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Efficiency Evaluation of European Countries Based on Case Fatality Rate of COVID-19 Using Data Envelopment Analysis

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A B S T R A C T

The COVID-19 pandemic appeared in China on 31 December 2019, and it spread fast in every part of the world, especially, in European countries like Italy and France, consequently, the search for a resolution to this pandemic in all these countries should also be taken into account.
The current study aimed to evaluate the efficiency of European Countries based on the case fatality rate of COVID-19, The sample spans 30 countries, the analysis made recourse to Data Envelopment Analysis, the study used population density and total cases as input indicators and case fatality rate (CFR) as output indicator. The results demonstrate that of 30 countries analyzed, only 6 proved efficient. The average efficiency of inefficient countries is 0.372. Greece achieved the least efficiency rate compared to other European countries. The highest case fatality rate has been registered in Belgium, the lowest case fatality rate has been registered in Monaco. We engaged in a year-long battle with a virus that has destroyed this world, that has caused pain, loss, and frustration and that has cost so many lives.

Keywords: ***COVID-19 pandemic; Data Envelopment Analysis; Evaluate the efficiency; European countries;Case fatality rate*.**

Introduction

In late fall of 2019, a novel acute respiratory disease, called coronavirus disease 2019 (COVID-19) emerged in Wuhan, China. COVID-19 is caused by severe acute respiratory syndrome-coronavirus 2 (SARS-CoV-2) (Guy, DiPaola, Romanelli, & Dutch, 2020, p. 1) A novel coronavirus (nCoV) was identified on 7 January 2020 and was temporarily named "2019-nCoV" It was subsequently named the COVID-19 virus. On February 11, 2020, As of March 24, countries have recorded more than a thousand deaths: China, France, Iran, Italy, and Spain. The World Health Organization (WHO) announced the COVID-19 outbreak as a pandemic on 11, March 2020. Coronaviruses (CoV) are a large family of viruses that cause illnesses ranging from the common cold to more severe diseases. COVID-19 is not only causing mortality but is also putting considerable stress on health systems with large case numbers.

The virus is mainly spread during close contact and by small droplets produced when the infected cough, sneeze or talk. these small droplets may also be produced during breathing. The virus is most contagious during the first 4-6 days after the onset of symptoms, although the spread is possible in asymptomatic conditions and later stages of the disease. The time from exposure to onset of symptoms (incubation period) is typically around 5 days but may range from 2 to 15 days. (Alamo, Reina, Mammarella, & Abella, 2020, p. 2) the WHO called all nations to apply severe limitations (for example worldwide reconnaissance, quarantine, isolation facilities, and control rehearses) trying to diminish the effects of this virus.

The public health response to coronavirus disease2019 (COVID-19) in China has illustrated that it is possible to contain COVID-19 if governments focus on tried and tested public health outbreak responses (Hopman & Mehtar, 2020, p. 1)

Data Envelopment Analysis is a comparatively "data-oriented" approach for assessing the performance of a set of peer entities called decision-making units, which convert multiple inputs into multiple outputs. In recent years, the DEA has emerged into a greater assortment of applications for utilizing and assessing the performance of many different types of entities engaged in many different activities in many different contexts in many different countries the world over. DEA represents an incredible movement of constant progress for data analysis (Nellutla, Goverdhan, & Haragopal, 2018, p. 54).

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COVID-19 is a rising infectious disease that represents a great challenge to world countries, as of 15 November 2020, there were 53,164,803 confirmed cases in the world and 1,300,576 deaths occurred. As the continuous COVID-19 pandemic has caused a genuine well-being danger around the world. In this respect, the following question has been raised:

What is the level of efficiency regarding the case fatality rate of COVID-19 in European countries according to the results of data envelopment analysis?

Research Method

Several studies have been published on the topic under study these are Some later studies that will help complete the current study.(Breitenbach, Ngobeni, & Aye, 2020) used data envelopment analysis (DEA) to analyze the (31) most infected countries during the first (100) days since the outbreak of COVID-19 Coronavirus, the study used four inputs (Number of days to lockdown, Number of doctors per 1000 population, Total tests per 1 million population, Spending on health % of GDP) and one output (Number of days left in a cycle after reaching persistent COVID-19 reduced infections (Spared days)), the study reveals that (12) of the (31) countries in the sample were efficient and (19) inefficient in the use of resources to manage the flattening of their COVID-19 contagion curves. Among the worst performers were some of the richest countries in the world, Germany, Canada, the USA, and Austria.

(Shirouyehzad, Jouzdani, & Khodadadi-Karimvand, 2020) used two-stage data envelopment analysis to evaluate the performance of (the 29) most seriously affected countries regarding contagion control and medical treatment of COVID-19. the first stage used two inputs (population density, an average of 13 IHRCCS) and one output (confirmed cases) in the second stage used one input (confirmed cases) and two outputs (death cases, recovered cases), the results show that Singapore, Vietnam, and Belgium are the countries with the highest efficiency in both aspects. more specifically, Singapore with the highest efficiency among the countries even with one of the highest population densities in the southeast of Asia, is far ahead of others, In Europe, Belgium is the most efficient while Italy is the least. In the Middle East, Iran has been the most efficient in contagion control, and although Egypt has been the least in this regard, it has been the most efficient in medical treatment.

(Shirouyehzad, Jouzdani, & Khodadadi-Karimvand, 2020) used a model of models data envelopment analysis known as the Malmquist productivity index to estimate the performance of the most severely affected European countries based on the average contagion rate over two weeks, the sample of the study consists of (30) countries, the study used two inputs (days since the first confirmed case, population density) and one output (average contagion rate) the result detect that Russia, Germany, and France did not have high relative contagion rates in either of the two weeks, Italy shows growth in relative contagion rate, Spain also shows growth from the first week to the second, Belgium, UK, Portugal, Ukraine, and Lativa have the same situation, Iceland has had a constant contagion rate The high contagion rate in this country is due to its low population density.

(Ghasemi, Boroumand, & Shirazi, 2020) used also data envelopment analysis with the Malmquist index to calculate the inefficiency of preventing coronavirus spread and the inefficiency of preventing deaths caused by a coronavirus from February,2 to April, 12, the sample of the study consists of (19) countries. the first model used two inputs (population, and population density) and one output (coronavirus-confirmed cases), in the second model used three inputs (population, population density, and age 65% and above of population) and one output (coronavirus-confirmed deaths). The results show that the inefficiency trend of preventing coronavirus spread in Singapore, South Korea, China, and Australia are decreasing during the period under review, also Australia, Finland, Japan, Malaysia, Singapore, and Thailand have experienced less inefficiency in preventing deaths caused by coronavirus compared to other countries.

Data Envelopment Analysis

Data Envelopment Analysis is a Non-parametric approach, that is used to define the relative efficiency of a given Decision-Making Unit. 100% relative efficiency accomplished by any DMU does not give proof of inefficiency in the utilization of any input or output (Charnes, Clark, Cooper, & Golany, 1984, pp. 96-97) the ratio of relative efficiency is equal to 1, and indicates an efficient unit. The formula for the application of DEA efficiency is the following: (Marković, Knežević, Brown, & Dmitrović, 2015, p. 3).

Charnes, Cooper, and Rhodes introduced (the CCR) model (1978) under the assumption of constant return to scale, as a part of Data Envelopment Analysis, in their pioneering work, according to this point that in many cases return to scale is variable, Banker, Charnes, and Cooper introduced (BCC) model (1984) as a developing CCR model and considered a different return to scale (increasing, constant, decreasing). (Banker, Charnes, & Cooper, 1984). The use of the CCR model specification when not all DMUs are operating at their optimum results in measures of technical efficiency, which are confounded by scale efficiency (SE). The use of the BCC model specification permits the calculation of technical efficiency (TE) without these scale efficiency effects. The scale inefficiency can be calculated based on differences between the BCC and the CCR technical efficiency scores. The term technical and scale efficiency (TSE) describes the technical efficiency scores obtained using a CCR model. Meanwhile, pure technical efficiency (PTE) refers to the technical efficiency scores obtained from a BCC model. (Wu, Tsia, Cheng, & Lai, 2006, p. 535).

Evaluation of de return of scale: (Zhang, Cao, Meng, Qiu, Hu, & Cheng, 20 October 2020, p. 5)

1-When the scale return remains unchanged which means the production has reached a relative optimum.

2-When, the scale return is increasing which means that increasing the input of a DMU by one unit can bring more output than a unit.

3-When the scale return is decreasing which means that one unit of input of each DMU will only get less than a unit of output.

Two substitute methodologies are available in DEA to decide the efficient frontier. The first one is input-oriented, and the second one output-oriented. an input-oriented model where

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the inputs are minimized and the outputs are kept at their current levels. (Zhu, 2009, p. 5) vector and matrix form of this model is as follows: (Cooper, Seiford, & Zhu, 2000, p. 3).

Input-orientation model

$$\theta^* \min = \theta$$

$$s.t. \quad \sum_{j=1}^{n} \lambda_j X_{ij} \leq \theta X_{io} \quad i = 1, 2, \ldots, m$$

$$\sum_{j=1}^{n} \lambda_j Y_{rj} \geq Y_{ro} \quad r = 1, 2, \ldots, s$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \quad j = 1, \ldots, n$$

Data

-The sample of this study consists of (30) European countries. The efficiency of countries in effectively reducing the case fatality rate of the COVID-19 pandemic will be analyzed. (see Table 01).

-The efficiency was evaluated through the use of R software.

Table N° 1: The sample of study

No	Country	No	Country
01	Albania	**16**	Italy
02	Andorra	**17**	Latvia
03	Austria	**18**	Lithuania
04	Belarus	**19**	Luxembourg
05	Belgium	**20**	Malta
06	Croatia	**21**	Monaco
07	Czechia	**22**	North Macedonia
08	Denmark	**23**	Norway
09	Estonia	**24**	Portugal
10	Finland	**25**	Poland
11	France	**26**	Romania
12	Germany	**27**	Russia
13	Greece	**28**	Serbia
14	Iceland	**29**	Switzerland
15	Ireland	**30**	Ukraine

Source: Researchers preparation

The Input and Output

In the current study, we used the "input-oriented BCC model "with the variable return to scale is used to evaluate the efficiency of countries regarding the reduction of the case fatality rate caused by the COVID-19 pandemic. To calculate the efficiency of countries we considered population density and total cases as input indicators and case fatality rate (CFR) as output indicator. Population Density is defined as a measurement of the number of people in an area that is calculated by dividing the number of people by the area. the efficient DMUs are the countries with relatively high population density and a decrease in total cases of this virus.

The case fatality rate (CFR) represents the proportion of cases that eventually die from a disease. Once an epidemic has ended, it is calculated with the formula: (Coronavirus (COVID-19) Mortality Rate, 2020)

The case fatality rate (CFR)= deaths/cases.

But while an epidemic is still ongoing, as is the case with the current novel coronavirus outbreak. it is calculated with the formula:

CFR = deaths at day.x/cases at day.x-{T} (where T = average time period from case confirmation to death)

Due to the difficulty of determining the value of the variable T. American Journal of Epidemiology study indicated to the alternative method can be used to calculate the case fatality rate with the formula:

CFR = deaths/(deaths + recovered)

The main technical issues that need to be addressed in compiling case fatality rates are: (Daly, Mason, & Goldacre, 2000, p. 74).

- methods of linking data about hospital episodes and mortality
- type of hospital admission and diagnostic specificity
- time cut-off point and inclusion of all deaths within the period or only those which occur in hospital
- method of death diagnosis recording used
- dealing with patient transfer
- adjusting for the severity of the condition and other potential confounders
- accuracy and completeness of data
- statistical power.

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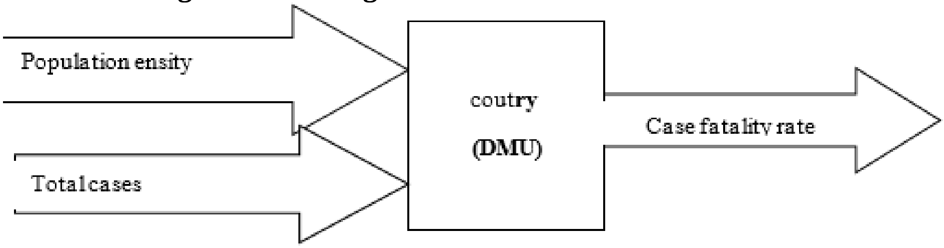
Figure N°1: The general scheme of the DEA model



Source: Researchers preparation

To measure the efficiency of European countries in reducing the case fatality rate caused by COVID-19, input and output data were collected on November 15, 2020(see Table. 3.).

Table N° 2: The inputs and outputs data on November 15, 2020

No.	Country	Inputs		Output
		Population Density	Total cases	Case fatality rate(CFR)
01	Albania	105	27,233	0.04574333
02	Andorra	164	5,725	0.01578947
03	Austria	109	198,291	0.00867961
04	Belarus	47	112,870	0.01089373
05	Belgium	383	531,280	0.30426089
06	Croatia	73	81,844	0.01553572
07	Czechia	139	458,229	0.01844471
08	Denmark	137	61,078	0.01592645
09	Estonia	31	7,637	0.01679801
10	Finland	18	19,102	0.02568028
11	France	119	1,954,599	0.24127251
12	Germany	240	788,899	0.02450677
13	Greece	81	72,510	0.09388607
14	Iceland	3	5,186	0.00521703
15	Ireland	72	67,526	0.07805225
16	Italy	206	1,144,552	0.0979639
17	Latvia	30	10,231	0.07396088
18	Lithuania	43	33,387	0.02852455
19	Luxembourg	242	26,544	0.0141853
20	Malta	1,380	7,917	0.01638779
21	Monaco	26,337	545	0.00446429
22	North Macedonia	83	46,062	0.04532588
23	Norway	15	28,434	0.0241836
24	Portugal	111	211,266	0.02626727
25	Poland	124	712,972	0.0339133
26	Romania	84	353,185	0.03555579
27	Russia	9	1,925,825	0.02252692
28	Serbia	100	81,086	0.03040738
29	Switzerland	219	257,135	0.02321425
30	Ukraine	75	535,857	0.0382518

Source: (Countries in the world by population, 2020)**,** (Report coronavirus cases, 2020)

Figure.2. shows the case fatality rate in each country, Most of them with a case fatality rate of more than 1 percent. The highest case fatality rate (CFR) is in the countries of Belgium, France, Italy, and Greece. The last case fatality rate (CFR) is in the countries of Monaco Iceland and Austria. In Belgium, the fatality rate (CFR) reached 30.42 percent, which is the largest percentage in the study sample. And in Monaco, the case fatality rate (CFR) was 0.44 percent, which is the smallest percentage in the study sample. A comparison of the rates of case fatality in the 30 countries reveals that rates vary between countries, sometimes quite considerably.

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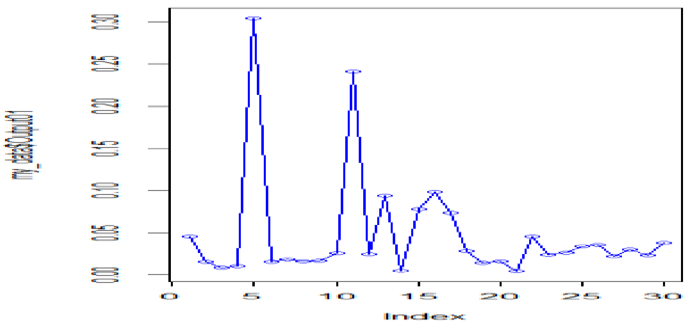
Figure N°2: Case fatality rate (CFR) for a sample of study



Source: R program outputs

Table. 3. indicates the efficiency scores for each country using the "input-oriented BCC model "with variable return for 30 European countries showing that in 30 countries analyzed, only 6 proved efficient, namely Albania, Austria, Belgium, France, Italy, and Malta.

Greece achieved the least efficiency rate estimate at 0.185, with the countries ranked as follows: first Albania, Austria, Belgium, France, Italy, and Malta, followed by Portugal, Serbia, Russia, Finland, Latvia, Norway, Czechia, Poland, Denmark, Switzerland, Andorra, Luxembourg, Iceland, Monaco, Lithuania, Germany, Estonia, Romania, Ireland, Ukraine, Croatia, and then Greece. The average efficiency of inefficient countries is 0.372.

Table N°3: efficiency of the countries and their ranks

No.	**Countries**	Efficiency	Efficiency rank
01	Albania	1.000	1
02	Andorra	0.375	11
03	Austria	1.000	1
04	Belarus	0.407	9
05	Belgium	1.000	1
06	Croatia	0.187	19
07	Czechia	0.454	6
08	Denmark	0.425	8
09	Estonia	0.234	16
10	Finland	0.500	4
11	France	1.000	1
12	Germany	0.263	15
13	Greece	0.185	20
14	Iceland	0.283	13
15	Ireland	0.211	17
16	Italy	1.000	1
17	Latvia	0.500	4
18	Lithuania	0.263	15
19	Luxembourg	0.357	12
20	Malta	1.000	1
21	Monaco	0.272	14
22	North Macedonia	0.208	18
23	Norway	0.468	5
24	Portugal	0.833	2
25	Poland	0.426	7
26	Romania	0.211	17
27	Russia	0.500	4
28	Serbia	0.757	3
29	Switzerland	0.405	10
30	Ukraine	0.208	18

Source: researcher’s preparation according to R-3.6.2 outputs

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Table. 4. The original DEA efficiency scores range from0.1852 to1.000 for VRS, the Mean of 30 European countries was0.4980, the value of the median was estimated at 0.4167, the value of the first and third quarters estimated at 0.2632, 0.6928 respectively. This is shown in the table below:

Table N°4: descriptive statistics of efficiency score

Variable	value
Min	0.1852
1st Qu	0.2632
Median	0.4167
Mean	0.4980
3rd Qu	0.6928
Max	1.000

Source: researcher's preparation according to R-3.6.2 outputs

By observing **Table.5** Which shows the slack of efficiency, the number of inputs to be reduced and the amount to be added to outputs for getting efficiency, we find that during the period of study, the efficiency of the European countries is achieved by keeping the inputs (population density, total cases) unchanged and increased output (undesirable) by an average of 10.056 percent. Except for Russia, we have to reduce the population density by 2 and increase output (undesirable) by 0.075.

Germany also represents an exception situation, although this country has not achieved efficiency, it is The number of inputs and outputs will be kept unchanged.

Table N°5: **The slack of efficiency**

No.	**Countries**	Efficiency	Sl.Slack	Sx1	Sx2	Sy1
01	Albania	1.000	FALSE	0	0	0.000
02	Andorra	0.375	TRUE	0	0	0.007
03	Austria	1.000	FALSE	0	0	0.000
04	Belarus	0.407	TRUE	0	0	0.161
05	Belgium	1.000	FALSE	0	0	0.000
06	Croatia	0.187	TRUE	0	0	0.073
07	Czechia	0.454	TRUE	0	0	0.0008
08	Denmark	0.425	TRUE	0	0	0.014
09	Estonia	0.234	TRUE	0	0	0.071
10	Finland	0.500	TRUE	0	0	0.215
11	France	1.000	FALSE	0	0	0.000
12	Germany	0.263	FALSE	0	0	0.000
13	Greece	0.185	TRUE	0	0	0.031
14	Iceland	0.283	TRUE	0	0	0.130
15	Ireland	0.211	TRUE	0	0	0.055
16	Italy	1.000	FALSE	0	0	0.000
17	Latvia	0.500	TRUE	0	0	0.956
18	Lithuania	0.263	TRUE	0	0	0.188
19	Luxembourg	0.357	TRUE	0	0	0.193
20	Malta	1.000		0	0	0.000
21	Monaco	0.272	TRUE			0.078
22	North Macedonia	0.208	TRUE	0	0	0.176
23	Norway	0.468	TRUE	0	0	0.064
24	Portugal	0.833	TRUE	0	0	0.001
25	Poland	0.426	TRUE	0	0	0.011
26	Romania	0.211	TRUE	0	0	0.202
27	Russia	0.500	TRUE	2	0	0.075
28	Serbia	0.757	FALSE	0	0	0.000
29	Switzerland	0.405	TRUE	0	0	0.180
30	Ukraine	0.208	TRUE	0	0	0.135

Source: researcher's preparation according to R-3.6.2 outputs.

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Results and Discussion

As might have been expected, our finding has often been consistent with the literature review, there are 6 out of 30 countries achieved full efficiency that are Albania, Austria, Belgium, France, Italy, and Malta. showing that these countries have acted in contagion control and can be benchmarked. the study by (Shirouyehzad, Jouzdani, & Khodadadi-Karimvand, 2020), indicated that Belgium is the most efficient regarding contagion control and medical treatment of COVID-19 while Italy is the least.

Portugal, Serbia, Russia, Finland, Latvia, Norway, Czechia, Poland, Denmark, Switzerland, Andorra, Luxembourg, Iceland, Monaco, Lithuania, Germany, Estonia, Romania, Ireland, Ukraine, Croatia, and then Greece have experienced inefficient in a case fatality rate of COVID-19 be compared to other countries. The average efficiency of inefficient countries is 0.372. for getting efficiency. The study of (Ghasemi, Boroumand, & Shirazi, 2020) indicated that Finland has experienced less inefficiency in preventing deaths caused by coronavirus compared to other countries.

In Belgium, the fatality rate (CFR) reached 30.42 percent, which is the largest percentage in the study sample. And in Monaco, the case fatality rate (CFR) was 0.44 percent, which is the smallest percentage of the study sample. The CFR of the same disease varies greatly in different countries, that is because affected by many factors such as detection efficiency, medical standards, and health control policies.

Greece achieved the least efficiency rate. for getting efficiency, inputs were kept unchanged and increased the case fatality rate by 0.031.

Germany is in a different case from all other countries, in this country, the case fatality rate reached 0.024, and The efficiency rate was estimated at 0.263, Although this country has not achieved efficiency, however, the number of inputs and outputs will be kept unchanged. This indicates that this is the optimum level of efficiency That can be achieved. That is consistent with the study of (Shirouyehzad, Jouzdani, & Khodadadi-Karimvand, 2020), as it indicated that Germany did not have high relative contagion rates in either of the two weeks. It is also in line with the study of (Breitenbach, Ngobeni, & Aye, 2020) which indicated that Germany is one of the worst performers were some of the richest countries in the world.

Conclusions

To evaluate the efficiency of countries regarding the case fatality rate of COVID-19 using the input-oriented DEA model under the VRS the results demonstrate that of 30 countries analyzed, only 6 proved efficient. The average efficiency of inefficient units is 0.372. based on the results from this model, it can be stated, that insufficient efforts are being made in the world in general and European countries in particular to raise people's awareness in the field of healthcare. But looking to the future, however, we need a solution that is more and more insistent to break the deadlock.

Our work has led us to conclude and come up with a set of results:

-BCC model and CCR model differ concerning the nature of the relationship between inputs and outputs. If the relationship is linear, we follow the CCR model and if the relationship is non-linear, we follow the BCC model.

-The case fatality rate (CFR) represents the proportion of cases who eventually die from a disease. The CFR of the same disease varies greatly in different countries, that is because affected by many factors such as detection efficiency, medical standards, and health control policies. As well as the way used Collette information about death cases.

-The results of efficiency calculation indicate that Albania, Austria, Belgium, France, Italy, and Malta are the countries with full efficiency regarding the case fatality rate of COVID-19 that can be looked upon to reduce it.

-Greece achieved the least efficiency rate compared to other European countries.

-Germany is in a different case from all other countries, in this country, the case fatality rate reached 0.024, and The efficiency rate was estimated at 0.263, which is the optimum level of efficiency That can be achieved.

To this day, the high prevalence of the COVID-19 pandemic continues to be a major challenge for the country. one of the reasons for increased the number of infected cases of COVID-19 is population density. To put it another way, the COVID-19 pandemic hits population-dense countries, it provides an enabling environment for the spread of the virus, only prevention can halt the spread of the COVID-19 pandemic. Likewise, prevention is better than cure.

Our world cries out for even more intensified collective efforts at ridding the world of this and other pandemics. This is in addition to the sums you spend on anti-virus systems, as well as, the state's race to make a cure or effective vaccine that will limit the spread of the virus.

Vaccines can prevent infectious diseases and greatly reduce the risk of infection by training the immune system to recognize and fight pathogens. To this end, we need common action to save our world, let us continue to hard work together in our fight to combat the global COVID-19 pandemic.

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