Comparing Countries On COVID-19 Government Measures

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From January 2020 onward, many countries around the world adopted government measures with the purpose of restricting the COVID-19 pandemic. In this paper, we initially estimate 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), we first estimate their correlations with regard to their government measures to see how similarly they reacted to the tightening and the relaxing of measures and, secondly, we estimate 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 we attribute to the fact that their economies are mainly driven by the tourist sector.

CCS Concepts: • **Applied computing** → **Health informatics**.

Additional Key Words and Phrases: COVID-19 positive test rate, COVID-19 related government measures, correlation, cross-correlation

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1 INTRODUCTION

In December 2019 an epidemic of pneumonia emerged in Wuhan, China [22]. 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 [21]. On March 12, 2020 the World Health Organization declared COVID-19 as a global pandemic [20]. 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.

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 [18]. In addition, the mental health of many people appeared to be affected, with health-care workers showing higher rates of anxiety and depression [17]. Also, the lock-down reduced mental health and increased the gender gap in mental health [1].

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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 [10, 13], and there has been a high level of trust in government and satisfaction with democracy [5].

In this paper, 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 [6], 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.

Section 2 reviews the relevant literature. In Section 3 we describe 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. Section 4 presents all the analyses we performed on the collected data and the respective findings. Finally, Section 5 discusses the findings and gives pointers for further research on the subject.

2 REVIEW OF THE LITERATURE

Our extensive search on the literature using the keywords "covid", "government" and "measure or policy" did not identify other similar studies to the one we present in this paper. Our study examines the relationship between government measures and the COVID-19 epidemiological data and compares European countries on the basis of government measures taken before any immediate treatment such as vaccination of the population took place.

A study that deals with the public sentiment on governmental COVID-19 measures in Dutch social media appears in [19]. Another interesting study examines the correlation between increasing COVID-19 cases/deaths and the number of uncivil tweets directed to governments [11].

Governmental responses to the COVID-19 pandemic are used to understand political and cultural similarities and differences between three Scandinavian countries in [14]. Reference [16] among other analyses, contains an empirical discussion on how actions and decrees imposed by the Italian government over time impacted on the spread of COVID-19.

In [2], an attempt is made to understand how the quality of government information and citizens' partisanship impact citizens' well-being in terms of satisfaction with life and anxiety during COVID-19. [3] tries to identify the most important strategy against the COVID-19 pandemic that should be implemented by governments. Also, [4] studies the effectiveness of the local and state government restrictions and closures in Texas in limiting the spread of COVID-19.

A methodology based either on Deep Q-Learning or Genetic Algorithms for helping governments in planning the phases to combat the pandemic based on their priorities is presented in [9]. In a another study [7], the impact of government policy interventions on the infection chain structure is measured. The analysis shows that implemented policies decrease the high fluctuation in infection chain structures that were observed at the beginning of the pandemic.

3 DATA AND METHODS

3.1 Data Sources and Pre-Processing

This paper 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 is 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 [8].

Below, the thirteen (13) types of government measures for which data was available are listed:

(1) Freedom of individual movement (excluding inner-country travel and international transportation)
(2) Use of Mask
(3) Public Gatherings
(4) Education
(5) Food services (restaurants, bars, etc., excluding food retailers)
(6) Food retailers (supermarkets, grocery stores, etc., excluding food services)
(7) Sport Facilities (indoor, outdoor)
(8) Inner-country travel (between Municipalities, Regions, etc., excluding essential goods transportation and trade)
(9) International transportation (ships, planes, etc., excluding essential goods' transportation and trade)
(10) Work and other interior spaces not included in other categories (civil service/public employees, beauty salons, barber shops, etc.,)
(11) Public Events (concerts, conferences, festivals, etc.)
(12) Retail stores (clothes shops, outlets, shopping malls, etc.)
(13) Religious places and ceremonies (churches, marriages, funerals, etc.)

All the above measures take 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 paper, a single variable was created as the average value of all measures on a daily basis, as we wanted to give equal importance to all measures. Additional daily data of the COVID-19 PTR based on a 7-day rolling average were retrieved from the "Our World in Data" website [12].

3.2 Analysis Objectives and Chosen Methods

Our research had three objectives that we present below.

First, we were interested in analyzing 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, we decided to use the cross-correlation method. 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, we wanted to compare the behavior of a number of selected countries, namely, Cyprus, France, Greece, Ireland, Malta and Norway, in terms of COVID-19 government measures taken. We chose those countries because we were able to retrieve comparable year 2020 data for them. 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, we were interested in computing the time lag measured in days where the various countries exhibited the highest possible correlation in terms of governmental measures. Again, we used the cross-correlation method and we report (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.

4 ANALYSIS AND RESULTS

4.1 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 1 and 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. A period of very tight measures is observed from October until December (Fig. 1). The behavior of COVID-19 PTR appears to follow a similar pattern, with low values until October and a significant increase afterwards (Fig. 2).

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. (Fig. 3).

4.2 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 Fig. 4.

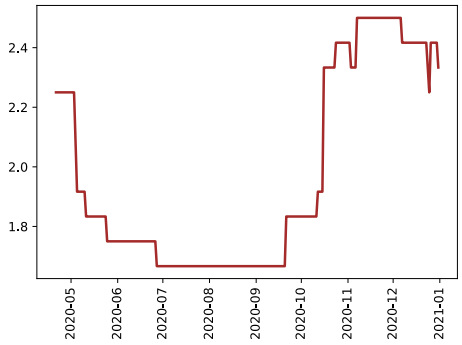

Fig. 1. Time series of Greek government measures.

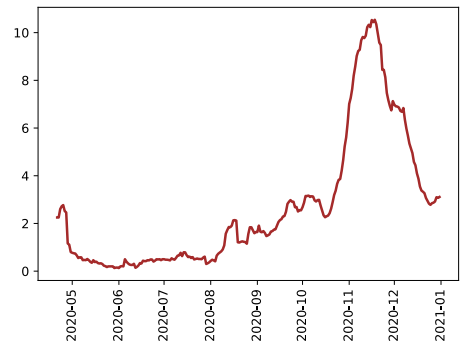

Fig. 2. Time series of Greek COVID-19 positive test rate.

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:

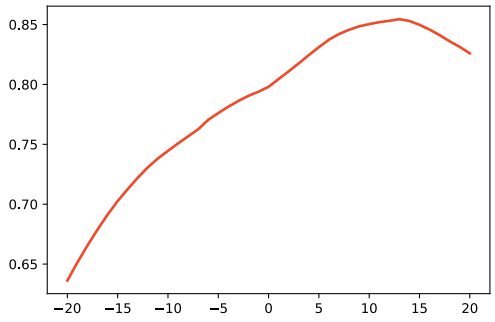

Fig. 3. Correlations between Greek government measures and COVID-19 PTR for various distance of days.

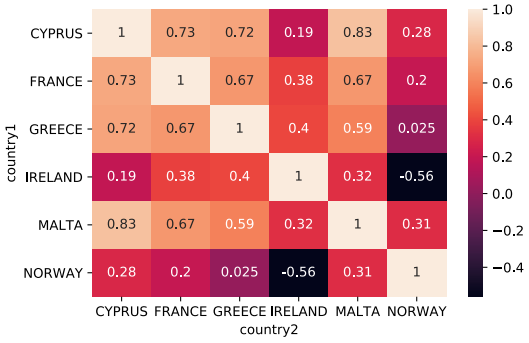

Fig. 4. Correlations between government measures for Cyprus, France, Greece, Ireland, Malta and Norway.

(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)

Fig. 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 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 (Fig. 4). This behavior can also be observed in Fig. 5.

4.3 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 Fig. 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, we observe 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
(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, we also report the cross-correlation values among the countries (Fig. 7). In other words, it may be

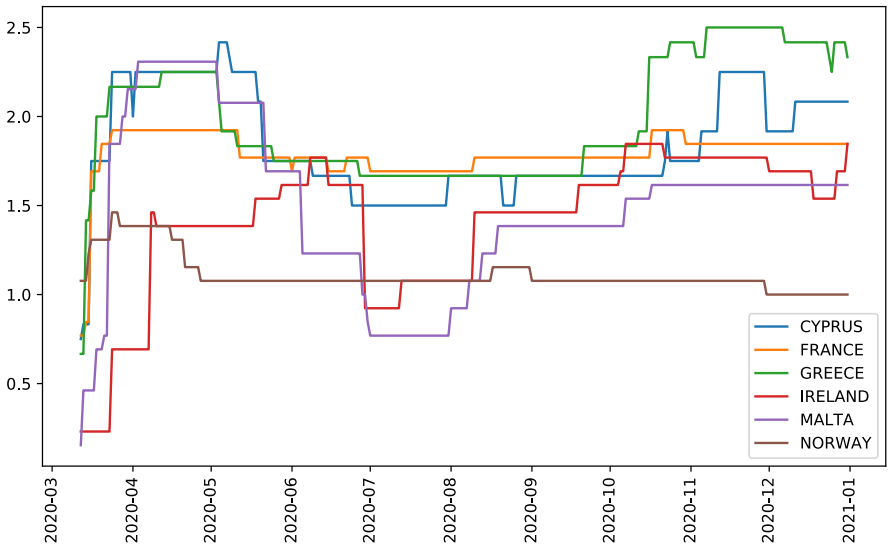

Fig. 5. Time series of government measures for Cyprus, France, Greece, Ireland, Malta and Norway.

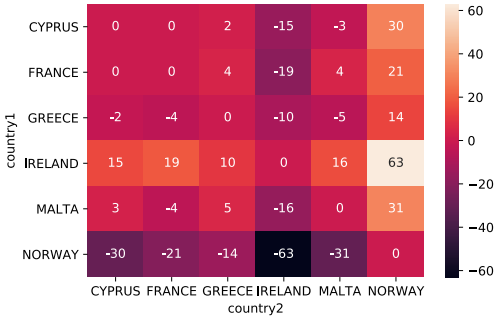

Fig. 6. For Cyprus, France, Greece, Ireland, Malta and Norway: government measures highest cross-correlation in distance of days.

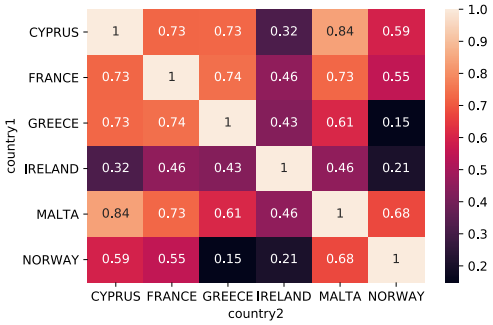

Fig. 7. For Cyprus, France, Greece, Ireland, Malta and Norway: government measures cross-correlation.

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, we report on them separately in the order we did for Fig. 6 and we observe values greater than 0.5 (between 0.61 and 0.84), 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)
(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.

5 DISCUSSION

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 we include the day without a shift) 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 [15].

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.

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