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An Analysis of the COVID-19 Contagion Growth in European Countries

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Abstract

The COVID-19 pandemic has affected many people around the globe. Europe, as one of the most seriously affected continents, has been struggling with the novel coronavirus for several months. Obviously, outbreak response management plays a critical role in the impact of the disease. Therefore, in this paper, Malmquist Productivity Index is used to evaluate the performance of the most severely affected European countries based on the average contagion rate. The results rank the countries and provide insight into the future.

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INTRODUCTION

In December 2019, the novel coronavirus, also known as 2019-nCoV, was observed for the first time in Wuhan, China (Wuhan City Health Committee (WCHC), 2020). The virus then spread to almost all of the countries around the world infecting hundreds of thousands of people and claiming thousands of lives. By 10 April 2020, there were more than 1,500,000 confirmed cases, and over 90,000 death cases globally, while the numbers were about 800,000 and 66,000 for the European region, respectively (World Health Organization, 2020). With more than 50% of the number of confirmed cases and more than 70% of the death cases in Europe, this continent is by far the most acutely stuck region in the world. Therefore, outbreak response management performance evaluation is critical to control the situation and provide insight for future epidemic crises in Europe.

The performance of a national outbreak response management system should be measured according to the conditions under which the system is operating. More specifically, the number of confirmed cases and the rate at which the epidemic spreads in a country depends on the features of that country. Although some indicators, such as confirmed Case Fatality Rate (cCFR) and confirmed Case Recovery Rate (cCRR), are already defined as used for performance evaluation of countries (Jouzdani, 2020), they may be insufficient for capturing the situation in which a country faces the outbreak. Few researches have addressed the outbreak response management performance evaluation from this perspective. Shirouyehzad, Jouzdani, and Khodadadi (2020) analyzed the performance of the countries, most significantly impacted by COVID-19, based on medical treatment of the patients and contagion control. They proposed a Data Envelopment Analysis (DEA) model to calculate the efficiency values in two consecutive steps. They considered several factors including population density, health care system condition, the number of confirmed cases, the number of deaths, and the number of recovered cases. They presented an evaluation of the outbreak response management performance in the countries, and provided a classification of the countries based on medical treatment and contagion control.

In this paper, the aim is to determine the relative growth/decline rate of COVID-19 contagion in the European countries that are most significantly affected by the disease. To achieve this goal, DEA, as a tool with the potential of providing relative comparisons, is utilized. Contact frequency among people is known as one of the major factors affecting the spread of diseases. A crucial factor that can increase the frequency of contact in a country is the population density which is a measurement of population per unit area. Therefore, the population density is considered as an input for the DEA model. To provide an appropriate basis for the comparison, the number of days since the confirmation of the first case is also regarded as an input for the model. 30 European countries in which, on 31 March 2020, more than a month is passed since the confirmation of their first case are considered as Decision-Making Units (DMUs), and the DEA model is run for the last two weeks of March 2020, and the Malmquist Productivity Index (MPI) is used to determine the relative growth/decline of average contagion rate in the countries. The results would be to distinguish the countries with critical relative progress and average contagion rate.

The exposition of the paper is as follows. In the next section, the methodology of this research is presented. Section 3 discusses the results, and Section 4 discusses the results and concludes the paper and suggests future research topics.

METHODOLOGY

The data envelopment analysis (DEA) technique is used to identify the strengths and weaknesses of a set of DMUs than can be evaluated using several different indicators including the relative efficiency, rankings, pattern coordinates, congestion in inputs, Malmquist productivity index, return on the scale, profit efficiency, and cost efficiency. For each DMU, belonging to a set of observed units, an independent optimization problem should be solved in order to achieve the aforementioned objectives (Lotfi, Ebrahimnejad, Vaez-Ghasemi, & Moghaddas, 2020).

MPI is known to be a well-known and widely-used tool for studying the performance progress or regress. As known, DEA models are linear programming (LP) models with which relative efficiency can be obtained. One of the important feature of DEA methodology is the estimation of production frontier. As regards, if a unit locates on the frontier, it is considered efficient, and inefficient otherwise. It can be said that the efficient units construct the frontier. Thus, as changes happen in DMUs' performance, from one period relative to another, the frontier may also change. In the MPI method, efficiency changes of DMUs and technology changes, are simultaneously considered. It is possible to estimate the MPI while DEA methodology is being utilized. In this regards, the efficient frontier may change from one time period to another, and for each time period, the frontier can be calculated by DEA (Lotfi, Jahanshahloo, Vaez-Ghasemi, & Moghaddas, 2013).

The method of research in this paper is based on the reliable data from the well-known international sources and the DEA and MPI as tools. In this research, an efficiency evaluation of the European countries, in which, on 31 March 2020, at least one month is passed from their first confirmed case, is performed. The MPI is utilized to determine the relative growth or decline of the contagion in two last weeks of March. The MPI was first introduced by Caves, Christensen, and Diewert (1982). Malmquist Index (MI) is initially introduced to compare the production technology of two economies; however, it can be utilized to address situations in which a comparison of DMUs based on performance needs to be done. The general steps of this study are as follows.

1) Defining the DMUs: In this study, the countries are considered as the DMUs because they are relatively compared. Countries from a single continent or multiple continents or even provinces within a country may be chosen for the study; however, because of the critical situation in Europe and in order to create a bed for a just comparison among similar DMUs, European countries with the aforementioned conditions are selected.

2) Determining the inputs and outputs: When the number of inputs or the number of outputs is large, DEA usually does not yield satisfying results for analysis. Therefore, this study considers two inputs and one output. More specifically, population density and the number of days passed since the observation of the first confirmed case are considered as the inputs, and the average contagion rate is taken as the output, as shown in Fig 1.

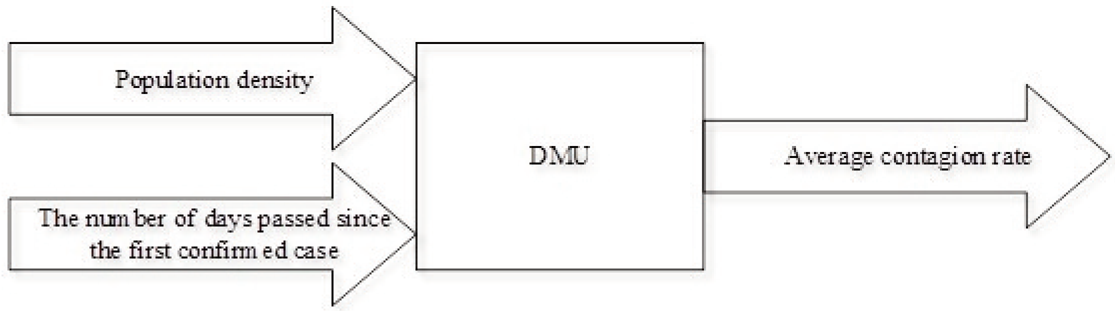

Fig. 1. The general scheme of the DEA model

3) Calculating the productivity progress/regress index: The MPI is utilized to determine the progress/regress index. It should be noted that according to the definitions of the inputs and the outputs, the efficient DMUs, i.e. countries, are the ones with a critical situation regarding the COVID-19 average contagion rate. In addition, when the MPI shows progress or a regress, it is an indicator of a growth or a decline in the average contagion rate. In order to calculate the MPIs, the efficiency values are calculated for the two weeks. Based on these values, the relative efficiency of each country is calculated in each week, giving analysis for each time period. In addition, the MPI is calculated to present the growth or decline of the average relative conta-

gion rates for the countries.

4) Analysis of the results: In this final step, the situations of the countries regarding the growth or decline of average contagion rates are discussed. In addition, the efficient countries in each of the two weeks, which are the ones with critical situations, are determined.

DATA ANALYSIS

The data, on the aforementioned countries (Table 1), are provided by the United Nations Statistics Division gathered from national statistical offices, and used to estimate the urbanization. Those estimates are presented in World Urbanization Prospects United Nations Statistics Division (The United Nations Statistics Division, 2020). To evaluate the efficiency of the countries in contagion control, the total number of confirmed cases of COVID-19 can be used. The data are provided by the World Health Organization (2020).

Table 1: The countries in the study

NO.	Country	NO.	Country	NO.	Country	NO.	Country	NO.	Country
1	Andorra	7	Denmark	13	Iceland	19	Monaco	25	Russia
2	Austria	8	Estonia	14	Ireland	20	Netherlands	26	Spain
3	Belarus	9	Finland	15	Italy	21	North Macedonia	27	Sweden
4	Belgium	10	France	16	Latvia	22	Norway	28	Switzerland
5	Croatia	11	Germany	17	Lithuania	23	Portugal	29	Ukraine
6	Czech	12	Greece	18	Luxembourg	24	Romania	30	United Kingdom

The data for the inputs and the output for the two last weeks of March 2020 are presented in Table 2. It should be noted that the contagion rate is calculated by differencing the number of confirmed cases on every two consecutive days, and the average contagion rate for each week is obtained by calculating the mean value of daily contagion rates throughout that week.

To solve the model for each of the two weeks, the input-oriented BCC is utilized. Furthermore, the return-to-scale is variable. The results of solving the model for each of the weeks are presented in Table 3 in which the average efficiency for each country is obtained by calculating the average of the efficiencies of the first week and the second week. It should be emphasized that the more efficient a country the larger the relative average contagion rate in that country. In other words, the country with a lower population density, fewer days passed since its first confirmed case, and higher rate of contagion is considered as efficient. In this Table, the countries are ranked based on their average efficiency number. Specifically, Iceland, Italy, Latvia, Portugal, Spain, and Ukraine are on the efficiency frontier and have the highest rank. This means that considering their population density and the number of days passed since the observation of their first confirmed case, they have had a relatively high rate of contagion introducing them critical countries from this perspective. Obviously, the situation is the opposite for Finland, Sweden, Belgium, and the United Kingdom.

Table 2: The input and output data for the two time periods

NO.	Country	First Week			Second Week		
		Days since the first confirmed case (input1)	Population Density (input2)	Average contagion rate (output)	Days since the first confirmed case (input1)	Population Density (input2)	Average contagion rate (output)
1	Andorra	16	164	18	23	164	30
2	Austria	22	109	564	29	109	700
3	Belarus	19	47	6	26	47	10
4	Belgium	43	383	432	50	383	1215
5	Croatia	22	73	45	29	73	69
6	Czech	17	139	143	24	139	273
7	Denmark	20	137	99	27	137	189
8	Estonia	20	31	21	27	31	54
9	Finland	49	18	67	56	18	89
10	France	54	119	2130	61	119	4315
11	Germany	51	240	3390	58	240	5546
12	Greece	21	81	51	28	81	82
13	Iceland	19	3	61	26	3	70
14	Ireland	18	72	158	25	72	272
15	Italy	47	206	5381	54	206	5231
16	Latvia	16	30	21	23	30	29
17	Lithuania	19	43	26	26	43	47
18	Luxembourg	18	242	137	25	242	154
19	Monaco	18	26338	2	25	26338	4
20	Netherlands	20	508	553	27	508	1012
21	North Macedonia	21	83	17	28	83	26
22	Norway	21	15	200	28	15	254
23	Portugal	16	111	273	23	111	726
24	Romania	21	84	87	28	84	207
25	Russia	46	9	54	53	9	263
26	Spain	46	94	4020	53	94	8005
27	Sweden	47	25	157	54	25	307
28	Switzerland	22	219	1025	29	219	961
29	Ukraine	15	75	12	22	75	78
30	United Kingdom	47	281	886	54	281	2474

Table 3: Weekly efficiency of the countries and their ranks

NO.	Country	First Week Efficiency	Second Week Efficiency	Average Efficiency	Average Efficiency Rank
1	Andorra	0.939	0.957	0.948	6
2	Austria	0.830	0.816	0.823	18
3	Belarus	0.832	0.876	0.854	16
4	Belgium	0.395	0.500	0.447	28
5	Croatia	0.714	0.774	0.744	23
6	Czech	0.912	0.929	0.920	7
7	Denmark	0.767	0.821	0.794	19
8	Estonia	0.825	0.868	0.847	17
9	Finland	0.382	0.457	0.419	30
10	France	0.578	0.635	0.607	25
11	Germany	0.686	0.739	0.713	24
12	Greece	0.742	0.796	0.769	21
13	Iceland	**1.000**	**1.000**	1.000	1
14	Ireland	0.899	0.913	0.906	9
15	Italy	**1.000**	0.770	0.885	11
16	Latvia	**1.000**	**1.000**	1.000	1
17	Lithuania	0.837	0.879	0.858	14
18	Luxembourg	0.860	0.885	0.872	13
19	Monaco	0.833	0.880	0.857	15
20	Netherlands	0.885	0.896	0.890	10
21	North Macedonia	0.731	0.794	0.762	22
22	Norway	0.917	0.921	0.919	8
23	Portugal	**1.000**	**1.000**	1.000	1
24	Romania	0.750	0.807	0.778	20
25	Russia	0.413	0.641	0.527	26
26	Spain	**1.000**	**1.000**	1.000	1
27	Sweden	0.409	0.485	0.447	29
28	Switzerland	0.935	0.827	0.881	12
29	Ukraine	**1.000**	**1.000**	1.000	1
30	United Kingdom	0.421	0.559	0.490	27

The increase/decrease index of the countries is calculated using the MPI, which is obtained by multiplying the technical efficiency change (TEC) index by the factor specific change (FS) index. TEC gives the progress/regress of a DMU compared to itself from one time period to another and FS calculates its relative progress/regress compared to the corresponding population. An MPI greater than 1 shows an efficiency progress while an MPI lower than 1 is an indicator of efficiency regress. In other words, for the former case, shows a growth in contagion rate from one week to the other, while the latter indicates a decline. The results of applying the MPI are presented in Table 4. According to this Table, Russia, France, Germany, the United Kingdom, Spain, and Belgium have had a growth in the relative contagion rate. Iceland shows a constant status, and other countries have had a decline in relative contagion rates.

In addition, Fig. 2 depicts the TEC, FS, and MPI for the countries. In this Figure, the horizontal line with the constant value of 1 is the basis for analysis. For any country, a point for TEC, FS, or MPI above 1 is considered as a sign of relative contagion rate growth. More specifically, the countries with a TEC above 1 are the ones in which relative contagion rate has grown, meaning that compared to their first week, their contagion rate in the second week is increased. For the countries with a FS above 1, the relative contagion rate has grown compared to other countries.

Finally, the MPI assesses the overall contagion rate status. In other words, the contagion rate of a country with an MPI over 1 has grown and that of a country with an MPI lower than 1 has declined.

Table 4: The growth/decline of contagion rate of the countries and their ranks

NO.	Country	TEC	FS	MPI	Efficiency Progress Statues	Contagion Rate Status	Efficiency Progress/Regress Rank
1	Andorra	1.019	0.802	0.817	Regress	Decline	19
2	Austria	0.983	0.827	0.813	Regress	Decline	21
3	Belarus	1.052	0.768	0.809	Regress	Decline	22
4	Belgium	1.268	0.808	**1.025**	**Progress**	**Growth**	6
5	Croatia	1.085	0.715	0.776	Regress	Decline	30
6	Czech	1.019	0.817	0.833	Regress	Decline	17
7	Denmark	1.071	0.745	0.797	Regress	Decline	25
8	Estonia	1.052	0.780	0.821	Regress	Decline	18
9	Finland	1.196	0.740	0.885	Regress	Decline	11
10	France	1.098	1.269	**1.394**	**Progress**	**Growth**	2
11	Germany	1.077	1.180	**1.272**	**Progress**	**Growth**	3
12	Greece	1.073	0.731	0.785	Regress	Decline	27
13	Iceland	1.000	1.000	1.000	Constant	Constant	7
14	Ireland	1.016	0.824	0.837	Regress	Decline	16
15	Italy	0.770	1.166	0.898	Regress	Decline	10
16	Latvia	1.000	0.857	0.857	Regress	Decline	13
17	Lithuania	1.050	0.778	0.816	Regress	Decline	20
18	Luxembourg	1.029	0.777	0.800	Regress	Decline	24
19	Monaco	1.056	0.754	0.796	Regress	Decline	26
20	Netherlands	1.012	0.866	0.876	Regress	Decline	12
21	North Macedonia	1.086	0.719	0.780	Regress	Decline	29
22	Norway	1.004	0.844	0.848	Regress	Decline	15
23	Portugal	1.000	0.915	0.915	Regress	Decline	9
24	Romania	1.075	0.747	0.803	Regress	Decline	23
25	Russia	1.553	1.025	**1.591**	**Progress**	**Growth**	1
26	Spain	1.000	1.107	**1.107**	**Progress**	**Growth**	5
27	Sweden	1.187	0.772	0.917	Regress	Decline	8
28	Switzerland	0.884	0.887	0.784	Regress	Decline	28
29	Ukraine	1.000	0.849	0.849	Regress	Decline	14
30	United Kingdom	1.328	0.902	**1.197**	**Progress**	**Growth**	4

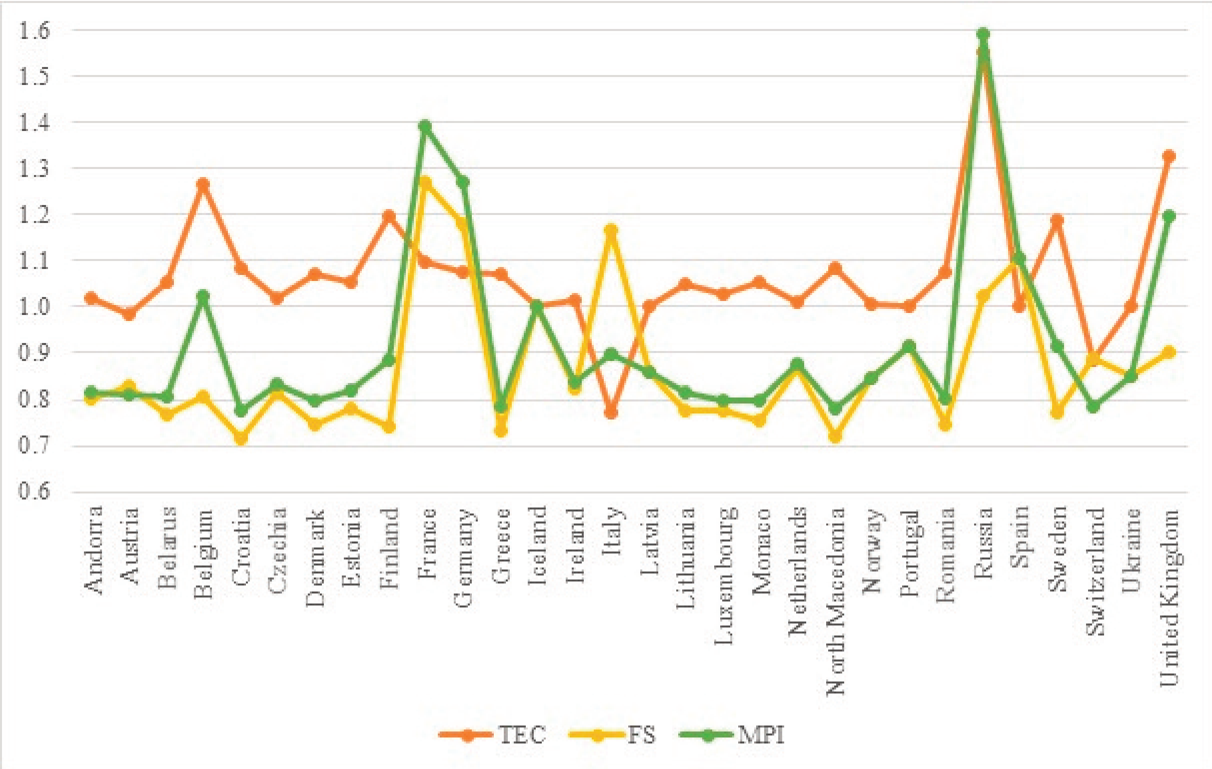

Fig 2. The TEC, FS, and the MPI for the countries

DISCUSSION AND CONCLUSIONS

The results in Table 3 and Table 4, summarized in Table 5, are worth analyzing simultaneously. The Table shows that Russia, Germany, and France did not have high relative contagion rates in either of the two weeks; however, they have experienced a growth in their contagion rate from the first week to the second, both considering them individually or in comparison with other countries.

Italy is in a different situation from all other countries. In this country, the contagion rate has been high in the first week, while in the second week this is not the case, showing the contagion rate control. In addition, it shows a large improvement when comparing its first week with the second, meaning a decline in the contagion rate compared to itself; however, compared to others, it shows a growth in relative contagion rate.

Spain is also in a unique situation. It has had a relatively high contagion rate in both weeks, while the contagion rate, compared to itself, remained constant, showing no change in contagion rate from one week to the other. On the other hand, the relative contagion rate, compared to other countries, for Spain shows a growth from the first week to the second.

Belgium and the United Kingdom have the same condition. In addition, their relative contagion rate declined from the first week to the other. However, although their contagion rates in the two weeks are not high, when considered individually, their contagion rate shows a growth. This means that considered the two weeks in each of these countries, the contagion rates increased.

Portugal, Ukraine, and Latvia are in the same situation. Although the contagion rate during these two weeks has been high in these countries, the rates within each country, considered individually, are constant, showing no change in the contagion rate. In addition, their contagion rates declined from the first week to the second. Therefore, these are the countries that performed well in controlling the growth of the contagion rate.

Finally, Iceland with a unique situation among all the countries have had a constant contagion rate during the two weeks. This, along with the fact that it has had high relative contagion rates during the two weeks, puts this country in a situation that needs to be investigated to define actions to cause the contagion rate to decline. In addition, it should be noted that the reason for the high contagion rate in this country may be partly due to its low population density, meaning that considering its low population density, the contagion rate is relatively high in comparison with other countries.

For future research, other influential inputs may be considered, and several time periods can be taken into account. With more than two periods of time, Window DEA can be applied to provide more insight into the dynamics of the outbreak response management performance.

Table 5: The overall status of the European countries

NO.	Country	Relative Contagion Rate		Relative Contagion Rate Status		
		First Week (based on first week's efficiency)	Second Week (based on second week's efficiency)	Compared to Self (based on TEC)	Compared to Others (based on FS)	Overall (based on MPI)
1	Belgium	Not High	Not High	Growth	Decline	Growth
2	France	Not High	Not High	Growth	Growth	Growth
3	Germany	Not High	Not High	Growth	Growth	Growth
4	Iceland	High	High	Constant	Constant	Constant
5	Italy	High	No High	Decline	Growth	Decline
6	Latvia	High	High	Constant	Decline	Decline
7	Portugal	High	High	Constant	Decline	Decline
8	Russia	Not High	Not High	Growth	Growth	Growth
9	Spain	High	High	Constant	Growth	Growth
10	Ukraine	High	High	Constant	Decline	Decline
11	United Kingdom	Not High	Not High	Growth	Decline	Growth

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