Survival Analysis of COVID-19 on Democracy with Cox Proportional Hazards Model

Yue Zhao (yue.zhao@atlasstatsresearch.com)
Atlas Statistical Research https://orcid.org/0000-0003-1884-5012

Deepika Dilip
Memorial Sloan Kettering Cancer Center

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RESEARCH

Survival Analysis of COVID-19 on Democracy with Cox Proportional Hazards Model

Yue Zhao[1*] and Deepika Dilip[2]

[*]Correspondence:
yue.zhao@atlasstatsresearch.com
[1]Atlas Statistical Research, King of Prussia, PA, United States
Full list of author information is available at the end of the article

This is the title page of the research paper.

Abstract

Background: The outbreak of Coronavirus disease 2019 (COVID-19) has struck us in many ways and we observed that China and South Korea found an effective measure to contain the virus. Conversely, the United States and the European countries are struggling to fight the virus. China is not considered a democracy and South Korea is less democratic than the United States. Therefore, we want to explore the association between the deaths of COVID-19 and democracy.

Methods: We collected COVID-19 deaths data for each country from the Johns Hopkins University website and democracy indices of 2018 from the Economist Intelligence Unit website in May 2020. Then we conducted a survival analysis, regarding each country as a subject, with the Cox Proportional Hazards Model, adjusting for other selected variables.

Result: The result showed that the association between democracy and deaths of COVID-19 was significant (p=0.04), adjusting for other covariates.

Conclusion: In conclusion, less democratic governments performed better in containing the virus and controlling the number of deaths.

Keywords: COVID-19; survival analysis; democracy

Background

The Coronavirus disease 2019 (COVID-19) was first identified in Wuhan, China in December 2019.[1] Shortly after the outbreak in China, the cases in South Korea started to skyrocket.[2] However, the epicentre of the virus begun to move to Europe and North America, while China and South Korea successfully contained the virus outbreak by March 2020.[3] By observing the geopolitical characteristics, European and North American countries are more democratic than China and South Korea.

This paper is to explore the relationship of the COVID-19 deaths and democracy, thus makes health policy recommendations based on the analysis. In the public health crisis setting, a democratic government may face more constraints when taking draconian measures against disease control, simply due to its structure and likelihood of opposition In this case, this could mean more challenges in containing the disease and reducing mortality rates.

In the case of the United States, the authors of the constitution could not have foreseen the population surges, rise of densely populated cities, or biomedical advances that could affect the role of the federal government in pandemics. As such, in the event of a pandemic, in the event of an ineffective federal government, there are few actions that could result in more draconian measures. One of the exceptions to this is states' rights. This can be reflected in states relying on foreign nations for support when the federal branch has been slow to act: Maryland received COVID-19 tests from South Korea while New York received ventilator donations from the Chinese government. While ideas regarding individual human liberties have historically been partisan, the COVID-19 pandemic has proven this is not always the case; both Republican and Democratic governors have implemented stay-at-home orders.[4] The Supreme Court has ruled in favour of public health over individual liberties; in 1905, the Court ruled in Jacobson v. Massachusetts (1905) that

mandatory vaccinations were constitutional.[5] Similarly, in the case of Korematsu v. United States (1944), the court ruled that pressing national interests could take place over individual rights.[6] Yet the question still remains: are democratic institutions more inefficient when assembling a national emergency response, simply due to their structure?

In this analysis, we quantify the association between COVID-19 deaths and democratic indices, while controlling for co-factors. The quantitative analysis of the relationship between democracy and COVID-19 has never been studied before. On the other hand, the limitation of the study is that the reporting of the deaths is subject to accurately testing the disease. Many COVID-19 deaths were classified as caused by influenza, but the true cause of deaths was actually COVID-19. [7]

Methods

Survival analysis is commonly used in biomedical research to analyse time-to-event data for specific diseases and/or interventions. However, it is very rarely used in the setting of an aggregate macro variable such as democracy. Time-to-event variable of the disease was the dependent variable and the exposure is the independent variable.

In this paper, we treat each country as an observation. We use the Kaplan-Meier Estimator [8] and the Cox Proportional Hazards Model [9] to perform the survival analysis.

Event

We first define the event to be the number of deaths of COVID-19 reaches 0.0001%, which is same as 1 out of 1 million, of the country's total population. For instance, an event would be that a country of 300 million people reaches 300 deaths for COVID-19. This event adjusts for the population of each country.

Survival Time

The survival time is defined as the days it takes for the country to reach the event from 0 deaths to the first event, marked by a death count equating to 0.0001% of the population . For instance, if the United States as a country takes 15 days to reach the event, then the survival time for the US is 15 days.

Democracy

Democracy is measured by the democracy index of each country published by the Economist Intelligence Unit in 2018. This was a weighted average derived from five aspects: electoral process and pluralism, civil liberties, the functioning of government, political participation, and political culture. The 2019 democracy indices report had missing data, so we decide to use the 2018 democracy indices.

Survival Analysis

In order to convert this metric into a categorical variable to apply to the Kaplan Meier Estimator, the countries are divided into three groups. The high democracy countries are defined as having a democracy index greater or equal to 6. The medium democracy countries are defined as having a democracy index greater or equal to 3 and less than 6. The low democracy countries are defined as having a democracy index less than 3. The Kaplan Meier Estimator performs both the Log-rank

Test and Wilcoxon Test. Before performing the Cox Proportional Hazards Model, we collect the GDP per capita in Purchasing Power Parity (PPP) terms, which measures the overall wealth of the country, as a covariate for our model.[10] To allocate for differences in geographical location, we also used the average latitude of each country. Latitude is represented in the absolute value form because there are south and north in the original data. We would make the correlation matrix of democracy and the covariates and then decide what we need for the interaction terms. We decide not to take censoring into consideration because censoring is applied to avoid underestimation of survival time. In this study, due to the potential government data falsification and the knowledge about the COVID-19 disease, the survival time should already be overestimated. Therefore, we should not adjust for the underestimation of the survival time.

Results

Figure 1 Kaplan-Meier Estimator

Table 1 Log-Rank and Wilcoxon tests

Test	Chi-Square	DF	Pr > Chi-Square
Log-Rank	3.6158	2	0.1640
Wilcoxon	11.0051	2	0.0041

We can see the survival curves in Figure 1 from the KM Estimator that countries in the high democracy group overall have a significantly lower survival rate than the other two groups. In Table 1, the Log Rank Test is not significant in this case since it is more sensitive in the tail part, as the curves in the graph converge in the tail. On the other hand, the Wilcoxon Test is significant at 0.01 level since it is more sensitive in the beginning of the curves. Based on the result, democracy is statistically associated with the survival rate of COVID-19, without adjusting for other variables.

Then we want to include the covariates indicated in the methods section and perform the Cox Proportional Hazards Model. The assumption of the Cox Proportional Hazards Model is that the hazard is independent from the time variable. We assume this to be true in our analysis because it was not until the number of cases and deaths of COVID-19 skyrocketed that the governments, finally and reluctantly, started to impose social distancing policies and stay-at-home orders. When the intervention happened, the threshold of deaths should already surpass the event we defined in the methods section, which is 0.0001% of the country's population.

Table 2 Correlation Matrix

	Demo	Latitude	GDP
Demo	1.000		
Latitude	0.422	1.000	
GDP	0.405	0.441	1.000

The correlation matrix in Table 2 shows that the democracy index is both linearly associated with GDP and latitude. From a logical perspective, GDP should interact with democracy because a democratic country is typically wealthier and wealthier

people should have more time to be involved in politics. Geographical location could also impact GDP; industries such as agriculture are dependent on a country's location Conversely, democracy should not interact with latitude. We decide to include the interaction of democracy with GDP and GDP with latitude in our final Cox Model.

Our final model is:

$$h(t) = h_0(t)exp(\beta_1 demo + \beta_2 gdp + \beta_3 lat + \beta_4 demo * gdp + \beta_5 gdp * lat) \quad (1)$$

where demo stands for democracy and lat stands for latitude.

Table 3 Cox Regression Parameter Estimates

Parameter	DF	Parameter Estimate	Standard Error	Chi-Square	Pr > ChiSq
Demo	1	0.01674	0.00827	4.1024	0.0428
lat	1	0.00298	0.01087	0.0754	0.7836
GDP	1	0.0000140	0.0000128	1.1908	0.2752
lat*GDP	1	8.15208E-7	4.28711E-7	3.6158	0.0572
Demo*GDP	1	-5.5281E-7	2.5177E-7	4.8210	0.0281

Table 3 shows that democracy is a significant hazard for the survival rate of COVID-19 at the 0.05 significance level, although beta1=0.016 and HR= 1.02 do not have a clinical meaning since it is too close to 0. On the population level, it should have a significant meaning because people are measured in millions in this study. The interaction term between democracy and GDP is also significant at 0.05 significance level. This indicates that when democracy and GDP are both high, the hazard of deaths of COVID-19 is slightly lower, but it can be ignored since the hazard ratio is rounded to 1.00 for this interaction term. The other variables are not statistically significant and the beta parameters are too close to 0.

Conclusion

In our analysis, democracy is a significantly associated with the survival rate of COVID-19 (p=0.04), adjusting for other factors in the model. Therefore, the policy recommendation would focus on allocating certain privileges in the event of an international emergency. South Korea is considered a democracy but less democratic than the U.S., which dealt with COVID-19 more efficiently and contained the number of virus infection within three weeks.

Discussion

While this model uses group-level data and cannot be applied to individuals, it raises a question: does having a more democratic index influence individual behaviours? The United States has witnessed "freedom rallies" across the nation, with individuals protesting shelter-in-place restrictions due to the infringement of individual liberty. Similar rallies have occurred in both France and Germany. In order to answer this, we will need information concerning violations of pandemic laws on a country-by-country basis.

From an epidemiological viewpoint, a potential weakness of this paper is that there might be a mediator in between democracy and COVID-19 deaths, which is the stringency in the public health system. We assume that a less democratic government has a more stringent public health system. But this is not always true.

For example, Japan has a culture of wearing masks when being sick,[11] which is proven to be an effective way to block the transmission of COVID-19.[12] Since Japan has a medium to high level democracy, the culture of Japan has actually made a very stringent public health system spontaneously.

The quantification of the stringency in the public health system, just as democracy, is not available by any means in the current research, so we only analysed the relationship between democracy and COVID-19 deaths.

A potential confounding factor could be the transparency of the government. An intransparent government could cause the democracy index to be high due to the falsification of government data. It could also cause the reported deaths of COVID-19 to be low. This is a strong confounding factor, but we, the researchers, do not have a way to obtain the real data if falsification by the government exists.

Indeed, the best medicine to treat COVID-19 is a government quick to react and effective public health policies, which is more feasible with a less democratic political system.

Declarations

Ethics approval and consent to participate

The ethics committee of Atlas Statistical Research has approved the study. Patient consent is waived since no personally identifiable data is collected. Only the aggregate data was used in the study.

Consent for publication

Not applicable.

Availability of data and materials

Data was collected from the following publicly accessible sources:
Covid 19 deaths were collected from JHU online website.
https://data.humdata.org/dataset/novel-coronavirus-2019-ncov-cases
Democracy index was collected from the Economist Intelligence Unit.
https://www.gapminder.org/data/documentation/democracy-index/
Population of Countries in 2018 was collected from World Bank
https://data.worldbank.org/indicator/SP.POP.TOTL
GDP Per Capita in PPP 2018 was collected from World Bank
https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

Yue Zhao has conducted statistical analysis and wrote the entire paper. Deepika Dilip has edited the wording of the paper and provided some good ideas.

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Author details

[1]Atlas Statistical Research, King of Prussia, PA, United States. [2]Memorial Sloan Kettering Cancer Center, New York, United States.

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Figures

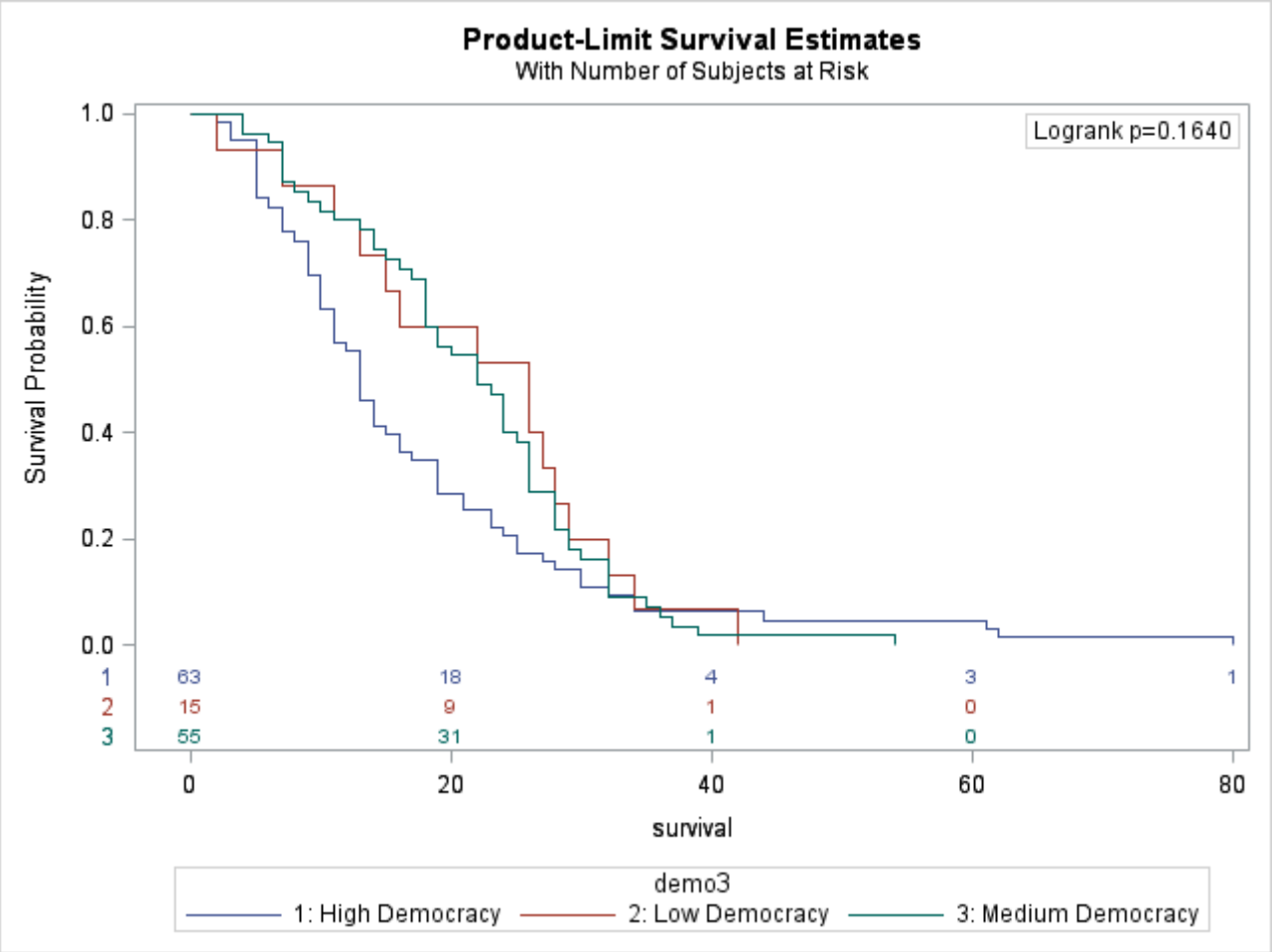

Figure 1

Kaplan-Meier Estimator