Efficiency Evaluation of European Countries in terms of COVID-19

Gökçen Bayram, Özlem Yurtsever

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Abstract

Background: The COVID-19 Pandemic has effected millions of people all over the world. Therefore the behaviour of countries are important to minimise the losses.

Objective: The aim of this study is to evaluate and compare the performance of 27 European Countries on spread and deaths caused by COVID-19 pandemics by using input-oriented data envelopment analysis (DEA) method. A comparison was done between the 27 European Countries for contagion control efficiency and medical treatment efficiency.

Methods: The DEA model is performed in two stages. In the first stage, the contagion control efficiency is analysed whereas in the second stage the medical treatment efficiency is evaluated. Moreover, the countries are classified into the four zone by using the area chart. For the countries in each zones, some recommendations are given.

Results: Luxembourg has a poor performance in contagion control. In addition, Denmark and Iceland have a good performance in medical treatment of COVID-19 patients in comparison to other countries in the study. Malta, Montenegro, Cyprus, Denmark, Estonia, Finland, Greece, Netherlands and Norway are in Area 1, showing that these countries have been acted efficiently both in contagion control and medical treatment of the patients. Italy, Spain, Iceland and Portugal are in Area 2. These countries have had good performance in medical treatment but they have had controlled the contagion inefficiently. The countries which have been acted inefficiently both in contagion control and medical treatment of the patients are in Area 3. Luxembourg, North Macedonia, Switzerland and Turkey are in critical conditions in this manner. Lastly, Poland, Romania, Slovakia, Austria, Bulgaria, Czechia, Hungary, France, Germany and Croatia are in Area 4. These countries have been successful in providing a good performance in contagion control but they have had poor performance in medical treatment.

Conclusions: The countries are classified in to the four zones according to their performance. Countries in Area 1 has a high performance in both contagion control and medical treatment. All the other countries should follow the footprints of the countries in Area 1. In addition, Luxembourg, North Macedonia, Switzerland and Turkey are in critical conditions and need a special attention.

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Introduction

A pandemic can be defined as an epidemic or a new infectious disease that spread of a large area, continent or worldwide. It can effect a substantial number of people. Throughout the course of history, there has been a number of pandemics. In Table 1, the pandemics in history are listed [1].

Table 1. Pandemics throughout the History

Name of Pandemic	Year	The Number of Deaths
Plague of Athens	430 B.C.	Nearly 100,000
Antonine Plague	A.D. 165-180	5 million
Plague of Cyprian	A.D. 250-271	5,000
Plague of Justinian	A.D. 541-542	30 – 50 million
Japanese Smallpox Epidemic	A.D. 735-737	1 million
The Black Death	1346-1353	200 million
Smallpox	1520	56 million
Cocoliztli Epidemic	1545-1548	15 million
Great Plague of London	17th Century	3 million
Great Plague of Marseille	18th Century	600,000
Russian Plague	1770 - 1772	100,000
Philadelphia Yellow Fever Epidemic	1793	5,000
Cholera Epidemic	1817 - 1923	1 million
Plague	1855	12 million
Flu Pandemic	1889 - 1890	1 million
American Polio Epidemic	1916	6,000
Spanish Flu	1918 - 1920	40 – 50 million
Asian Flu	1957 - 1958	1,1 million
Hong Kong Flu	1968 - 1970	1 million
AIDS Pandemic and Epidemic	1981 – present day	25 – 35 million
SARS Pandemic	2002 - 2003	770,000
H1N1 Swine Flu Pandemic	2009 - 2010	200,000
MERS Pandemic	2012 – present day	850,000
Ebola Epidemic	2014 - 2016	11,300
COVID-19	2019 – present day	400,000 (still continues)

The novel coronavirus, which is also known as COVID-19, was detected for the first time in China in December 2019. Afterwards, the virus have spread to almost all of the countries. Globally there are more than 8 million confirmed cases and over 400,000 death cases by June 18, 2020 [2]. Total case distribution of the regions are given in Figure 1.
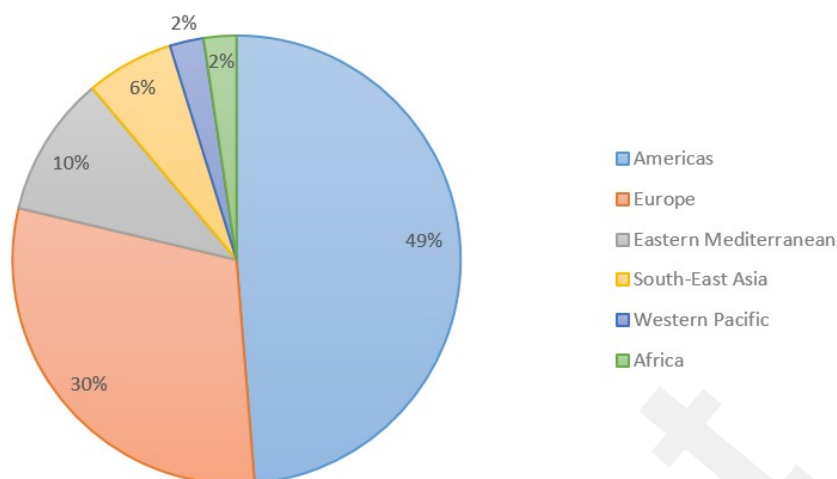
Figure 1. Share of Total Confirmed Case

COVID-19 has infected a tremendously larger population around the world and has many more death cases compared to previously well-known coronaviruses such as SERS or MERS [3]. The number of confirmed and death cases in a country and the increase/decrease rate depend profoundly on the readiness and the conditions of a country. Since COVID-19 become a focus issue for everyone, the studies on this disease are conducted with different perspectives [4], [5], [6], [7], [8], [9].

In one study, authors have compared 19 selected countries in two dimensions by using dynamic data envelopment analysis. For the two analysis, population, population density and age 65 and above were the inputs where, the first output was COVID-19 virus confirmed cases and the second output was COVID-19 virus confirmed deaths. By using the first model, the objective was to compare the countries on controlling the prevalence of COVID-19, the objective of the second model was preventing the mortality caused by of COVID-19 [10]. In another study, authors have compared and classified 29 countries by using DEA model in two steps. In the first step, population density and average of 13 International Health Regulations Core Capacity Scores (IHRCC) were considered as inputs whereas the confirmed cases were outputs. In the second part of their model, confirmed cases were considered as input whereas the death and recovered cases were chosen as outputs. As a result, Singapore, Vietnam, and Belgium were the countries with the highest efficient in both models [11]. The same authors have performed another DEA model among with 30 countries by using the two weeks data. In this study, as input they considered days since the first confirmed case and population density, and as an output average contagion rate is chosen [12].

In this study, the effectiveness of the countries in dealing with the COVID-19 pandemic is analysed by using the DEA model. Apart from the literature mentioned above, the DEA model is conducted in two stages. In the first stage, the effect of population and health security capabilities of the countries are questioned on confirmed cases. Later on, the death cases are analyzed according to the confirmed cases, hospital beds and 65 and over population of the countries. In order to find out the health security capabilities of the countries, Global Health Security (Index) is used.

GHS Index, which covers global health security capabilities in 195 countries, is developed between the Nuclear Threat Initiative, Johns Hopkins Center for Health Security, and the Economist Intelligence Unit. GHS Index prioritizes countries' capacities as well as existence of functional, tested, proven capabilities for stopping outbreaks at the source by using 140 questions. These questions are categorized into six categories with 34 indicators as shown in the Table 2.

Table 2. GHS Index Categories

Category	Explanation	Indicators
Prevent	Preventing the emergence or release of pathogens	1.1) Antimicrobial resistance (AMR) 1.2) Zoonotic disease 1.3) Biosecurity 1.4) Biosafety 1.5) Dual use research and culture of responsible science 1.6) Immunisation
Detect	Early detection and reporting epidemic of potential international concern	2.1) Laboratory systems 2.2) Real time surveillance and reporting 2.3) Epidemiology workforce 2.4) Data integration between human/animal/environmental health sectors
Respond	Rapidly responding to and mitigating the spread of an epidemic	3.1) Emergency preparedness and response planning 3.2) Exercising response plans 3.3) Emergency response operation 3.4) Linking public health and security authorities 3.5) Risk communication 3.6) Access to communications infrastructure 3.7) Trade and travel restrictions
Health	Sufficient and robust health sector to treat the sick and protect health workers	4.1) Health capacity in clinics, hospitals and community care centres 4.2) Medical countermeasures and personnel deployment 4.3) Healthcare access 4.4) Communications with healthcare workers during a public health emergency 4.5) Infection control practices and availability of equipment 4.6) Capacity to test and approve new medical countermeasures
Norms	Commitments to improving national capacity, financing and adherence to norms	5.1) International Health Regulations (IHR) reporting compliance and disaster risk reduction 5.2) Cross-border agreements on public health emergency response 5.3) International commitments 5.4) JEE and PVS 5.5) Financing 5.6) Commitment to sharing of genetic & biological data & specimens
Risk	Risk environment and vulnerability to biological threats	6.1) Political and security risk 6.2) Socio-economic resilience 6.3) Infrastructure adequacy 6.4) Environmental risks 6.5) Public health vulnerabilities

The scores are normalized between 0 and 100, where 100 is the most favorable. According to the index, there are three tiers. Countries that score between 0 and 33.3 are in the bottom tier, between 33.4 and 66.6 are in the middle tier, and between 66.7 and 100 are in the upper or "top" tier.

The GHS Index ranks the countries that are best prepared for an epidemic or pandemic. According

the 2019 report, among all of the 195 countries, none of them is fully prepared for the epidemics or pandemics [13]. According to the Index, for the year 2019, the top 10 country over the world is given in Table 3.

Table 3. Top Ten Countries According to GHS Index, 2019

Rank	Country	Score/100
1	United States	83.5
2	United Kingdom	77.9
3	Netherlands	75.6
4	Australia	75.5
5	Canada	75.3
6	Thailand	73.2
7	Sweden	72.1
8	Denmark	70.4
9	South Korea	70.2
10	Finland	68.7

The construction of the paper is as follows. In the next section, the methodology is explained as well as the data definition and selection. Section 3, presents the results of the applied model with the several analyses. Finally, Section 4 concludes this paper.

Material and Method

The performance of the countries dealing with the COVID-19 pandemics is analysed. The novel disease is appeared rapidly and the countries faced to deal with this uncertain conditions. Thus, the research is still young about this disease. Inorder to choose the method, a brief literature survey is conducted. In healthcare system, DEA method is frequently used in the literature to measure the efficiency [14], [15], [16], [17], [18], [19].

In this study, to analyse the effectiveness of the countries dealing the COVID-19 pandemics, the DEA method is chosen for two reasons. Bu using the DEA method, efficiency is measured by comparing the best application instead of the average. Additionally, unlike from the other parametric methods, DEA does not necessitate as much data [10].

DEA is a linear programming method planned to measure the relative efficiencies of a set of Decision Making Units (DMU) such as hospitals, education, manufacturing sector and banking sector with multiple inputs and multiple outputs [20]. In addition, DEA which is a data oriented method is used to compare and sort the efficiency of DMUs [21].

DEA is materialized as the assumption of constant returns to scale based on Charnes, Cooper, Rhodes (CCR). The CCR model can be input or output oriented. In an input orientation, for a certain level of output, DEA minimizes the input which shows how much an institution can decrease its input for a particular output. In an output orientation, for a certain level of input, DEA maximizes the output which shows how much an institution can increase its output for a particular input [22]. The controllability of inputs and outputs is the main factor on deciding the main theme of the model [23]. In other words, if the decision maker has an audit on input, the model is input oriented whereas, if the decision maker has an audit on output, the model is output oriented. In health sector, for the decision makers it is generally hard to control the outputs however they have the authority to control

the inputs.

This study designed as three stages based on DEA:

1. Definition and selection of DMUs: Since the countries are compared, they are considered as the DMUs. The critical situation in Europe led the study based on the European countries which are listed in the data selection part.

2. Detection the variables of inputs and outputs: DEA does not perform adequate results when the number of inputs or outputs are large. Consequently, this study is executed in two stages. In the first stage as shown in Figure 2, GHS Index of a country is taken as input whereas the ratio of confirmed cases to the population is output. In the second stage, the output is the ratio of death cases over confirmed cases where hospital beds and 65&over population are inputs as shown in Figure 3.
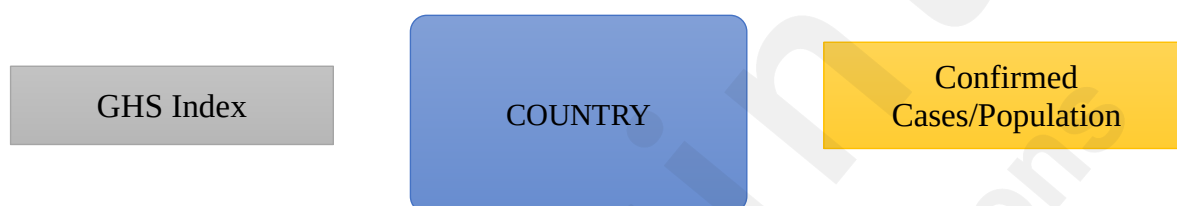
GHS Index	COUNTRY	Confirmed Cases/Population

Figure 2. The First Stage of the DEA Model

It should be noted that the ratio of confirmed cases to the population is an undesirable output. A solution to the first stage of the model gives the Contagion Inefficiency for each country.
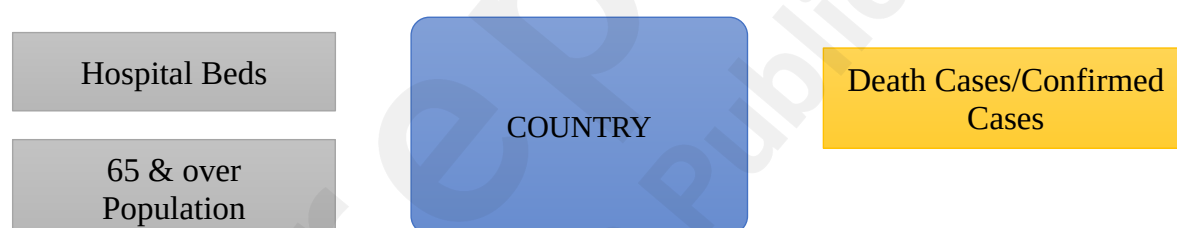
Hospital Beds		
	COUNTRY	Death Cases/Confirmed Cases
65 & over Population		

Figure 3. The Second Stage of the DEA Model

It should be noted that Population ages 65 and above (% of total population) is an undesirable input and the ratio of death cases to the confirmed cases is an undesirable output. A solution to this model gives the Medical Treatment Efficiency for each country.

3. Implementation of the model and evaluation of the results: In the final part of the study, the conditions of the countries regarding the confirmed cases and death cases are discussed.

In one study, Shirouyehzad and his friends have compared and classified 29 countries by using DEA model as mentioned before. They have classified the countries by using the chart area [11]. In this paper, similar to the mentioned paper, European Countries are classified as shown in Figure 4. The horizontal axis and vertical axis represent the medical treatment efficiency and contagion inefficiency, respectively. The total mean values of the DEA result will be used to divide the chart into four areas.
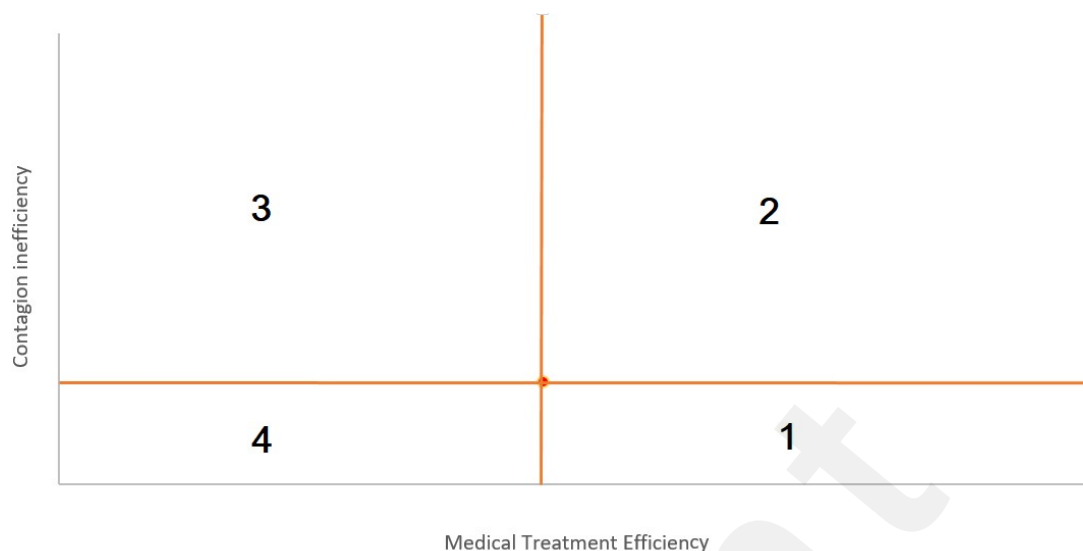
Figure 4. Classification Area of European Counties

The countries are placed in the chart according to their DEA results in the first and second step. The description of the areas is given as in Table 4.

Table 4. Description of the Classification of Countries

Area	Description
1	Good performance both in contagion spread and efficiency in medical treatment
2	Good performance in medical treatment but poor performance in spread of contagion
3	Poor performance both in contagion spread and efficiency in medical treatment
4	Poor performance in medical treatment but good performance in spread of contagion

In order to get a meaningful analysis, suitable inputs and outputs must be selected. The selection of factors that design the model and analyzed process is the most important task [18]. In this study the CCR model that depends on constant returns to scale, is used as input oriented method.

In literature there are two explanations about the sufficient number of DMUs [24]:

1. When, m is the number of inputs and p is the number of outputs, the number of DMUs (N) should be at least one more than the total of inputs and outputs as shown in the Equation 1.

$$N \geq m + p + 1 \tag{1}$$

2. When, m is the number of inputs and p is the number of outputs, the number of DMUs must be at least two times of the sum of total number of inputs and outputs as show in the Equation 2.

$$N \geq 2 \times (m + p) \tag{2}$$

Due to the data limitation, 27 European countries were selected for which information on COVID-19, hospital beds, population and GHS Index is available. The selected countries are Austria, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Luxembourg, Malta, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Slovakia, Spain, Switzerland and Turkey. The year and source of the data used for this study is summarized as in Table 5.

Table 5. Summary of the Data used in DEA

Data Description	Data Source	Year
Cumulative cases of COVID19	World Health Organization (WHO)	2020 (latest data is on June 18)
Cumulative deaths from COVID19	World Health Organization (WHO)	2020 (latest data is on June 18)
Population of the countries	Worldbank	2018
Population ages 65 and above (% of total population)	Worldbank	2018
Available hospital beds	EUROSTAT	2017
GHS index values	GHS index	2019

Results

Since the number of hospital beds will vary depending on the country population, the number of hospital beds per thousand people is used as the input variable. In this study, the measurement of the effectiveness of decision units (countries) was carried out with the DEAP 2.1 program. The effectiveness of European countries on spread and deaths caused by COVID-19 pandemics is evaluated by using input-oriented DEA model. In health industry, the power of countries to control and change output is limited. Countries can make changes in inputs to carry out more effective policies. Thus, they can achieve the goals they want to reach in the output. In addition to the input-oriented method, the CCR model was used in this study.

In this study, data envelopment analysis compares the countries to identify the causes of ineffectiveness in countries' health systems. Therefore, it is not possible to conclude that the countries which are effective, are the countries with the best health system. However, it can be said that they have relatively effective health systems compared to the existing decision units in the model.

In this paper DEA analysis is conducted in two stages to compare the 27 European countries in terms of COVID-19. In the first stage, to find out the contagion control efficiency, GHS Index of a country is taken as input whereas the ratio of confirmed cases to the population is output. In the second stage, to find out the medical treatment efficiency, hospital beds and 65&over population are taken as inputs whereas the ratio of death cases over confirmed cases is output. The first stage efficiency column represents the contagion control inefficiency in comparison to other countries. In the first stage efficiency column, the value 1 indicates that the related country has had poor performance in contagion control of COVID-19 according to the GHS Index and the number of confirmed cases to population. The results of the DEA analysis are demonstrated in Table 6.

Table 6. The Efficiency Values of the Stages

No	Country	1st Stage Efficiency Contagion Control Inefficiency	2nd Stage Efficiency Medical Treatment Efficiency	No	Country	1st Stage Efficiency Contagion Control Inefficiency	2nd Stage Efficiency Medical Treatmen

							t Efficiency
1	Austria	0.212	0.476	15	Luxembourg	1	0.555
2	Bulgaria	0.072	0.496	16	Malta	0.245	0.901
3	Croatia	0.074	0.622	17	Montenegro	0.075	0.680
4	Cyprus	0.122	0.745	18	Netherlands	0.242	0.761
5	Czechia	0.126	0.548	19	North Macedonia	0.351	0.505
6	Denmark	0.195	1	20	Norway	0.162	0.815
7	Estonia	0.172	0.727	22	Poland	0.094	0.474
8	Finland	0.124	0.971	22	Portugal	0.390	0.995
9	France	0.220	0.441	23	Romania	0.171	0.439
10	Germany	0.228	0.488	24	Slovakia	0.041	0.533
11	Greece	0.036	0.754	25	Spain	0.516	0.858
12	Hungary	0.048	0.359	26	Switzerland	0.351	0.634
13	Iceland	0.720	1	27	Turkey	0.274	0.495
14	Italy	0.454	0.942		**Average**	**0.249**	**0.675**

According to the results, Luxemburg has an efficiency value of 1 showing that it has a poor performance in contagion control. In addition, Denmark and Iceland have an efficiency value of 1 showing that these countries have had good performance in medical treatment of COVID-19 patients in comparison to other countries in the study.

Discussion

In this study, European countries are analysed and compared in two steps in the context of COVID-19 pandemics. In the first step, GHS Index was taken as input and the ratio of confirmed cases over population was taken as output. Data Envelopment Analysis shows the active countries as the value 1. However, the value 1 for the ratio of confirmed cases over population means that these countries are very active to spread the COVID-19 which is an undesirable output. In the analysis the countries that have value 1 are accepted as ineffective countries.

The values in Table 6, are used to create the four areas depicted in Figure 5. In this figure, the

average efficiency for the first stage, 0.249, and for the second stage, 0.675, are used to divide the chart into four areas. According to these areas, the countries are classified in to the four group to analyze their efficiencies.
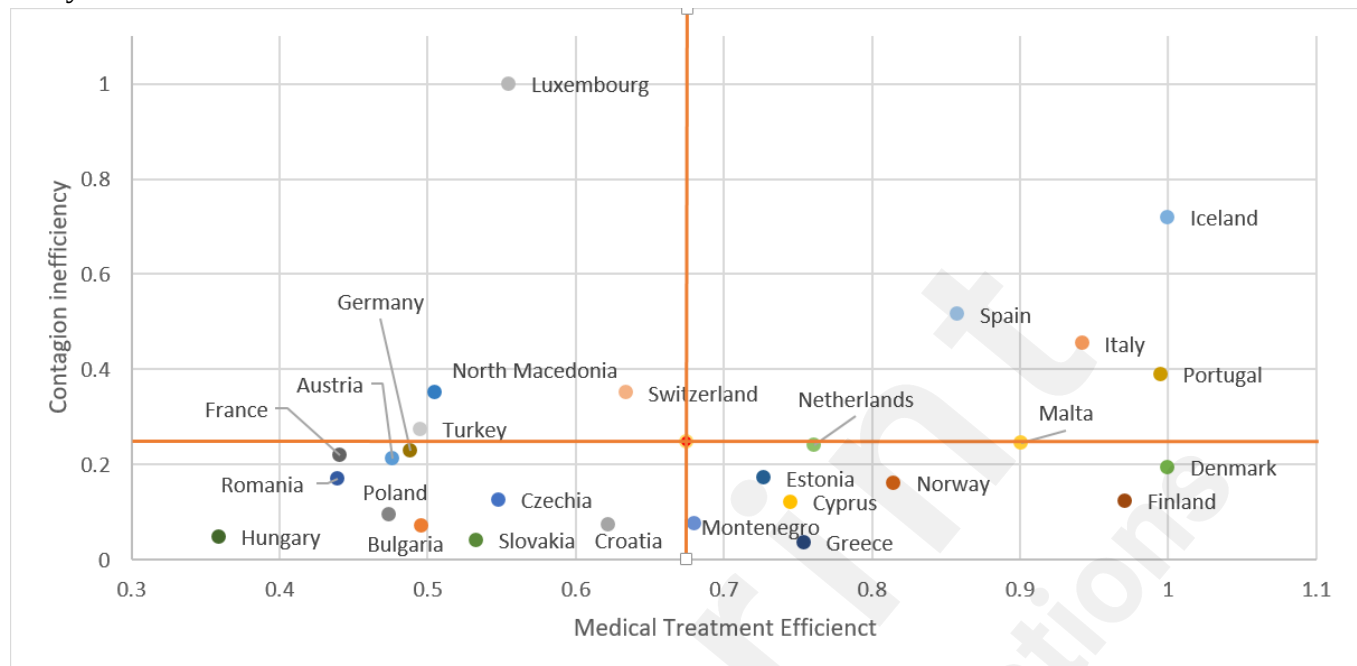

Figure 5. The Area Chart for Classification of the European Countries

From Figure 5, it can be seen that Malta, Montenegro, Cyprus, Denmark, Estonia, Finland, Greece, Netherlands and Norway are in Area 1, showing that these countries have been acted efficiently both in contagion control and medical treatment of the patients. After all, Malta lies on the border is considered in the first area since its contagion control inefficiency value, 0.245, is slightly below to the average value of all the countries, 0.249. Italy, Spain, Iceland and Portugal are in Area 2. These countries have had good performance in medical treatment but they have had controlled the contagion inefficiently. The countries which have been acted inefficiently both in contagion control and medical treatment of the patients are in Area 3. Luxembourg, North Macedonia, Switzerland and Turkey are in critical conditions in this manner. Lastly, Poland, Romania, Slovakia, Austria, Bulgaria, Czechia, Hungary, France, Germany and Crotia are in Area 4. These countries have been successful in providing a good performance in contagion control but they have had poor performance in medical treatment.

According to the classification of areas in Figure 5, Montenegro, Netherlands, Malta, Germany, France and Austria need to pay a special attention to maintain their current performance.

Montenegro is in the first area which is the best performance area. However, if Montenegro acts as Hungary in terms of medical treatment efficiency, then the performance area will change to the fourth zone. Since the average value of stage 2 analysis is 0.675 and the value for Hungary is 0.359, it means that Hungary is the worst country in terms of medical treatment efficiency. Thus, Montenegro needs to be careful in keeping its medical treatment capability as it is.

The contagion control inefficiency value of Netherlands and Malta are 0.242 and 0.245, respectively. These values are very close to the average value of 0.249. The countries with the values below 0.249 are efficient whereas the others are inefficient. Inefficiency increases as it approaches to the value of 1. The most inefficient country of stage 1 analysis is Luxemburg. If Netherlands and Malta behave like Luxemburg, then their zone will change from 1 to 2. Thus they will be one of the contagion

control inefficient countries.

Germany, France and Austria are in the fourth zone. In this zone they are already inefficient in terms of medical treatment. However they are trying to control their contagion efficiently. Like Netherlands and Malta, if these countries act like Luxemburg their zone will downgrade to the third area which is the worst case.

On the other hand, the average value of contagion control inefficiency is 0.249 whereas Turkey's value is 0.274. Turkey which is on the third area, can easily go up to the fourth area with a little effort by controlling the contagion efficiently like Greece and Slovakia.

In summary, the countries are classified in to the four zones according to their performance in this manner. The classification of the countries and the conclusion about these countries are given in Table 7.

Table 7. Classification of the Countries

Area	Countries	Conclusion
1	Malta, Montenegro, Cyprus, Denmark, Estonia, Finland, Greece, Netherlands, Norway	High performance
2	Italy, Spain, Iceland, Portugal	Average performance, needs to learn contagion control as in the countries in the area 1 and 4
3	Luxembourg, North Macedonia, Switzerland, Turkey	In critical conditions
4	Poland, Romania, Slovakia, Austria, Bulgaria, Czechia, Hungary, France, Germany, Crotia	Average performance, needs to learn medical treatment as in the countries in the area 1 and 2

According to Table 7, Malta, Montenegro, Cyprus, Denmark, Estonia, Finland, Greece, Netherlands, and Norway are the countries with high performance both in contagion control and medical treatment. Thus all the other countries should take these countries as an example. However, Luxembourg, North Macedonia, Switzerland and Turkey are in critical conditions and need a special attention.

If the bed numbers in hospitals are low, then it means that, because of the low capacity the patients cannot be treated fully leading the higher number of death ratios. If the number of beds in hospitals is high, patients diagnosed with COVID-19 can be quarantined in hospitals, the possibility of spread is reduced, and mortality rates can be reduced with rapid treatment.

In addition, it is known that the possibility of death from COVID-19 for elderly people (65+) and people with chronic diseases are high then the others. Thus, if the population of elderly people (65+) is relatively low then it is expected the death rates being low.

The indicators chosen can affect the results of the model easily. Therefore, different inputs and outputs can change the results and analysis. These indicators can be more comprehensive in further studies for extended results.

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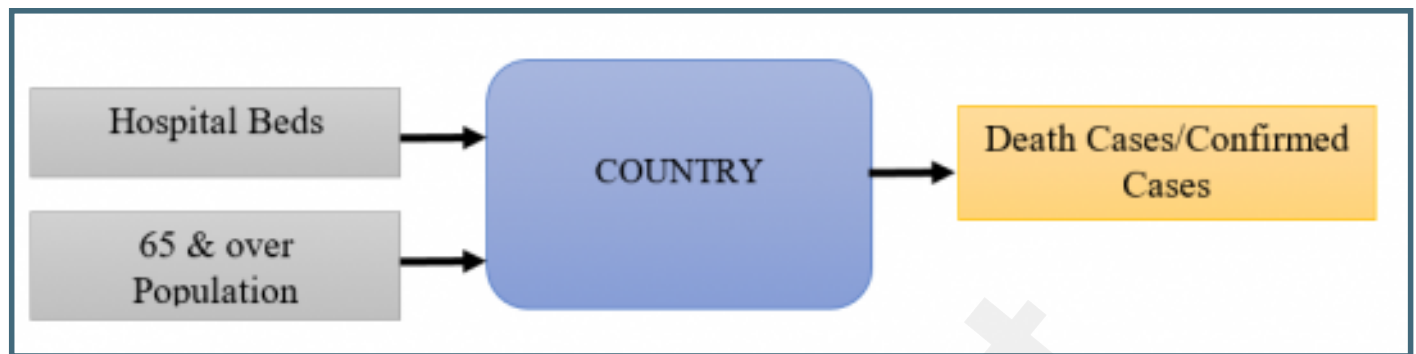**Supplementary Files**

Figures

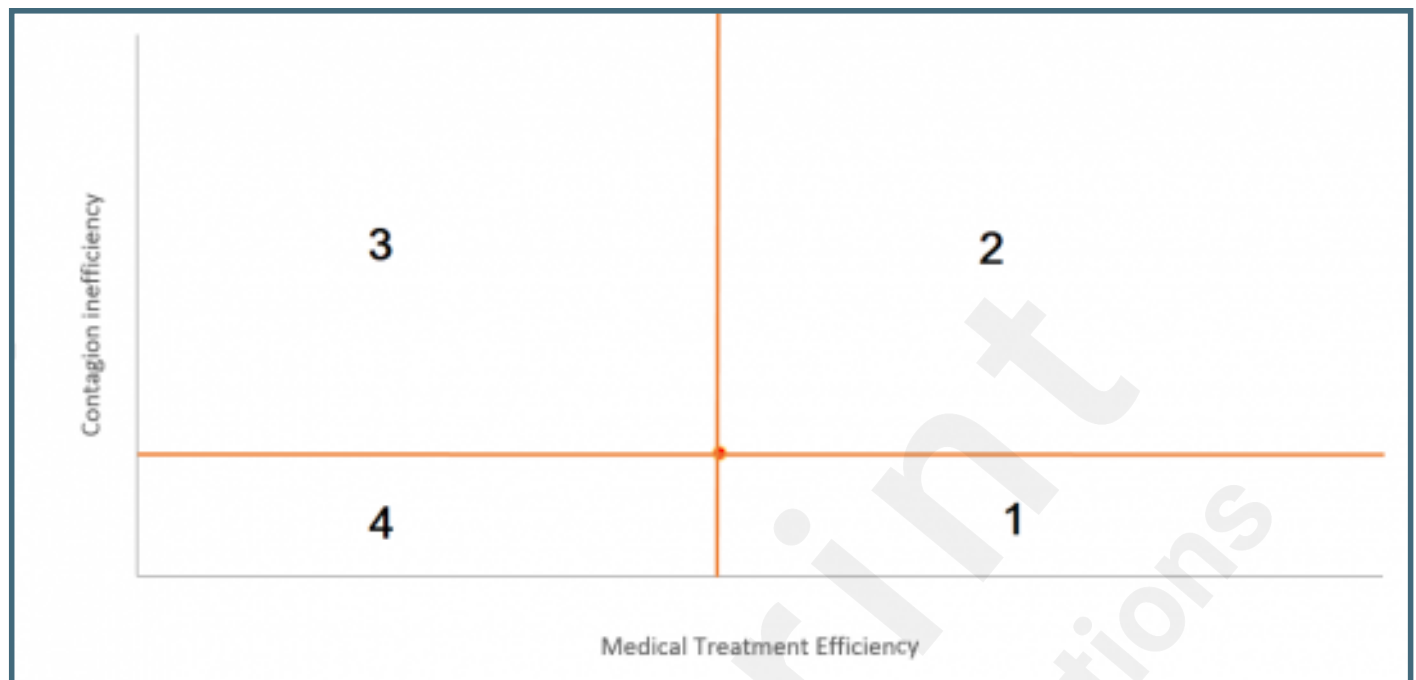Share of total confirmed case.
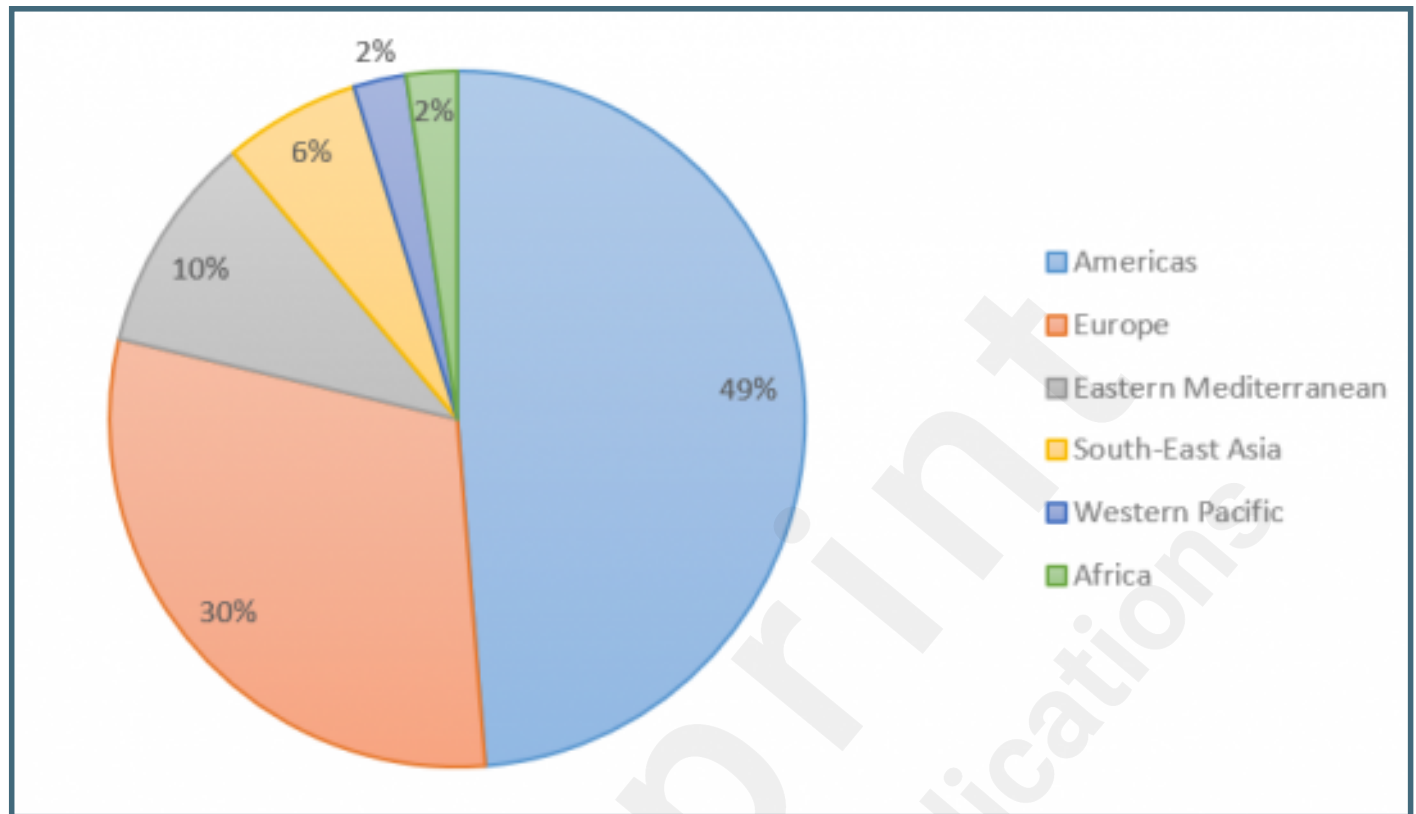
The first stage of the DEA model.

The second stage of the DEA model.

Classification area of European counties.

The area chart for classification of the European countries.