used in the proposed approaches determine that the strategy of "mandatory quarantine and strict isolation" is the most important strategy to be implemented by governments.

Also, (26) studies the effectiveness of the local and state government restrictions and closures in Texas in limiting the spread of COVID-19, with the use of a time-dependent SIR model together with Lasso in order to monitor the trajectories of the transmission and recover rates in relation to the government closures and restrictions and to further predict the number of cases. The one-day prediction error for the confirmed cases was approximately 2.47% and less than 1% for the recovered cases. The authors also find that there are many intervention methods that corresponded to changes in infection rate and population recovery rate.

Using a simulation of the spread of the COVID-19 pandemic in a population based on a SEIR epidemiological model, a methodology based on either Deep Q-Learning or Genetic Algorithms to help governments plan phases during a pandemic in order to safeguard public health as well as mitigate the negative impact on the economy is presented in (27). The actions of confinement, self-isolation, two-meter distance or not taking restrictions were evaluated and according to the results of the study, the Deep Q-Learning based approach outperforms that based on Genetic Algorithms and is a valid tool for governments to mitigate the negative impacts of a pandemic.

In another study (28), the impact of government policy interventions on the infection chain structure in Korea is measured using multiple linear regressions to enable governments to identify and implement effective policies that could stop the rapid spread of the virus. The analysis shows that implemented policies decrease the high fluctuation in infection chain structures that were observed at the beginning of the pandemic.

In (29), the authors, using data up to mid-April 2020 from five Countries (US, India, UK, Germany and Singapore) that have different healthcare systems, run the COVID-19 tests in different places and apply different policies. They developed a model to forecast the evolution of the pandemic at the country level using statistics, epidemiological models, machine and deep learning models and a novel hybrid prediction method based on nearest neighbours and clustering. The forecasts estimate excess demand for products and services during a pandemic, using Google trends and simulating government decisions in order to help policymakers and planners make better decisions during current and future pandemics.

Chapter 3

Dashboard review

The dashboard is considered a visual representation of the most important information needed to achieve one or more goals, their use in business is remarkable as it can help save time and improve decision making by business owners. Dashboards are often accessible via web browsers and are usually linked to regularly updated data sources.

The COVID-19 pandemic has brought other dashboards to the forefront to better analyse the pandemic and draw better conclusions. Some examples are the Johns Hopkins coronavirus tracker, the UK government coronavirus tracker and the Covid-DExp exploratory data analysis, which will be presented in this chapter.

3.1 Johns Hopkins coronavirus tracker

One of the best known dashboards for covid-19 and recognized by TIME as the "go-to data source" for COVID-19 is the Johns Hopkins Coronavirus Resource Center (CRC) (30), a continuously updated source of COVID-19 data and expert guidance. The CRC collect and analyze data related to cases, deaths, tests, hospitalizations, and vaccines to help the public, policymakers, and healthcare professionals worldwide respond to the pandemic.

The main Visiualization shown in Figure 3.1 is an interactive map showing the spread of the coronavirus and for each country or region the user can click to see cases and deaths in 28 days and the total number of cases and deaths. Above the map the cases, deaths and vaccine doses administered worldwide in total and over 28 days are shown. There are also three charts positioned to the right of the map showing weekly cases, deaths and doses administered of coronavirus.

However, other interesting visualizations are also provided by CRC, for example an examination of U.S. Hospital Capacity shown in Figure 3.2. This chart displays the

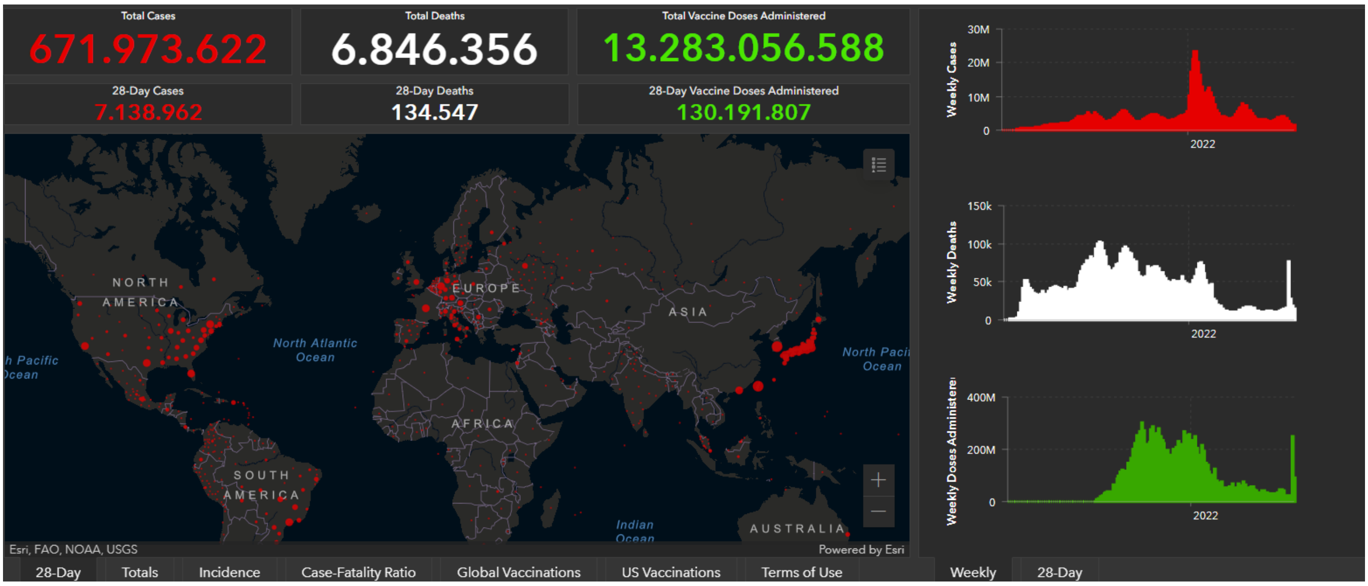


Figure 3.1: CRC interactive map

7-day trend in overall and Covid-19-specific hospitalization occupancy data, including:

- Beds occupied by Covid-19 patients (ICU and Inpatient), which appear in orange.
- Beds occupied by non-Covid-19 patients (ICU and Inpatient), which appear in teal.
- Beds not occupied (ICU and Inpatient), which appear in grey.
- Percentage of beds occupied overall (ICU and Inpatient), which will appear when you hover the cursor over the chart.

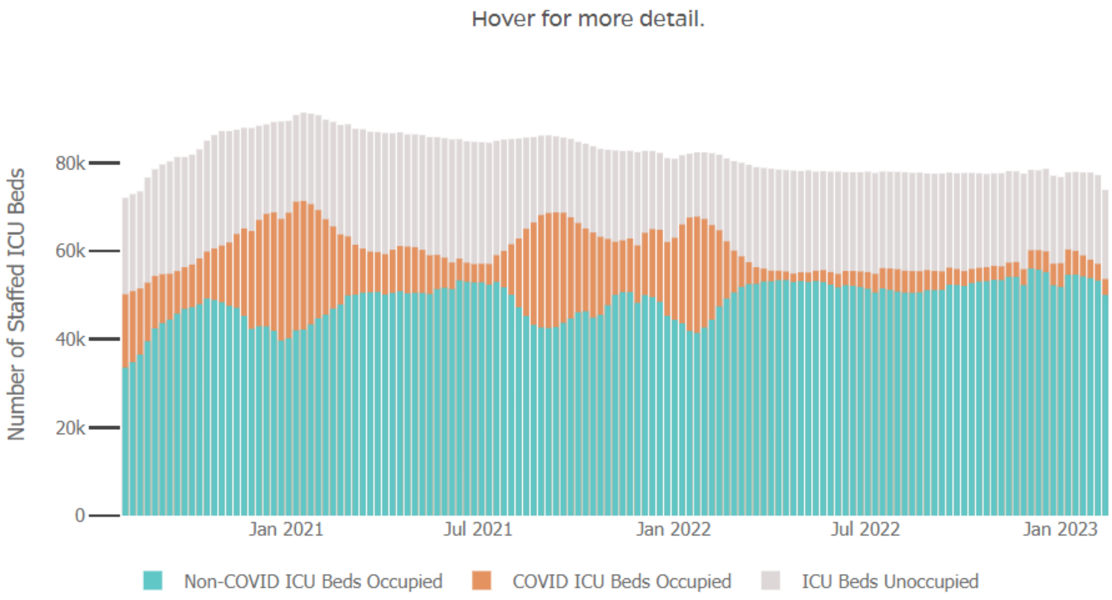


Figure 3.2: CRC Examination of U.S. Hospital Capacity

3.2 UK government coronavirus tracker

Another interesting dashboard is the (31) being developed and maintained by Public Health England. This dashboard is an up-to-date and authoritative summary of key information about the COVID-19 pandemic. This includes levels of infections, the impact on health in the UK and on measures taken to respond.

The main visiualization shown in Figure 3.3 is a interactive map showing the 7-day case rate per 100,000 people, with different colouring per local authority. The case rate is calculate by dividing the 7-day total by the area population and multiplying by 100,000. The dashboard provides additional visualizations for test, case, healthcare, vaccination and death data categories. Some examples are as follows:

- Figure 3.4 shows the number of people who received a polymerase chain reaction (PCR) test in the previous 7 days, and the percentage of those who had at least one positive COVID-19 PCR test result in the same 7 days.
- Figure 3.5 shows the age breakdown of the number of COVID-19 patients admitted to hospital since the start of the pandemic.
- Figure 3.6 shows the age and sex breakdown of the total number of people who died within 28 days of being identified as a COVID-19 case by a positive test since the start of the pandemic.

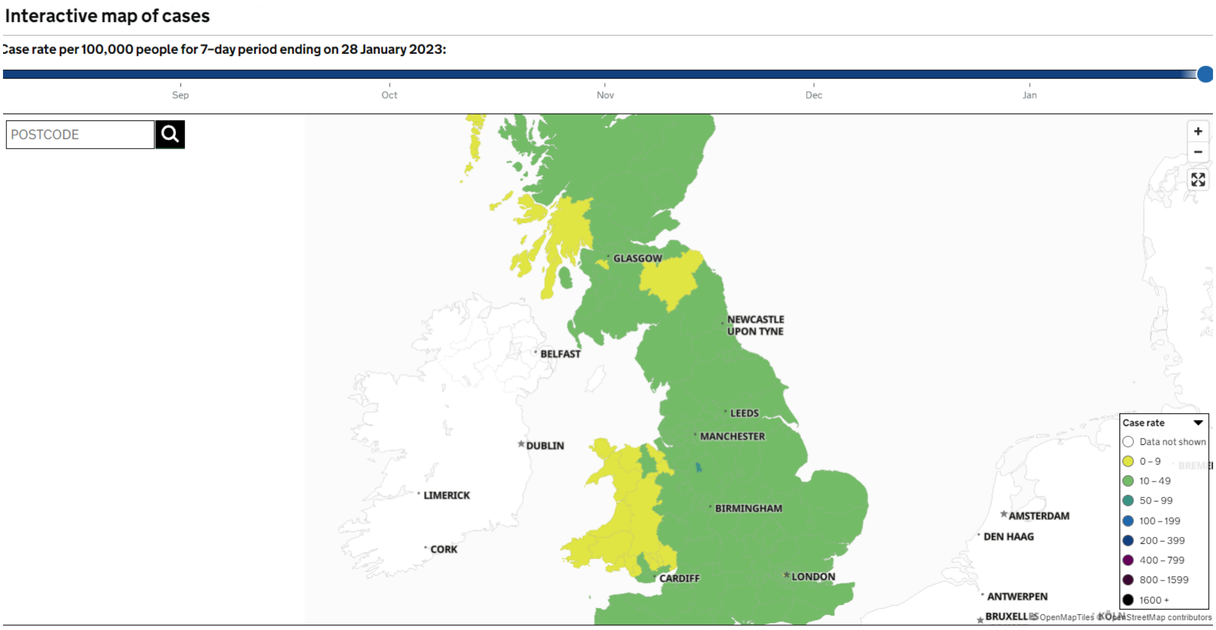


Figure 3.3: UK map shows 7-day case rate per 100,000 people

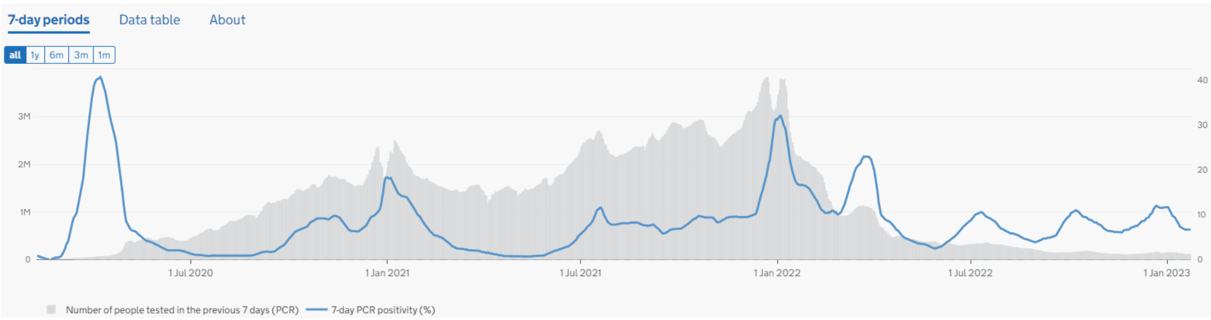


Figure 3.4: Weekly number of people receiving a PCR test and positivity

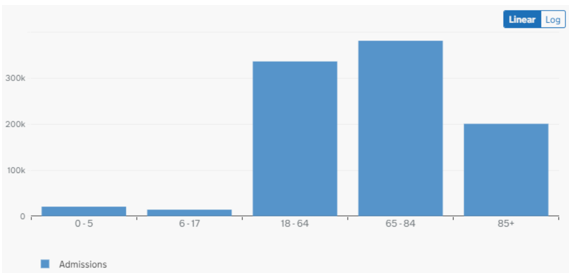


Figure 3.5: Patients admitted to hospital, by age

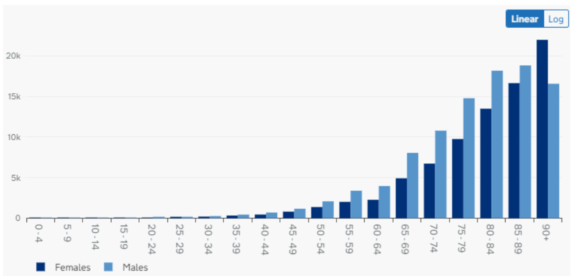


Figure 3.6: Deaths by age and sex

3.3 CovidDEXP (Covid-19 Data Exploration)

CovidDExp (COVID-19 Data Exploration) (32) is an exploratory data analysis tool with a visually presentation of the COVID-19 pandemic, launched and supported by members of the Data and Web Science Lab (DATALAB) an active research group engaged in ICT research and innovation on data science and multi scope analytics under the Department of Informatics, Aristotle University of Thessaloniki, Greece. This dashboard is developed in the R programming language, like the one in this thesis.

The CovidDEXP (Covid-19 Data Exploration) platform presents through interactive graphs data collected from multiple open data sources from reputable international institutions and organisations, which are not only epidemiological data at each phase of the pandemic, but also how these are correlated with socio-economic indicators, such as health expenditure and population vaccinations, and with the measures adopted by governments to limit the spread of the coronavirus, collected from the Oxford COVID-19 government response tracker (16).

Some of these interactive graphs are as follows:

Epidemic Plots:

- Cases per Country

  This plot 3.7a presents the temporal evolution of the number of confirmed cases on a global scale. The user can see the new number of cases, as well as the total number of cases.

- Case Fatality

  This plot 3.7b presents the temporal evolution of case fatality. Case fatality is defined as the ratio between deaths due to COVID-19 and confirmed cases.

Socioeconimic Plots:

- Health Expenditure

  This plot 3.8a presents the correlation between the Health Expenditure of Countries and the number of Confirmed/Active Cases/Deaths and Recoveries.

- Life Expectancy

  This plot 3.8b presents the correlation between the average life expectancy age per country and the number of Confirmed/Active Cases/Deaths and Recoveries.

Government Response:

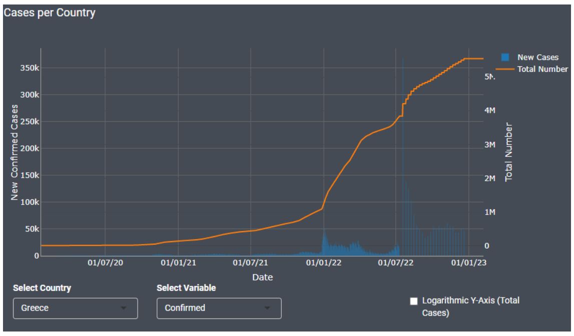
- Government actions with respect to confirmed cases

  This histogram 3.9a presents the distribution of government response times worldwide for the selected indicator, with respect to confirmed cases.

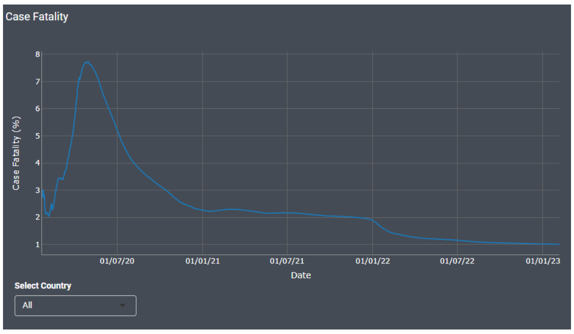
- Government actions with respect to deaths

  This histogram 3.9b presents the distribution of government response times worldwide for the selected indicator, with respect to recorded deaths.

Since, the case of Greece is important for the lab, there is also a specialized section that examines the evolution of the disease in Greece , as well as an analysis of social media (Twitter) traffic.

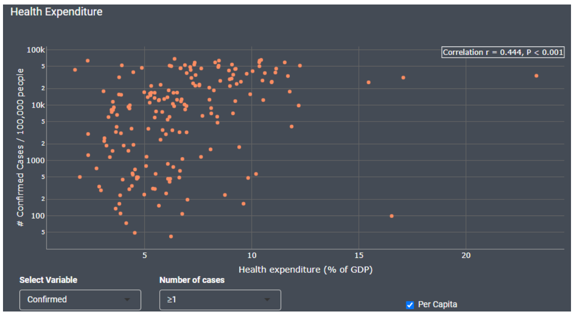


(a) Cases per Country

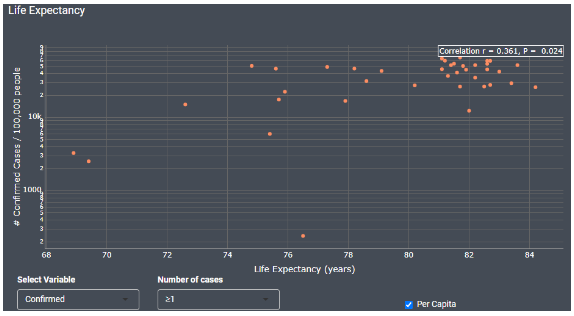


(b) Case Fatality

Figure 3.7: CovidDEXP Epidemic Plots

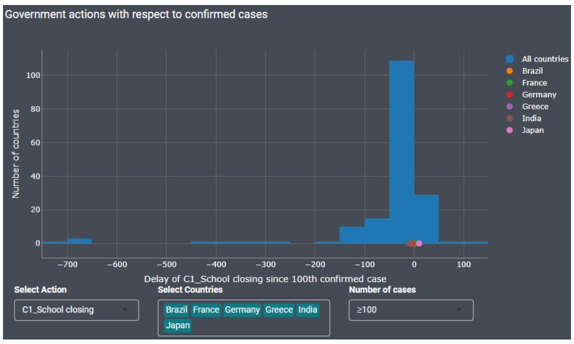


(a) Health Expenditure

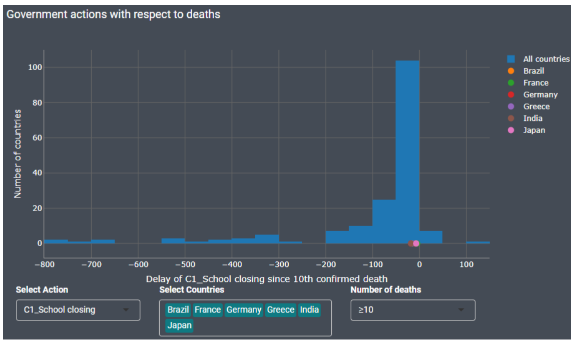


(b) Life Expectancy

Figure 3.8: CovidDEXP Socioeconimic Plots



(a) confirmed cases



(b) deaths

Figure 3.9: CovidDEXP Government actions with respect to:

Chapter 4

Data and Methods

4.1 Data Sources and Pre-Processing

This thesis uses various data for both the dashboard and the analyses performed. More specifically, the data used and presented in this section are as follows: Government measures taken during the covid, positive test rate and health certificates.

4.1.1 Government measures

This thesis uses daily data of government measures that were adopted, before any immediate treatment such as vaccination of the population took place, by different countries around the world from January 2020 onward with the purpose of restricting the COVID-19 pandemic. The data are collected by and is freely available from the research program entitled "Observatory of Government Restrictive Measures for the COVID-19 Pandemic (GovRM-COVID19)" of the Center for Research on Democracy & Law (CEDLAW) of the Department of International & European Studies of the University of Macedonia, Thessaloniki, Greece (33).

Table 4.1 shows the thirteen (13) types of government measures.

All the measures take integer values from 0 to 3, based on their "strictness", with 0 denoting no action taken and 3 denoting the most strict action taken for the corresponding measure. For the analyses of this thesis, a single variable was created as the average value of all measures on a daily basis, as equal importance to all measures wanted to be given.

Category	Intensity	Description
Freedom of individual movement (excluding inner-country travel and international transportation)	1	Recommendation to avoid exiting the house
	2	Partial restriction on freedom of movement
	3	Complete restriction
Use of Mask	1	Recommendation for use
	2	Mandatory use in some indoor/outdoor spaces
	3	Mandatory in all indoor and outdoor spaces
Public Gatherings	1	Recommendation for avoiding public gatherings
	2	Ban some public gatherings
	3	Ban of all public gatherings
Education	1	Recommendation for closure
	2	Partial closure (of some or all grades, with some or no measures)
	3	Total closure
Food Services (restaurants, bars, etc., excluding food retailers)	1	Recommendation for closure
	2	Partial closure
	3	Total closure
Food Retailers (supermarkets, grocery stores, etc., excluding food services	1	Recommendation for closure
	2	Partial closure
	3	Total closure

Sports' Facilities (indoor, outdoor)	1	Recommendation for closure
	2	Partial closure
	3	Total closure
Inner-country travel (between Municipalities, Regions, etc., excluding essential goods' transportation and trade)	1	Recommendation to avoid travel
	2	Restriction of travel
	3	Complete restriction of travel (all areas of a country)
International transportation (ships, planes, etc., excluding essential goods' transportation and trade)	1	Mandatory test presentation or check or quarantine
	2	1 plus ban of travel from some countries
	3	1 plus ban of travel from all countries
Work and other interior spaces not included in other categories (civil service/public employees, beauty salons, barber shops, etc.,)	1	Recommendation for working remotely
	2	Partial closure of workplaces
	3	Total closure of workplaces
Public Events (concerts, conferences, festivals, etc.)	1	Recommendation for not holding public events
	2	Partial ban of public events
	3	Ban of all public events
Retail stores (clothes shops, outlets, shopping malls, etc.)	1	Recommendation for closure
	2	Partial closure
	3	Total closure

Religious places and ceremonies (churches, marriages, funerals, etc.)	1	Recommendation for closure
	2	Partial closure
	3	Total closure

Table 4.1: Types of Government Measures

4.1.2 Positive Test Rate

In order to study the spread of the pandemic, citizens were tested to diagnose whether they were affected from covid or not. For the analyses, additional daily data of the COVID-19 PTR (Positive Test Rate) based on a 7-day rolling average were retrieved from the "Our World in Data" website (34).

4.1.3 Health Certificates

In an effort to contain the pandemic, the use of health certificates for COVID-19 was initiated, giving citizens certain freedoms based on whether they have been vaccinated, infected or tested negative for COVID-19. The type of certificates accepted by each country is different, specifically:

- No need of Certifacate
- Vaccination/Recovery Certifacate only
- Vaccination/Recovery or test Certifacate

These data of the certificate used by each country and the date when its implementation started are also collected by research program entitled "GovRM-COVID19" (33) and were only used in the dashboard.

4.2 Analysis Objectives and Chosen Methods

The thesis research had three objectives which are presented below.

First, the interest arose to analyse the year 2020 data for Greece in order to determine the distance of days with the highest correlation value between the average value of government measures and the observed COVID-19 PTR. To achieve this, the cross-correlation method was used. The method works by keeping the measures time series constant and shifting to the left or to the right the COVID-19 PTR series on a daily basis to calculate the corresponding correlations.

Second, a comparison of the behaviour of some selected countries, namely Cyprus, France, Greece, Ireland, Malta and Norway were carried out, in terms of COVID-19 government measures taken. These countries were chosen because there were comparable data for the year 2020 that could be retrieved. Their similarity in terms of government measures was calculated in order to find whether they reacted similarly to the tightening and relaxation of measures in the time period Mar 12, 2020 to Dec 31, 2020.

Third, it was interesting to compute the time lag, measured in days, where the various countries exhibited the highest possible correlation in terms of governmental measures. Again, the cross-correlation method was used and was reported (a) the time lag in days that achieves the highest correlation for all pairs of countries, and, (b) the cross-correlation matrix.

Data analysis and visualization were performed using the Python programming language and its libraries. The interested reader can reproduce the analysis using our datasets and code provided at https://tinyurl.com/4mcxh3br.

Chapter 5

Dashboard

For the needs of the laboratory "Center for Research on Democracy & Law (CEDLAW)" of the Department of International & European Studies of the University of Macedonia, Thessaloniki, Greece and more specifically for the data of the research program entitled "Observatory of Government Restrictive Measures for the COVID-19 Pandemic (GovRM-COVID19)" (33) a dashboard has been developed which provides five interactive visualisations to assist the laboratory's needs for analysis and conclusions.

The dashboard was developed in the R programming language and using the libraries it provides such as shiny, leaflet, ggplot2 etc. The visualisations included will be presented below. Specifically, they are interactive maps with different colorations of the countries depending on the variable under consideration (the colours change every 0.5), and additional bar plots which provide the possibility of comparing countries.

For these visualisations, the user is given a number of options to draw different conclusions. These are the time period of examination, where the user is given the possibility to choose the time range of days between the earliest and most recent date that appeared in the countries' data, the indicator to study and the countries for which the comparison can be made.

Most dashboard visualizations make use of data of the government measures that were adopted with the purpose of restricting the COVID-19 pandemic. Except for the last tab "Covid-19 Health Certificates" which uses the health certificate data for covid as presented in the 4.1.3.

5.1 Restrictiveness Index (RI)

The first tab, which is the main tab of the dashboard, presents an interactive map that allows the user to select the time period to be examined and calculates the Restrictiveness Index of each country as follows:

$$RI = 2W \sum (X_{1-4}) + W \sum (X_{5-13}) \tag{5.1}$$

and W is calculated as:

$$1 = 2W * 4 + W * 9 \tag{5.2}$$

Where W is the differential weighted average of 13 indicators; X_{1-4} refers to four NPIs: freedom of individual movement, public gatherings, inner-country travel, and religious places and ceremonies; X_{5-13} refers to the remaining nine NPIs. Solving (4.2) and expressing it in percent, W = 5.88 percent.

Figure 5.1 presents an example of a test run of the "Restrictiveness Index (RI)" tab, which has calculated the RI of the countries for the period Jan 03, 2020 to May 01, 2022.

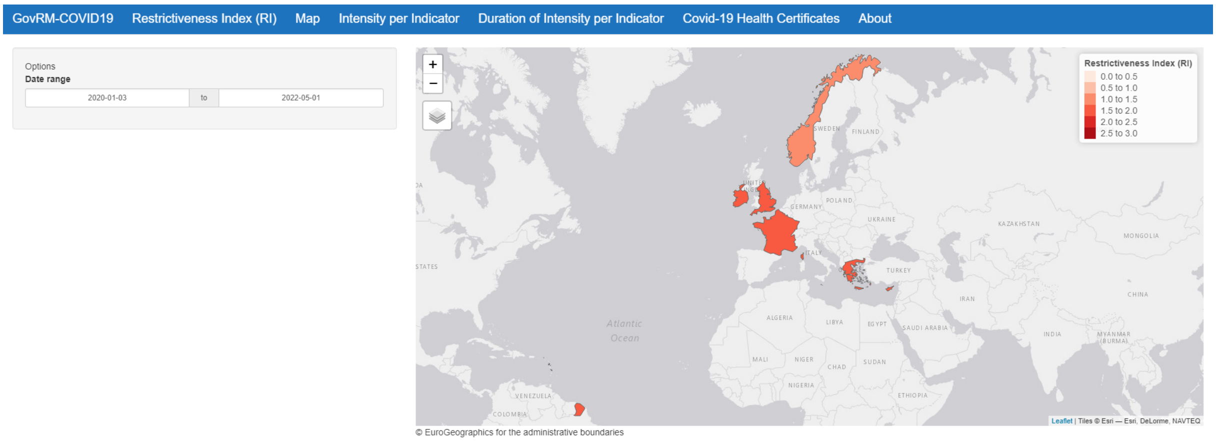


Figure 5.1: Restrictiveness Index (RI)

5.2 Map

The next tab has a similar format to the one above, as again an interactive map is presented. However, apart from the possibility to select the time period, the user can selects one indicator to examine and compare countries based on. For the selected Indicator, the average values of the countries are calculated.

For example, in Figure 5.2, the time period between Feb 06, 2020 and Apr 03, 2022 and the education indicator have been selected, allowing a comparison of countries, based on the stringency of government measures on education for the aforementioned time period.

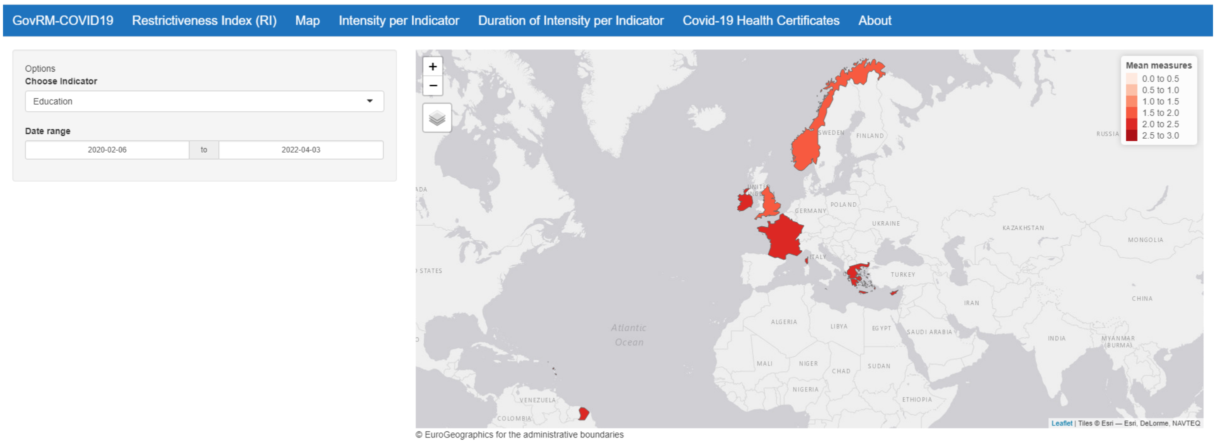


Figure 5.2: Map

5.3 Intensity per Indicator

An interactive bar plot is presented in the "Intensity per Indicator" tab, where for the selected country all the average values for the various Indicators for the period of time selected to be examined are displayed. Below the bar plot an interactive table is given which shows the average values to the first decimal place. Figure 5.3, shows the average values of Greece for all indicators for the period Jan 03, 2020 to May 01, 2022.

But apart from examining one country, it is possible to study more than one country in the given bar plot, for example Figure 5.4, presents the average values of Greece, France and Cyprus for all indicators for the period Jan 03, 2020 to May 01, 2022.

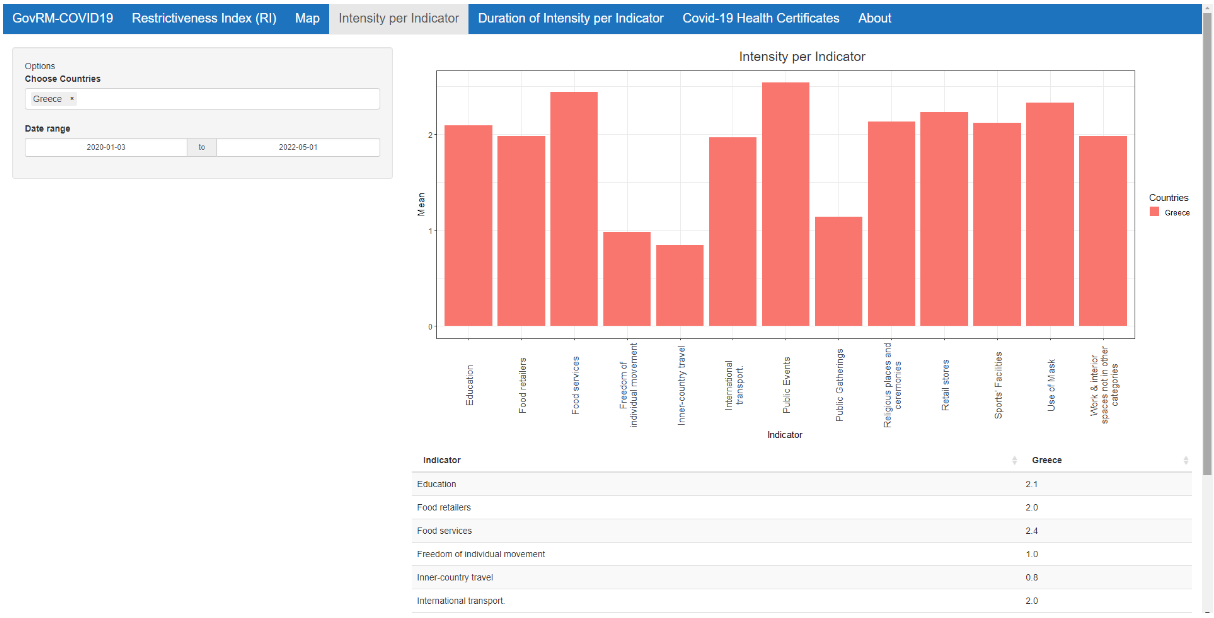


Figure 5.3: Intensity per Indicator (only Greece)

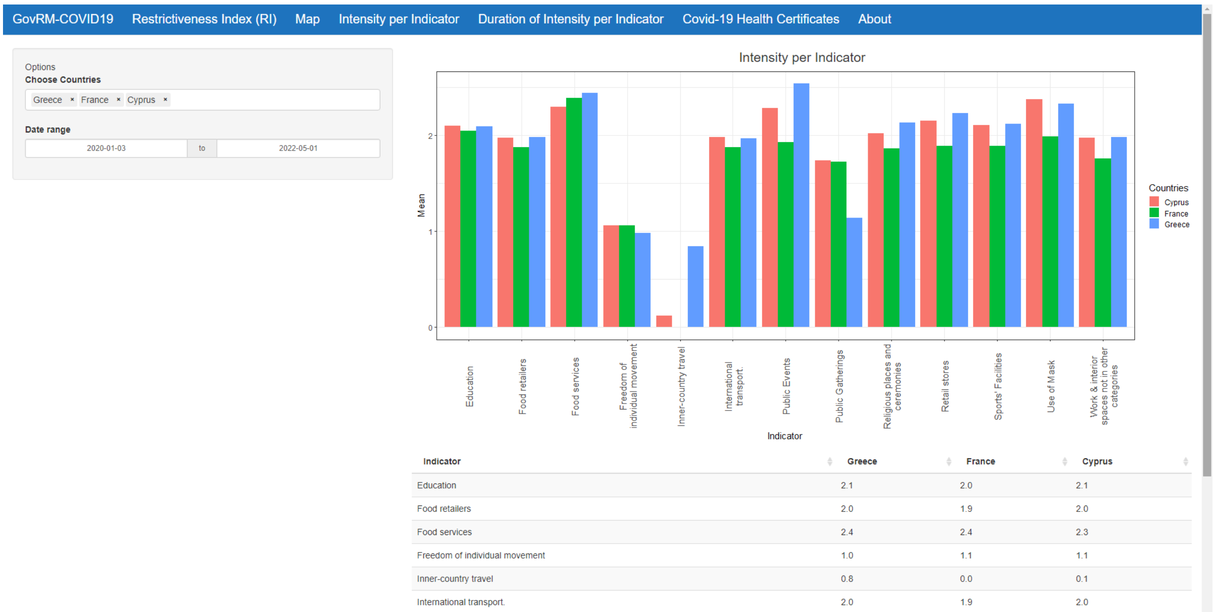


Figure 5.4: Intensity per Indicator (Greece, France and Cyprus)

5.4 Duration of Intensity per Indicator

The next tab has a similar format to the "Intensity per Indicator". An interactive bar plot and table are presented for the selected time period, Indicator and country/countries. In this case, for each intensity value (0 to 3) the days for which the indicator has the specific intensity value are added up and presented.

For example Figure 5.5, presents the total days for each indensity value for the indicator "Food Services" of Greece, Ireland and France for the period Jan 03, 2020 to May 01, 2022.

Figure 5.5: Duration of Intensity per Indicator

5.5 Covid-19 Health Certificates

In this tab, differentiated from the previous ones, presents a non-interactive map, as no option is given to the user. The map 5.6 displays in a different colour the type of health certificate used by each country, and more specifically:

- Green for "No need of Certifacate"
- Yellow for "Vaccination/Recovery Certifacate only"
- Blue for "Vaccination/Recovery or test Certifacate"

Below the map there is a table 5.7 with two columns, "Vaccination/Recovery Certifacate only" and "Vaccination/Recovery or test Certifacate" where if this type of restriction is selected for a country in the row of tables, the date of application of the measure is given as a hyperlink directing the user to the relevant legislation.

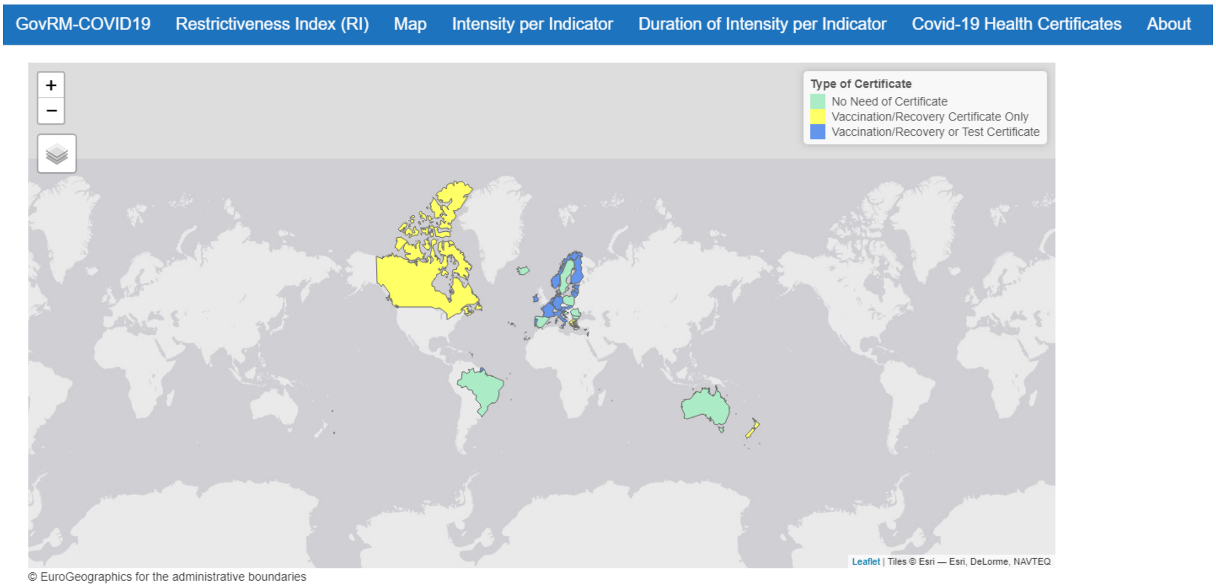


Figure 5.6: Map Covid-19 Health Certificates

Leaflet | Tiles © Esri — Esri, DeLorme, NAVTEQ

© EuroGeographics for the administrative boundaries

Show 10 entries Search:

Country	Vaccination/Recovery Certificate Only	Vaccination/Recovery or Test Certificate
Australia		
Austria		28/05/2021
Belgium		02/08/2021
Brazil		
Bulgaria		
Canada	06/10/2021	
Croatia		
Cyprus		17/07/2021
Czech republic		03/05/2021
Denmark		06/04/2021
Country	Vaccination/Recovery Certificate Only	Vaccination/Recovery or Test Certificate

Showing 1 to 10 of 35 entries Previous 1 2 3 4 Next

Figure 5.7: Table Covid-19 Health Certificates

Chapter 6

Analysis and Results

6.1 Cross-Correlation of Greece's government measures and COVID-19 PTR

For the period of Apr 21, 2020 to Dec 31, 2020 the time series of Greece's government measures and the COVID-19 PTR are shown in Figures 6.1 and 6.2, respectively. The measures for COVID-19, while initially showing a tightening, seem to be relaxed in the period from May to October. This is attributed to the lifting of travel restrictions during the summer season (35). A period of very tight measures is observed from October until December (Figure 6.1). The behavior of COVID-19 PTR appears to follow a similar pattern, with low values until October and a significant increase afterwards (Figure 6.2).

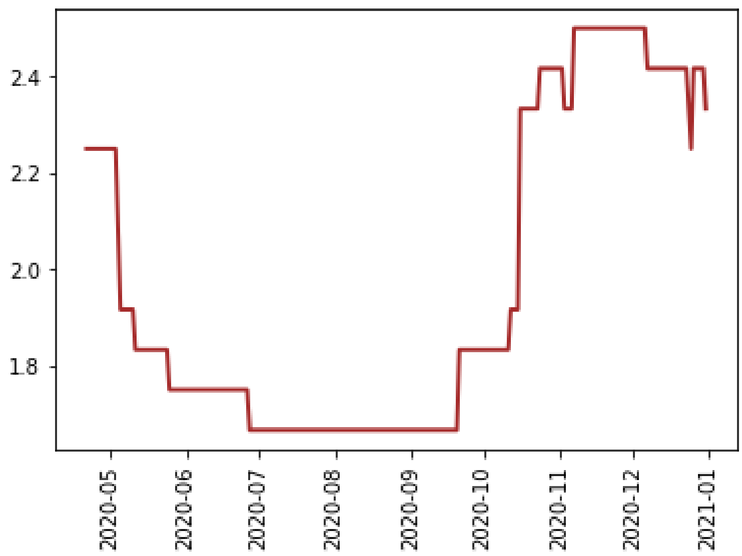


Figure 6.1: Time series of Greek government measures.

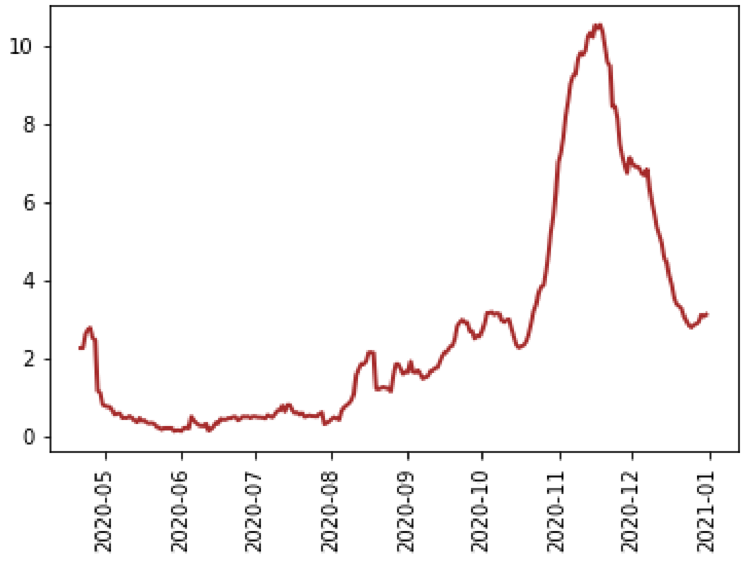


Figure 6.2: Time series of Greek COVID-19 positive test rate.

Using the cross-correlation method, correlations with a single day sliding window were calculated for a range of -20 to 20 days. The highest value of correlation was found at +13 days ($r = .85$, $P < .001$), which was statistically significant. The conclusion that can be drawn is that the changes in government pandemic measures followed the changes in COVID-19 PTR with a 13-day period delay. (Figure 6.3).

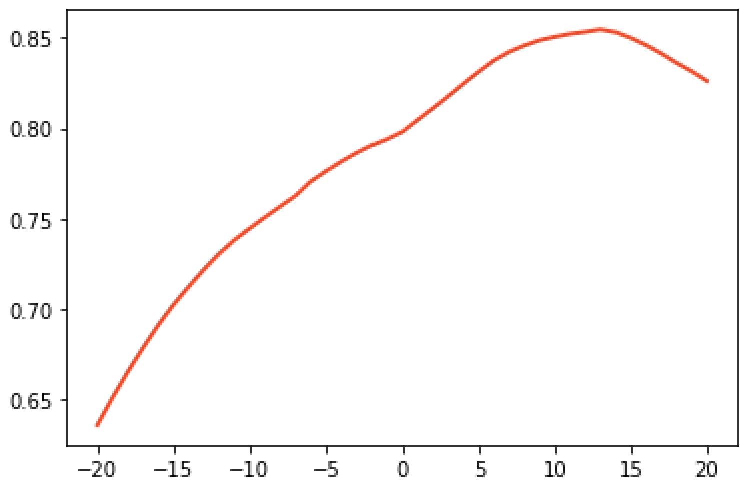


Figure 6.3: Correlations between Greek government measures and COVID-19 PTR for various distance of days.

6.2 Correlation of selected European countries government measures

For the selected countries (Cyprus, France, Greece, Ireland, Malta and Norway) and for the time period from Mar 12, 2020 to Dec 31, 2020, the correlation values of the measures taken were calculated as shown in the heatmap of Figure 6.4.

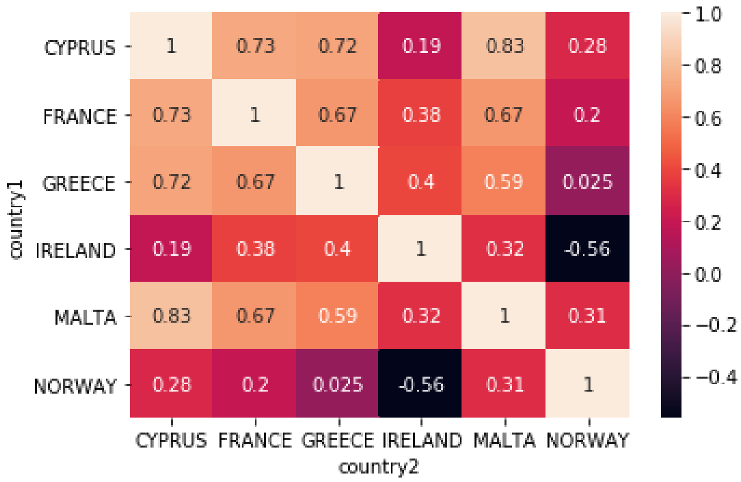


Figure 6.4: Correlations between government measures for Cyprus, France, Greece, Ireland, Malta and Norway.

Cyprus, France, Greece and Malta have similar behavior in terms of their reaction to the tightening and relaxation of measures, with their correlations having values greater than 0.5 (between 0.59 and 0.83), which indicates a positive correlation.

Correlations in descending order:

1. Cyprus and Malta ($r = .83$, p-value $< .05$)
2. Cyprus and France ($r = .73$, p-value $< .05$)
3. Cyprus and Greece ($r = .72$, p-value $< .05$)
4. France and Greece ($r = .67$, p-value $< .05$)
5. France and Malta ($r = .67$, p-value $< .05$)
6. Greece and Malta ($r = .59$, p-value $< .05$)

Figure 6.5 shows the time series of the government measures taken for all the examined countries in the specific time period. An observation that can be made is that Cyprus, France, Greece and Malta indeed demonstrate similar behaviour, with

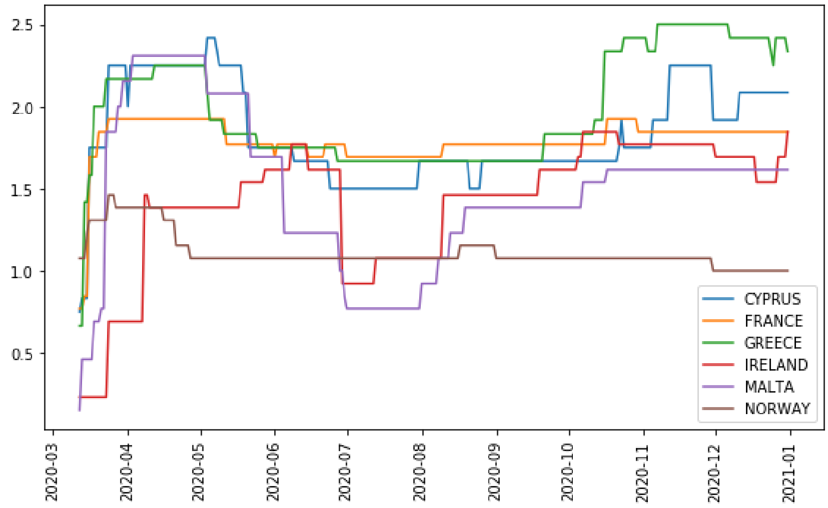


Figure 6.5: Time series of government measures for Cyprus, France, Greece, Ireland, Malta and Norway.

the relaxation of measures starting in May and the tightening of measures starting after August or September.

In contrast, Ireland and Norway seem to have no or very low correlation with the above countries (correlations between 0.025 and 0.4), and even a negative correlation of -0.56 is observed among these two countries (Figure 6.4). This behavior can also be observed in Figure 6.5.

6.3 Cross-Correlation and time lag of selected European countries government measures

For the same European countries and the time period from Mar 03, 2020 to Dec 31, 2020, the cross-correlation method was used to find the distance of the days with the highest correlations among countries with respect to their government measures. The results are shown in the heat map in Figure 6.6.

Cyprus, France, Greece and Malta still have similar behavior in terms of their reaction to the tightening and relaxation of measures. The greatest distance in days is equal to 5. More specifically, the following similarities among these countries with absolute distance of days in ascending order:

1. Cyprus and France 0 days
2. Cyprus and Greece 2 days
3. Cyprus and Malta 3 days

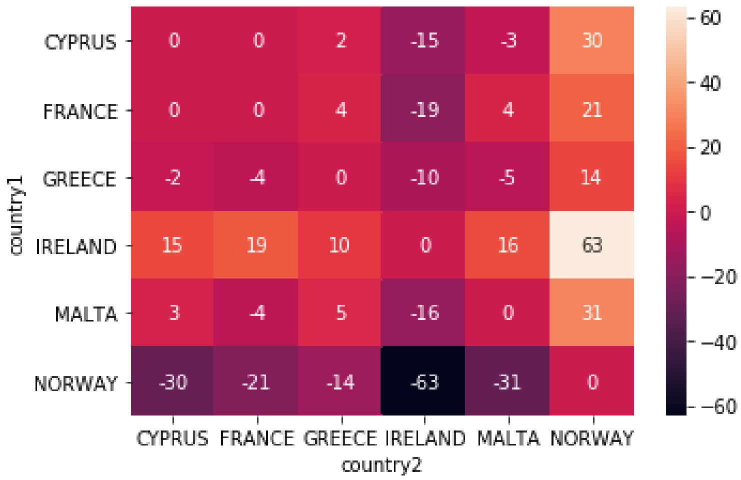


Figure 6.6: For Cyprus, France, Greece, Ireland, Malta and Norway: government measures highest cross-correlation in distance of days.

4. France and Greece 4 days

5. France and Malta 4 days

6. Greece and Malta 5 days

In contrast, Ireland and Norway not only show the least similarity among them since they are 63 days apart, but also with the rest of the countries, with Norway showing the greatest distances. An interesting finding is that both countries are closer to Greece than the rest of the countries (10 and 14 days respectively).

In order to better evaluate the above similarities, the cross-correlation values among the countries was used (Figure 6.7). In other words, it may be the case that Norway is only 14 days away from Greece in terms of highest cross-correlation, but the question is what is the value of that correlation?

Again, Cyprus, France, Greece and Malta have the highest cross-correlation values. Below, they were reported on separately in the order of Figure 6.6 and values greater than 0.5 (between 0.61 and 0.84) that were observed, which indicates a positive correlation:

1. Cyprus and France ($r = .73$, p-value $< .05$)

2. Cyprus and Greece ($r = .73$, p-value $< .05$)

3. Cyprus and Malta ($r = .84$, p-value $< .05$)

4. France and Greece ($r = .74$, p-value $< .05$)

5. France and Malta ($r = .73$, p-value $< .05$)

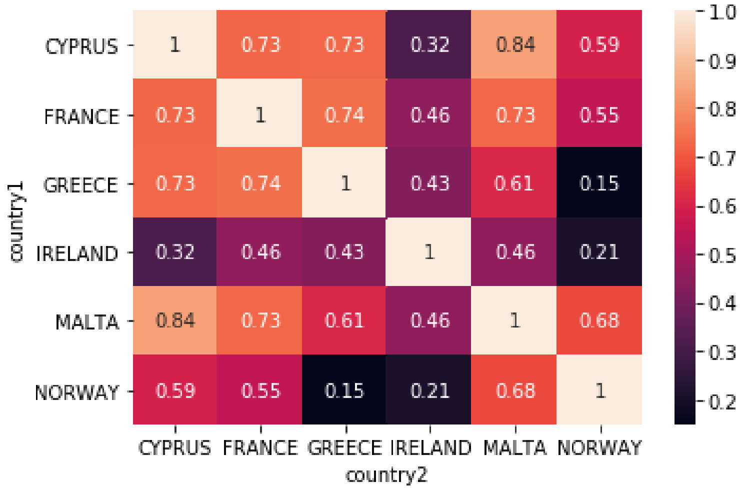


Figure 6.7: For Cyprus, France, Greece, Ireland, Malta and Norway: government measures cross-correlation.

6. Greece and Malta (r = .61, p-value < .05)

Ireland and Norway show little or no correlation with the rest of the countries. For example, Norway shows no correlation with Greece and Ireland and the relatively good correlation values with Cyprus, France and Malta (0.59, 0.55 and 0.68) happen at a distance of 30, 21 and 31 days respectively. Obviously, such long day distances cannot be considered as meaningful in terms of correlation. Similarly, Ireland shows low correlation despite the relatively lower day distances it has with most of the countries.

Chapter 7

Discussion

7.1 Summary and conclusions

The dashboard as presented in Chapter 5 has been developed following suggestions for visualisations given to the lab "Center for Research on Democracy & Law (CEDLAW)" of the Department of International & European Studies of the University of Macedonia. The selected visualisations were chosen based on the needs of the lab for the analyses they will be interested in carrying out.

The Greek government's measures to restrict the pandemic showed a high correlation with the COVID-19 PTR, at a distance of +13 days. This can be explained by the fact that the measures were usually taken for a period of week(s), until the next reassessment, as documented in the "Official Government Gazette, of the Hellenic Republic". Thus, the value of 13 (14 if the day without a shift is included) is a multiple of 7, which corresponds to a distance of two weeks from the reassessment of the measures.

Cyprus, France, Greece and Malta that showed high correlation values without large daily shifts, have similar behavior with the relaxation of measures starting in May and their tightening starting after August. This similarity can be explained by the fact that all these countries are Mediterranean countries, rely on tourism during the summer periods, with a large percentage of the their GDP being contributed by travel and tourism (36).

7.2 Future extensions

Regarding the dashboard, it could be enriched in the future with new visualisations or upgrading of existing ones, based on lab needs in terms of analyses or potential additional data collection.

It would be interesting to perform all the above analyses on all or most countries of the world, a difficult feat considering the (non) availability of the required data. Such an extended study would probably reveal more and interesting clusters of countries with regard to their government measures during the COVID-19 pandemic. Another possibility would be to include a numerical time series reflecting the quality of weather for each country during the examined periods so that countries and their government measures are correlated not only with COVID-19 PTR but with the weather conditions, too.

Bibliography

[1] P. Zhou, X.-L. Yang, X.-G. Wang, B. Hu, L. Zhang, W. Zhang, H.-R. Si, Y. Zhu, B. Li, C.-L. Huang, H.-D. Chen, J. Chen, Y. Luo, H. Guo, R.-D. Jiang, M.-Q. Liu, Y. Chen, X.-R. Shen, X. Wang, X.-S. Zheng, K. Zhao, Q.-J. Chen, F. Deng, L.-L. Liu, B. Yan, F.-X. Zhan, Y.-Y. Wang, G.-F. Xiao, and Z.-L. Shi, "A pneumonia outbreak associated with a new coronavirus of probable bat origin," *Nature*, vol. 579, no. 7798, pp. 270–273, Feb. 2020. [Online]. Available: https://doi.org/10.1038/s41586-020-2012-7

[2] WHO/Europe, "Who/europe — health emergencies - 2019-ncov outbreak: first cases confirmed in europe," https://www.euro.who.int/en/health-topics/health-emergencies/pages/news/news/2020/01/2019-ncov-outbreak-first-cases-confirmed-in-europe, (Accessed on 05/20/2022).

[3] ——, "Who/europe — coronavirus disease (covid-19) outbreak - who announces covid-19 outbreak a pandemic," https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic, (Accessed on 05/20/2022).

[4] I. Mrad, R. Hamila, A. Erbad, T. Hamid, R. Mazhar, and N. Al-Emadi, "Machine learning screening of COVID-19 patients based on x-ray images for imbalanced classes," in *2021 9th European Workshop on Visual Information Processing (EUVIP)*. IEEE, Jun. 2021. [Online]. Available: https://doi.org/10.1109/euvip50544.2021.9484001

[5] S. Namasudra, S. Dhamodharavadhani, and R. Rathipriya, "Nonlinear neural network based forecasting model for predicting COVID-19 cases," *Neural Processing Letters*, Apr. 2021. [Online]. Available: https://doi.org/10.1007/s11063-021-10495-w

[6] N. S. Punn, S. K. Sonbhadra, and S. Agarwal, "Covid-19 epidemic analysis using machine learning and deep learning algorithms," *medRxiv*, 2020. [Online].

Available: https://www.medrxiv.org/content/early/2020/06/01/2020.04.08.20057679

[7] D. Fanelli and F. Piazza, "Analysis and forecast of COVID-19 spreading in china, italy and france," *Chaos Solitons Fractals*, vol. 134, no. 109761, p. 109761, May 2020.

[8] V. Bhatnagar, R. C. Poonia, P. Nagar, S. Kumar, V. Singh, L. Raja, and P. Dass, "Descriptive analysis of COVID-19 patients in the context of india," *Journal of Interdisciplinary Mathematics*, vol. 24, no. 3, pp. 489–504, Jun. 2020. [Online]. Available: https://doi.org/10.1080/09720502.2020.1761635

[9] P. Verma, A. Dumka, A. Bhardwaj, A. Ashok, M. C. Kestwal, and P. Kumar, "A statistical analysis of impact of COVID19 on the global economy and stock index returns," *SN Computer Science*, vol. 2, no. 1, Jan. 2021. [Online]. Available: https://doi.org/10.1007/s42979-020-00410-w

[10] T. V. Tran, H. C. Nguyen, L. V. Pham, M. H. Nguyen, H. C. Nguyen, T. H. Ha, D. T. Phan, H. K. Dao, P. B. Nguyen, M. V. Trinh, T. V. Do, H. Q. Nguyen, T. T. P. Nguyen, N. P. T. Nguyen, C. Q. Tran, K. V. Tran, T. T. Duong, H. X. Pham, L. V. Nguyen, T. T. Vo, B. N. Do, T. H. Duong, M. K. Pham, T. T. M. Pham, K. T. Nguyen, S.-H. Yang, J. C. J. Chao, and T. V. Duong, "Impacts and interactions of COVID-19 response involvement, health-related behaviours, health literacy on anxiety, depression and health-related quality of life among healthcare workers: a cross-sectional study," *BMJ Open*, vol. 10, no. 12, p. e041394, Dec. 2020. [Online]. Available: https://doi.org/10.1136/bmjopen-2020-041394

[11] A. Adams-Prassl, T. Boneva, M. Golin, and C. Rauh, "The impact of the coronavirus lockdown on mental health: Evidence from the US," 2020.

[12] M. M. Rahman, K. C. Paul, M. A. Hossain, G. G. M. N. Ali, M. S. Rahman, and J.-C. Thill, "Machine learning on the COVID-19 pandemic, human mobility and air quality: A review," *IEEE Access*, vol. 9, pp. 72 420–72 450, 2021. [Online]. Available: https://doi.org/10.1109/access.2021.3079121

[13] R. Nigam, K. Pandya, A. J. Luis, R. Sengupta, and M. Kotha, "Positive effects of COVID-19 lockdown on air quality of industrial cities (ankleshwar and vapi) of western india," *Scientific Reports*, vol. 11, no. 1, Feb. 2021. [Online]. Available: https://doi.org/10.1038/s41598-021-83393-9

[14] D. BOL, M. GIANI, A. BLAIS, and P. J. LOEWEN, "The effect of COVID-19 lockdowns on political support: Some good news for democracy?" *European Journal of Political Research*, vol. 60, no. 2, pp. 497–505, May 2020. [Online]. Available: https://doi.org/10.1111/1475-6765.12401

[15] covid19.gov.gr, "Daily overview — covid19.gov.gr," https://covid19.gov.gr/covid19-live-analytics, (Accessed on 05/20/2022).

[16] T. Hale, N. Angrist, R. Goldszmidt, B. Kira, A. Petherick, T. Phillips, S. Webster, E. Cameron-Blake, L. Hallas, S. Majumdar, and H. Tatlow, "A global panel database of pandemic policies (oxford covid-19 government response tracker)," *Nature Human Behaviour*, vol. 5, no. 4, pp. 529–538, Apr 2021. [Online]. Available: https://doi.org/10.1038/s41562-021-01079-8

[17] S. Liu, T. Ermolieva, G. Cao, G. Chen, and X. Zheng, "Analyzing the effectiveness of covid-19 lockdown policies using the time-dependent reproduction number and the regression discontinuity framework: Comparison between countries," *Engineering Proceedings*, vol. 5, no. 1, 2021. [Online]. Available: https://www.mdpi.com/2673-4591/5/1/8

[18] S. Wang, M. Schraagen, E. T. K. Sang, and M. Dastani, "Public sentiment on governmental COVID-19 measures in dutch social media," in *Proceedings of the 1st Workshop on NLP for COVID-19@ EMNLP 2020, Online, December 2020*, K. Verspoor, K. B. Cohen, M. Conway, B. de Bruijn, M. Dredze, R. Mihalcea, and B. C. Wallace, Eds. Association for Computational Linguistics, 2020. [Online]. Available: https://doi.org/10.18653/v1/2020.nlpcovid19-2.17

[19] K. Nishi, "The impact of increasing COVID-19 cases/deaths on the number of uncivil tweets directed at governments," *CoRR*, vol. abs/2107.10041, 2021. [Online]. Available: https://arxiv.org/abs/2107.10041

[20] C. Júnior, M. Loutfi, and S. W. M. Siqueira, "The impact of the covid-19 cases with twitter users in their perception of the brazilian government," in *55th Hawaii International Conference on System Sciences, HICSS 2022, Virtual Event / Maui, Hawaii, USA, January 4-7, 2022*. ScholarSpace, 2022, pp. 1–10. [Online]. Available: http://hdl.handle.net/10125/79683

[21] C. Chatzopoulou, D. Tsolkanakis, S. M. Vasileiadou, K. Kyriakidis, K. Skoutzouri, D. Kirtikidou, S. I. H. Shah, and V. Peristeras, "E-government and COVID-19: an empirical study in greece," in *Metadata and*

Semantic Research - 15th International Conference, MTSR 2021, Virtual Event, November 29 - December 3, 2021, Revised Selected Papers, ser. Communications in Computer and Information Science, E. Garoufallou, M. A. Ovalle-Perandones, and A. Vlachidis, Eds., vol. 1537. Springer, 2021, pp. 307–321. [Online]. Available: https://doi.org/10.1007/978-3-030-98876-0_27

[22] K. Schnaider, S. Schiavetto, F. Meier, B. Wasson, B. B. Allsopp, and D. Spikol, "Governmental response to the COVID-19 pandemic - A quantitative ethnographic comparison of public health authorities' communication in denmark, norway, and sweden," in *Advances in Quantitative Ethnography - Second International Conference, ICQE 2020, Malibu, CA, USA, February 1-3, 2021, Proceedings*, ser. Communications in Computer and Information Science, A. R. Ruis and S. B. Lee, Eds., vol. 1312. Springer, 2020, pp. 406–421. [Online]. Available: https://doi.org/10.1007/978-3-030-67788-6_28

[23] D. Tosi and M. Chiappa, "Understanding the geographical spread of COVID-19 in relation with goods regional routes and governmental decrees: The lombardy region case study," *SN Comput. Sci.*, vol. 2, no. 3, p. 203, 2021. [Online]. Available: https://doi.org/10.1007/s42979-021-00597-6

[24] N. Alamsyah and Y. Zhu, "We shall endure: Exploring the impact of government information quality and partisanship on citizens' well-being during the COVID-19 pandemic," *Gov. Inf. Q.*, vol. 39, no. 1, p. 101646, 2022. [Online]. Available: https://doi.org/10.1016/j.giq.2021.101646

[25] N. Alkan and C. Kahraman, "Evaluation of government strategies against COVID-19 pandemic using q-rung orthopair fuzzy TOPSIS method," *Appl. Soft Comput.*, vol. 110, p. 107653, 2021. [Online]. Available: https://doi.org/10.1016/j.asoc.2021.107653

[26] L. S. Araiinejad, Y. Li, J. R. Carlton, and J. Zheng, "Assessing the impact of government interventions on the spread of COVID-19 with dynamic epidemic models: A case study of texas," in *IEEE International Conference on Bioinformatics and Biomedicine, BIBM 2020, Virtual Event, South Korea, December 16-19, 2020*, T. Park, Y. Cho, X. Hu, I. Yoo, H. G. Woo, J. Wang, J. C. Facelli, S. Nam, and M. Kang, Eds. IEEE, 2020, pp. 2274–2281. [Online]. Available: https://doi.org/10.1109/BIBM49941.2020.9313591

[27] L. Miralles-Pechuán, F. Jiménez, H. Ponce, and L. Martínez-Villaseñor, "A methodology based on deep q-learning/genetic algorithms for optimizing

COVID-19 pandemic government actions," in *CIKM '20: The 29th ACM International Conference on Information and Knowledge Management, Virtual Event, Ireland, October 19-23, 2020*, M. d'Aquin, S. Dietze, C. Hauff, E. Curry, and P. Cudré-Mauroux, Eds. ACM, 2020, pp. 1135–1144. [Online]. Available: https://doi.org/10.1145/3340531.3412179

[28] A. Haberling, J. Laurisch, and J. Altmann, "South korea as the role model for covid-19 policies? an analysis of the effect of government policies on infection chain structures," in *Economics of Grids, Clouds, Systems, and Services - 17th International Conference, GECON 2020, Izola, Slovenia, September 15-17, 2020, Revised Selected Papers*, ser. Lecture Notes in Computer Science, K. Djemame, J. Altmann, J. Á. Bañares, O. A. Ben-Yehuda, V. Stankovski, and B. Tuffin, Eds., vol. 12441. Springer, 2020, pp. 104–114. [Online]. Available: https://doi.org/10.1007/978-3-030-63058-4_10

[29] K. Nikolopoulos, S. Punia, A. Schäfers, C. Tsinopoulos, and C. Vasilakis, "Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions," *Eur. J. Oper. Res.*, vol. 290, no. 1, pp. 99–115, 2021. [Online]. Available: https://doi.org/10.1016/j.ejor.2020.08.001

[30] "Johns hopkins coronavirus resource center," https://coronavirus.jhu.edu/, (Accessed on 01/30/2023).

[31] "Coronavirus (covid-19) in the uk," https://coronavirus.data.gov.uk/, (Accessed on 01/30/2023).

[32] "Coviddexp - covid-19 data exploration," https://covid19.csd.auth.gr/, (Accessed on 01/30/2023).

[33] A. Kyriakidis and I. Papadopoulos, "Observatory of government restrictive measures for the covid-19 pandemic (govrm-covid19)," center for research on democracy and law (university of macedonia, greece)," https://en.kedid.org/research/programs/govrm-covid19/, 2020, (Accessed on 05/20/2022).

[34] O. W. in Data, "The share of covid-19 tests that are positive, may 19, 2022," https://ourworldindata.org/grapher/positive-rate-daily-smoothed, (Accessed on 05/20/2022).

[35] E. G. Kostaki, G. A. Pavlopoulos, K.-M. Verrou, G. Ampatziadis-Michailidis, V. Harokopos, P. Hatzis, P. Moulos, N. Siafakas, S. Pournaras,

C. Hadjichristodoulou, F. Chatzopoulou, D. Chatzidimitriou, P. Panagopoulos, P. Lourida, A. Argyraki, T. Lytras, S. Sapounas, G. Gerolymatos, G. Panagiotakopoulos, P. Prezerakos, S. Tsiodras, V. Sypsa, A. Hatzakis, C. Anastassopoulou, N. Spanakis, A. Tsakris, M. A. Dimopoulos, A. Kotanidou, P. Sfikakis, G. Kollias, G. Magiorkinis, and D. Paraskevis, "Molecular epidemiology of SARS-CoV-2 in greece reveals low rates of onward virus transmission after lifting of travel restrictions based on risk assessment during summer 2020," *mSphere*, vol. 6, no. 3, Jun. 2021. [Online]. Available: https://doi.org/10.1128/msphere.00180-21

[36] Statista, "Travel and tourism: share of gdp by country eu 2020 — statista," https://www.statista.com/statistics/1228395/travel-and-tourism-share-of-gdp-in-the-eu-by-country/, (Accessed on 05/20/2022).