The Effect of Hospital Capacity by State on Covid-19 Fatality Rates

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Abstract

For this study, I am analyzing/focusing on the relation between hospital capacity/utilization and Covid-19 fatality rates. I used a log-log regression model/approach to examine this relationship for both variables (independent – hospital capacity, dependent – Covid-19 fatality rate). I had done so with data collected from all the states in the United States (51 states) for all the variables of interest. Furthermore, the results show that there is a positive correlation between Hospital Capacity and Covid-19 Fatality Rates and a statistical significance for hospital capacity/utilization as its p-value as .001 at the 1% significance. Also, the model yielded results that show that for an increase of 1% in hospital capacity, Covid-19 fatality rate(s) increases by 1.20%. In addition, it is evident that there still seems to be a relation between higher fatality rates and poverty rates, which is a stemming problem that needs to be addressed sooner rather than later. Nonetheless, the significance of the results gathered from this study show that there is still needs to be an emphasis placed on having policies and resources to medical centers and states that are in need of assistance in times of crisis and epidemics

Introduction

For the majority of all of 2020, the world has been utterly altered by the spread of the Coronavirus (Covid-19). The discovery and spread of the virus have led to an insurmountable rise in cluttered/full hospitals across the United States and globally. In addition, there has also been an increase rate of beds occupied by Covid-19 patients in various countries; for example, according to the U.S. Department of Health and Human Services (HHS), certain states such as

Georgia and Mississippi as being relatively higher proportion of beds in hospitals being occupied by Covid-19 patients (U.S Department of Health and Human Services, 2020).

Many factors could be contributing to the rate of infections or mortality caused by the Covid-19; however, for this study, we will be focusing on the hospital capacity (patient beds utilization rate(s)) per state in the United States as the independent variable. Furthermore, we will be examining its effect on Covid-19 mortality. Thus, we are interested in whether a hospital that is close to max usage/capacity results in more or less Covid-19 mortality (deaths). There are various channels that may explain this situation. For example, by quarantine, region, medical care accessibility, medical resources, can all have an impact as to whether a hospitals capacity can result in more Covid-19 deaths. This is important to recognize and place an emphasis on not having overfilled hospitals and implementing new policies in place for hospital utilization to best combat the spread of dangerous/contagion viruses for the betterment of society.

As we have witnessed for the past 9 months, the spread of coronavirus has challenged not only many civilians, but also our institutions/entities such as schools, firms, hospitals, and government. Thus, we need to have a policy implemented to provide better health care infrastructure and liability to provide a better chance for the well-being of society to succeed during times of epidemic(s).

Literature Review

Based on current literature, examining the empirical relationship between hospital capacity (patient beds utilization rate(s)) and Covid-19 mortality are not as straightforward or clear. This is due to the limited current literature as the reality and existence of Covid-19 is still relatively new. Nonetheless, there has been currently a few attempts to implement a regulation or policy by

a few countries (such as Italy) to limit the number of patients in a hospital to avoid further spread of infection of Covid-19 with other medical conditions being present (New England Journal of Medicine, 2020). However, according to the New England Journal of Medicine, the rates of hospitalization decreased with a "suggested significance of increase of mortality not fully explained by Covid-19". The results nonetheless raise questions from this study regarding "whether some patients have died without seeking medical attention during the pandemic" due to the policies in place (New England Journal of Medicine, 2020).

Furthermore, according to Douglas White from the JAMA Network, there seems to be a recommendation for hospitals to have "a multi-principle allocation framework" in order to combat Covid-19 in worsening patients in critical need/care. In addition, it must be noted that this recommendation of allocation(s) for these patients will give them priority for certain ICU beds for "isolation precautions" (White, 2020). Thus, during this pandemic, hospitals and their ability to provide medical care/need is being tested to its limit as more inpatient beds and resources are being fully utilized for not only Covid-19 patients, but also for the other patients with or in critical care. One last note I would like to mention from this entry is that White responds to the threat of shortening allocation of resources in hospitals by suggesting their being policies implemented that more accurately and "fairly allocate these scarce resources (such as ICU equipment) that better support the patients in most need" (White, 2020).

It is critical that many of the medical facilities in the United States have enough resources and capacity to treat all patients. Since the introduction of Covid-19, there has been a utilization of "surge capacity" to determine whether "many hospitals faced emergency department crowding and strains on hospital capacity" (Blumberg, 2020). This is important when evaluating our study because even before the pandemic, "many American hospitals had an insufficient number of

beds in overall" (Blumberg, 2020). Lastly, it is important to note the hospitalization rates according to age groups, because there seems to be a trend that only "around 1% of people under 30 years of age, are likely to require hospitalization, in comparison to individuals over 80 years of age (20%)" (Medical Xpress Medical Research Advances and Health News, 2020). Thus, there may be a noticeable number (or perhaps not) of hospitals near full capacity with higher death rates if most of their Covid-19 patients are the elderly.

Empirical Model

The empirical model used for this project is a simple log-log regression model. In this project, we are using simple log-log regression, which is being used to calculate/provide an estimation for the relationship between the two variables Covid-19 Fatality Rate (dependent) per state and Hospital Capacity – measured by inpatient bed utilization proportion/rate (independent) per state.

The modeled equation below (1) is used in this paper:

$$Log\ (Covid19\ Fatality\ Rate) = \alpha + \beta_1\, Log\ (Hospital\ Capacity) + \beta_2\, Covid19\ Cases +$$

$$\beta_3\, Poverty\ Rate + \beta_4\, Covid19\ Deaths + \beta_5\, Region + \beta_6\, Testing + u$$

In the model above (1), our dependent variable *covid19 fatality rate* measures as a proportion the ratio of people who die from Covid-19 per state. Furthermore, the independent variable *Hospital Capacity* measures as a proportion/rate of beds occupied in the hospitals per state. Next, the variable Covid-19 cases measures the number of Covid-19 cases per 1 million of the population for each state. Next, the variable Covid-19 deaths measures the number of the Covid-19 deaths per 1 million of the population for each respective state. In addition, the variable Testing measures the total amount of tests done for Covid-19 daily per 1 million of the population for each state. Furthermore, I must point out the difference between Covid-19 deaths and Covid-19

fatality rate just in case of any confusion. The Covid-19 deaths are only the total amount of deaths from the virus, while the fatality rate of Covid-19 statistics/data is the proportion of deaths of individuals whom contracted the virus/ diagnosed with Covid-19 over a certain period of time. Another variable of interest added to this study to examine is the poverty rate for each state in the United States. Lastly, another variable taken into consideration is regional location (mid-west, northeast, west, south).

Data

The data collected/gathered was from various sources such as the Kaiser Family Foundation (for the statistical data on region, testing, hospital capacity, poverty rate(s), and Covid-19 metrics) which was reported by the National Center for Health Statistics (NCHS). As noted in the site, the data comprises of state level estimations for all the variables listed above based on a pooling of data from the years 2017 to 2019. The data can be accessed from https://www.kff.org/statedata/custom/. All of the variables tested and used in the Empirical Model can be set-up and gathered using the custom function provided on the Kaiser Family Foundation website, which allows for all these variables to be selected, along with states in which you want to receive the collected data/information of these variables. Furthermore, you can more detailed collected information for specific statistics on hospital capacity per state from www.healthdata.gov/dataset/covid-19-reported-patient-impact-and-hospital-capacity-state.

Descriptive Statistics

Table 1. Descriptive Statistics

Note: log transformation does not occur here (only for Empirical Regression Model)

```
. summarize covid19fatalityrate inpatientbedutilization covid19casesper1000000population covid19
> opulatio west south midwest northeast povertyrate covid19testingpermillion
```

Variable	Obs	Mean	Std. Dev.	Min	Max
covid19fat~e	51	.0237769	.0155117	.0050918	.06908
inpatientb~n	51	.7035908	.0663476	.492401	.860104
covid19cas~n	51	27034.96	10750.06	3454	55747
covid19dea~o	51	597.6471	395.2684	93	1840
west	51	.254902	.4401426	0	1
south	51	.3333333	.4760952	0	1
midwest	51	.2352941	.4284033	0	1
northeast	51	.1764706	.3850134	0	1
povertyrate	51	11.68431	2.384565	7.9	17.8
covid19tes~n	51	6281.608	5028.589	0	34467

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The table above (Table 1) provides insight into the following statistics: the state level fatality rate of Covid-19 varies from .51% (Alaska) to 6.9% (New Jersey). In addition, the mean for Covid-19 fatality rate hovers at 2.4%. Furthermore, hospital capacity at the state level for all states (variable-inpatient bed utilization) also has a variance between 49.2% hospital capacity (Wyoming) and 86% hospital capacity (Rhode Island). Meanwhile, the mean for hospital capacity is 70.4%. It should be noted that the variances for other variables are also quite drastic such as number of covid-19 cases per 1 million population per state, deaths from covid-19 per 1 million population per state, and covid-19 testing per 1 million population per state, etc.

Empirical (Regression) Results

Table 2. Regression Results

```
. replace inpatientbedutilization = log( inpatientbedutilization)
(51 real changes made)


. replace covid19fatalityrate = log( covid19fatalityrate)
(51 real changes made)
. regress covid19fatalityrate inpatientbedutilization covid19casesper1000000population covid19deathsper
> ulatio west south midwest northeast povertyrate covid19testingpermillion
note: northeast omitted because of collinearity
```

Source	SS	df	MS		
Model	16.5409947	8	2.06762434	Number of obs	= 51
Residual	1.63007537	42	.038811318	F(8, 42)	= 53.27
				Prob > F	= 0.0000
				R-squared	= 0.9103
				Adj R-squared	= 0.8932
Total	18.1710701	50	.363421402	Root MSE	= .19701

covid19fatalityrate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
inpatientbedutilization	1.203141	.3457538	3.48	0.001	.505382	1.900901
covid19casesper1000000population	-.0000335	3.63e-06	-9.24	0.000	-.0000408	-.0000262
covid19deathsper1000000populatio	.0012121	.0001001	12.11	0.000	.00101	.0014141
west	-.1597856	.1153276	-1.39	0.173	-.3925262	.0729549
south	-.0960641	.1144053	-0.84	0.406	-.3269433	.134815
midwest	.0270209	.121838	0.22	0.826	-.2188581	.2728999
northeast	0	(omitted)				
povertyrate	.0188877	.0137767	1.37	0.178	-.0089149	.0466902
covid19testingpermillion	-.0000144	6.02e-06	-2.38	0.022	-.0000265	-2.20e-06
_cons	-3.372538	.2114215	-15.95	0.000	-3.799204	-2.945872

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The logarithmic regression results in Table 2 (log-log) above show that hospital capacity (inpatient bed utilization) per state is an important factor in Covid-19 fatality rates for each state. This is depicted as hospital capacity (inpatient bed utilization) has a p-value < .01 (.001 < .01). Thus, this does make sense, as hospital become more filled and less medical services are available, there can be a higher tendency for patients to not be attended in a timely manner, leading to increase chances of fatality. Furthermore, since the p-value is less than .01, there is very much indeed a statistical significance present. In addition, other variables/factors of Covid-

19 fatality rate are Covid-19 cases per 1 million population per state having p-value < 0.01 (.000 < .01) and deaths from Covid-19 per 1 million of the population per state with a p-value < .01 (.000 < .01). In addition, another variable that has some statistical significance present is Covid-19 daily testing per 1 million population per state with a p-value < .05 (.022 < .05).

Furthermore, none of the other variables present as seen in the regression model in Table 2 above, are not statistically significant (surprised that poverty rate had no relevance in fatality rate, as well as region). Also, R-squared is .9103, with an N = 51.

Correlation Results (Estimate)

```
. correlate covid19fatalityrate inpatientbedutilization
(obs=51)

             | covid1~e inpati~n
-------------+------------------
covid19fat~e |   1.0000
inpatientb~n |   0.5034   1.0000

.
```

Furthermore, I also carried out a correlation of between the independent and dependent variable, resulting in positive correlation at a value of .5034.

Interpretation of all significant coefficients:

As hospital capacity (inpatient bed utilization) per state increases by 1%, the Covid-19 fatality rate per state increases by 1.20%. In addition, as hospital capacity increases by 1%, Covid-19 cases per 1 million population decrease by a proportion of 0000335 cases, Covid-19 deaths per 1 million population increases by a proportion of .0012121 additional deaths. Furthermore, as hospital capacity (inpatient bed utilization) per state increases by 1%, poverty rate increases by a proportion of .019. Meanwhile, for Covid-19 daily testing per 1 million population decrease by a proportion of .0000144 tests (less tests daily per 1 million population).

Diagnostic Tests:

Heteroskedasticity Test

```
. predict covid19fatalityratef, xb

. predict s1, residual

. gen s1s = s1^2
```

```
. regress s1s inpatientbedutilization covid19casesper1000000population covid19deathsper1000000popula
> h midwest northeast povertyrate covid19testingpermillion
note: northeast omitted because of collinearity
```

Source	SS	df	MS		
Model	.033486495	8	.004185812	Number of obs	= 51
Residual	.149102597	42	.003550062	F(8, 42)	= 1.18
				Prob > F	= 0.3343
				R-squared	= 0.1834
				Adj R-squared	= 0.0279
Total	.182589092	50	.003651782	Root MSE	= .05958

s1s	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
inpatientbedutilization	-.087648	.1045697	-0.84	0.407	-.2986781	.1233821
covid19casesper1000000population	6.24e-07	1.10e-06	0.57	0.573	-1.59e-06	2.84e-06
covid19deathsper1000000populatio	-.0000214	.0000303	-0.71	0.483	-.0000826	.0000397
west	-.0179564	.0348796	-0.51	0.609	-.0883464	.0524336
south	-.0271831	.0346007	-0.79	0.436	-.0970101	.042644
midwest	-.0498969	.0368486	-1.35	0.183	-.1242604	.0244667
northeast	0	(omitted)				
povertyrate	-.0060834	.0041666	-1.46	0.152	-.014492	.0023252
covid19testingpermillion	1.96e-06	1.82e-06	1.08	0.287	-1.71e-06	5.64e-06
_cons	.0808352	.0639423	1.26	0.213	-.0482055	.2098759

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The results above are from the Breusch-Pagan Test for heteroskedasticity (H_0 = Homoskedastic residuals). After overviewing the test, the F-statistic is .3343 and not significant at 5% (.3343 > .05). Furthermore, this regression passes the Heteroskedasticity Test (Breusch-Pagan Test).

Multicollinearity Test

```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
       south |      3.82    0.261643
     midwest |      3.51    0.284916
        west |      3.32    0.301256
covid19dea~o |      2.02    0.495567
covid19cas~n |      1.96    0.510422
inpatientb~n |      1.48    0.676284
 povertyrate |      1.39    0.719247
covid19tes~n |      1.18    0.846166
-------------+----------------------
    Mean VIF |      2.33

.
```

As the results show in the Variance Inflator Factor Test (VIF) conducted above, none of the variables have a VIF values are greater than 10. Thus, none of the variables merit any consideration as being a linear combination of other independent variables. In other words, this test is passed as none of the VIF values are above 10 as well as having tolerance(s) values greater than .1.

Normality Test

```
. sktest covid19fatalityrate inpatientbedutilization covid19casesper1000000population covid19deaths
> latio west south midwest northeast povertyrate covid19testingpermillion

                    Skewness/Kurtosis tests for Normality
                                                      ------- joint -------
    Variable |        Obs  Pr(Skewness)  Pr(Kurtosis) adj chi2(2)   Prob>chi2
-------------+-------------------------------------------------------------
covid19fat~e |         51     0.8767        0.7134        0.16         0.9236
inpatientb~n |         51     0.0068        0.0067       11.87         0.0026
covid19cas~n |         51     0.9127        0.4914        0.50         0.7802
covid19dea~o |         51     0.0004        0.0332       13.40         0.0012
        west |         51     0.0017        0.1983        9.64         0.0081
       south |         51     0.0327        0.0000       34.09         0.0000
     midwest |         51     0.0007        0.6427        9.81         0.0074
   northeast |         51     0.0000        0.1238       15.52         0.0004
 povertyrate |         51     0.0245        0.5242        5.29         0.0710
covid19tes~n |         51     0.0000        0.0000       47.77         0.0000

.
```

```
. sktest covid19fatalityrate

                    Skewness/Kurtosis tests for Normality
                                                              ------ joint ------
    Variable |        Obs  Pr(Skewness)  Pr(Kurtosis) adj chi2(2)    Prob>chi2
-------------+-------------------------------------------------------------------
covid19fat~e |         51     0.8767        0.7134        0.16         0.9236

.
```

The results above from the Normality Test conducted above, provide insight into whether or not the model/variables are normally distributed by whether or not the p-value(s) for the t-test and F-test are valid. For this particular Skewness-Kurtosis All Normality Test, the dependent variable (*covid-19 fatality rate)* has a resulting prob>chi squared value of .9236, which is not significant at 5% (.9236 > .05). Thus, this model passes the Normality Test and is not skewed. However, I do find it odd that some of my dummy variables (regions such as west and Midwest are not exactly 0.000).

Ramsey Test

```
. ovtest

Ramsey RESET test using powers of the fitted values of covid19fatalityrate
       Ho:  model has no omitted variables
                   F(3, 39) =      9.10
                   Prob > F =      0.0001

.
```

The Ramsey Test results as shown above, depict that I have a(n) F statistic of 9.10 and a p-value of .0001. From these results, the p-value is less than 5% and fails the Ramsey Test due to being insignificant (.0001), which means that this particular model probably has limitations and is probably skewed (as I already have a logarithmic model). The test could also suggest that the model I used probably has omitted variables.

Conclusion(s)/Policy Implications

The empirical results gathered from the regression model depicted that the hospital capacity proportion to be an important factor on Covid-19 fatality rates. These results/findings are in corroboration with other existing literature on the topic. As shown by the data and research gathered by Douglas White, there has been “attempts” to prioritize care and allocation of medical resources to individuals whom are classified as being ICU or of extreme conditions (White, 2020). However, with not enough resources available, the study conducted in Italy showed that with patients dying, hospitalization decreased. Thus, this shows that when under extreme external pressures to meet the medical needs of everyone at a medical facility such as hospitals, many patients under dire conditions may not receive the “appropriate” allocation of necessary resources needed to survive. Thus, by virtue of patients not surviving, did hospitalization decrease (leaving more available attention to be provided to more patients). Furthermore, many of the statistical figures provided in this study and data collected do not account for self-registered/reported cases of Covid-19 and medical care. As mentioned earlier, many of these findings of limited available capacity/beds in hospitals is also confirmed by Adam Blumberg in his study (Blumberg, 2020). Nonetheless, there may need to be policies in place that promote or in other words, “characterize” in determining which patients in ICU need immediate care and how funding is provided to these hospitals when under unforeseen circumstances. Another issue at play could be a market power problem, as money of the big powerful hospital(s)/systems will be able to sustain the ongoing assistance and medical attention needed during the pandemic, in comparison to smaller less powerful hospitals that do not have the funding or the resources at play to provide much services. In addition, some limitations to this project are the way in which the data is collected through surveys and some self-reporting (which can incur bias).

Limitations/Alternative Specifications

Furthermore, there can also be a limitation present when many individuals during the pandemic are not getting tested or are not seeking additional aid (medical or not reporting that they have been exposed). Another limitation as well, can be that there may also be a false positive individual categorized in the data collected. Furthermore, my log-log model failed the Ramsey Test, which shows that this model is probably limited in certain aspects/omitted variables. Some assumptions may have been violated as I did all I could do to explain why the Ramsey Test failed, even with my logarithmic model.

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