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Efficiency Analysis of U.S. States' Responses to COVID-19

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Abstract The year 2020 saw the beginning of a global pandemic unlike any in the previous century. Worldwide in 2020, there were over 115 million documented infections of SARS-CoV-2 and over 2.5 million deaths from the associated COVID-19 disease. In the United States of America alone there have been over 29 million cases and at least 525,000 deaths, at the time of writing. This has resulted in varying degrees of shutdowns, resulting in at least $2.04 trillion in lost GDP and an increase in nationwide unemployment rate from 3.5% in February 2020 to 14.7% in April 2020. With the US federal government distributing nearly $500 billion to state and local business and corporations, it is prudent to examine the efficiency by which these entities were able to use these funds, along with their existing resources, to dampen the effects of the unprecedented situation. This paper will discuss the herein performed Data Envelopment Analysis (DEA) for all 50 states, and the results and limitations thereof. DEA is useful in exploring relative inefficiencies of similar but distinct systems. DEA can only identify a system which is relatively inefficient compared to a composite weighted system and cannot provide much by way of suggested improvements. A detailed discussion of each input and output is provided so that subsequent analyses may be performed by others using different variables they deem important. Using the described inputs and outputs, it was discovered that 22 states are relatively inefficient, and the contributing factors are examined.

Keywords Data Envelopment Analysis, Linear Programming, Coronavirus

1. Introduction

The pandemic and respiratory disease, COVID-19, precipitated by the spread of the virus SARS-CoV-2 has impacted all aspects of human civilization in the 21st century. The virus first emerged sometime in late-2019 and arrived in the United States shortly thereafter with the first confirmed case coming in the early months of 2020. Since then, the virus has infected a recorded 74,000,000 and caused at least 1,600,000 deaths worldwide.

The United States has been affected disproportionately by this virus when compared to other countries, and recent analysis has shown that the United States as a country has been particularly inefficient in responding to the pandemic, as seen in Table 1 (Aydin & Yurdakul, 2020). At the time of that study, the United States had seen over 16,000,000 documented cases of COVID-19 which have caused over 300,000 deaths. Moreover, the US has seen at least $2,040,000,000,000 in lost GDP and an increase in unemployment from 3.5% in February 2020 to 14.7% in April 2020.

The scope of this article is strictly limited to the application of Data Envelopment Analysis (DEA). The article covers the literature gap by undertaking an efficiency analysis using DEA, which has not been attempted before for this topic. Moreover, the coverage is thorough because it considers specific production matters relevant to a full efficiency analysis.

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1.1. Background

This paper aims to investigate further the causes of the United States' low efficiency index on a world scale by analyzing the response of each state. It has often been asked which states are performing well and which aren't. Using Data Envelopment Analysis (DEA) it may be possible to discover systemic inefficiencies shared by states which can be improved upon at a national level, or the analysis may bring to light an outlier state responsible for a significant portion of the inefficiencies.

1.2. Objective

The goal of this analysis is to examine the performance efficiency of each of the 50 States in the United States and identify the parameters which affect their performance. The efficiency of each state is compared to the average composite efficiency of all the states in the United States. The inefficiency of a state is identified when the composite efficiency index, *E*, is found to be less than 1. This means that a composite state can be found which uses relatively fewer resources than the state being compared while reacting to the pandemic.

A state which can be thought of as efficient during the pandemic is one that is able to:

- minimize the spread of the virus
- confirm suspected cases with testing
- adequately handle positive cases
- minimize the closure of businesses
- minimize the impact to the working public

In order to effectively achieve these outputs, a state requires various resources of funds, prior investment, and local expertise including:

- Primary Care Physicians
- Hospital Infrastructure
- Critical Care Healthcare Professionals

Table 1. Relative Efficiencies of Selected Countries[1]

Country	Efficiency Level	Country	Efficiency Level
Afghanistan	0.894	Kazakhstan	1.000
Algeria	0.862	Kuwait	0.901
Argentina	0.867	Kyrgyzstan	0.916
Armenia	0.826	Malaysia	0.993
Australia	0.956	Mexico	0.786
Austria	0.785	Moldova	0.812
Azerbaijan	0.955	Morocco	0.863
Bahrain	0.982	Netherlands	0.759
Bangladesh	0.902	Nigeria	1.000
Belarus	0.949	Oman	0.981
Belgium	0.748	Pakistan	0.861
Bolivia	0.815	Panama	0.766
Brazil	0.765	Peru	0.770
Cameroon	0.851	Philippines	0.890
Chile	0.830	Poland	0.823
China	0.868	Portugal	0.767
Colombia	0.825	Qatar	1.000
Czech Republic	0.889	Romania	0.739
Denmark	0.809	Russia	0.931
Dominican Republic	0.757	Saudi Arabia	0.878
Ecuador	0.751	Singapore	1.000
Egypt	0.857	South Africa	0.885
Franc	0.729	South Korea	0.762
Germany	0.760	Spain	0.725
Ghana	0.999	Switzerland	0.796
India	0.868	Turkey	0.823
Indonesia	0.850	Ukraine	0.887
Iran	0.820	United Arab Emirates	0.853
Iraq	0.891	United Kingdom	0.770
Ireland	0.799	United States	0.764
Israel	0.855	Uzbekistan	1.000
Italy	0.700	Venezuela	1.000
Japan	0.956		

[1]After Aydin & Yurdakul (2020)

We expect this study to shed light on areas of relative inefficiency at the state level so that further analysis can be performed to help minimize these inefficiencies. It is assumed that decreasing inefficiencies at the state level will necessarily decrease inefficiencies at a national level. A decrease in inefficiency would imply more testing, fewer cases and mortalities, increase in GDP, and a decrease in unemployment.

1.3. Scope

This analysis considers all fifty (50) U.S. States. Out of scope of this analysis are districts, territories, and occupied zones. Specifically, it was decided to exclude the District of Columbia, Puerto Rico, U.S. Virgin Islands Guam, American Samoa, and Northern Mariana Islands because these entities are significantly different from the conterminous forty-eight (48) states in many ways which may affect the analysis and cause imprecise results.

2. Methodology

Data Envelopment Analysis (DEA) was performed using the linear programming computer software, LINDO, a popular analytical tool (LINDO 2003). DEA is often used by professionals and academics to quantify complex systems with many inputs and outputs. A major benefit to DEA is it does not require defining input or output parameters as a function of other variables. This method allows the linear program to construct a *composite system* (in this case, a composite *state*) which has an averaged quantity of inputs and outputs. This ratio of inputs to outputs of the composite system is the composite efficiency index, *E*. (Anderson *et al.* 1991).

Each system (state) can then be compared to this composite system to determine its relative efficiency. One significant drawback to DEA is that it is only able to determine if a system is relatively *inefficient* compared to the composite system and is unable to quantify by how much a system might be relatively *efficient*. Additionally, any system which has a maximum value for any given output is unable to be judged inefficient by the linear program, even if it might otherwise be so.

By virtue of the equations, a higher quantity for any given input serves to *decrease* efficiency while a higher quantity for any given output serves to *increase* efficiency. For our model of a state, we have some inputs and outputs which are directly related to efficiency and others which are inversely related. For this reason, each input and output was analyzed for its most significant relationship with regards to efficiency, and if it was deemed to be inversely related the quantity was reciprocated prior to inclusion into the DEA. This process is discussed in further detail in each respective section.

3. Inputs

Inputs are considered to be parameters that directly affect the outcomes of the states' responses to the COVID pandemic. The input parameters are an indicator of the method and assistance that each state receives to mitigate the effects of the virus. With much consideration, we made sure that our input parameters were directly COVID-related, and all data was available. The input information will allow us to measure each state's inefficiency by comparing what each state has to the composite of all the states.

3.1. COVID-Related Federal Funds Received

Total federal funds received in the state is considered to be the primary factor for this study and is therefore the first listed input. It is important to note, however, that DEA does not weight any input or output more than another. Initially it was surmised that only federal funds paid directly to state and local government agencies would be input to the analysis, but after further consideration it was determined that the more applicable value is total federal funds received by all entities within a state including business and non-profit organizations.

Total federal funds received in the state contributes not only to testing ability and medical supplies required for COVID-19 care, but also, because the funds tallied include those funds received by private businesses, the funds should help to temper losses in GDP and increases in unemployment rates. All COVID-related federal funds data is taken from the U.S. Bureau for Fiscal Service (BFS, 2020).

3.2. Population

Population is considered an input to the system because it affects all aspects of a state’s response. Additionally, a state’s population is correlated to the amount of federal funds it received. However, a state’s population is also directly correlated to the number of infections and deaths a state might see. For this reason, we also consider population density of a state as an input to the system. All population data is taken from the U.S. Census Bureau (UCB, 2020).

3.3. Population Density

Population density of a state is considered to be a reciprocal input to the system. That is, as a state's population density *decreases* it should be expected that the number of cases and deaths also *decreases*, mainly because of a naturally induced social distance. It is however also likely that a less dense population would make testing efforts more difficult and costly per person. All population density data is taken from the U.S. Census Bureau (USCB, 2020).

3.4. Average Age

Average age of a state’s population is suspected to play a factor in the rate of deaths. However, the range of average ages was 31 to 44.9, in Utah and Maine, respectively, and therefore may not be a significant input of the DEA. Average age is considered to be a reciprocal input to the system. Average age data is taken from the U.S. Census Bureau (USCB, 2020).

3.5. COVID-Applicable PCPs

Primary care physicians (PCPs) are expected to be the lowest level of healthcare, so to speak, for an infected citizen. For this input, we analyzed the total number of PCPs in each state and subtracted the number of PCPs in fields which we did not consider to be applicable to the diagnosis or treatment of COVID-19, namely obstetricians/gynecologists, etc. This number includes registered Physicians Assistants and Nurse Practitioners. All PCP data is taken from Kaiser Family Foundation (KFF, 2020).

3.6. Staffed Hospital Beds

Total staffed hospital beds in a state can be thought of as the initial hospital care that a patient would receive. Without enough hospital beds, patients might be unable to get the care their symptoms require and might progress to worse stages of the illness. All staffed hospital bed data is taken from the Kaiser Family Foundation (KFF, 2020).

3.7. 1st & 2nd Line HCPs

1st- and 2nd-line healthcare professionals are defined as ICU physicians and nurses, as well as Emergency Medical Technicians. The number of these professionals should be directly correlated to keeping hospitalized patients from dying. All data regarding 1st- and 2nd-line healthcare professionals is from Kaiser Family Foundation (KFF, 2020).

3.8. ICU Beds

The total number of ICU beds in a state is also expected to be directly correlated to ensuring that hospitalized patients receive the care they require. All ICU bed data is taken from Kaiser Family Foundation (KFF, 2020).

3.9. Input Summary

All input values used in this analysis are compiled in Appendix Table 1. Reciprocals are taken for both Population Density, and Average Age, due to the inverse relationship between these values and efficiency.

4. Outputs

Outputs are considered to be the outcome from the pandemic. The output parameters surely affect the performance of each state which makes it very important to study and identify the major effects it has on each state so that future preparation is made. The efficiency of each state is then measured from how well they were able to manage these output parameters.

4.1. Tests Performed

The number of tests performed are directly proportional to the efficiency of a state. While testing does not guarantee that the pandemic is managed, each test performed helps ensure that those testing positive are treated, and those people potentially exposed take appropriate precautions. Testing availability and costs varied greatly from state to state and is expected to be a key indicator in a state's efficiency. All testing data is taken from Johns Hopkins University of Medicine (JHUM, 2020).

4.2. COVID Cases

The number of reported COVID cases is considered to be a reciprocal output of the system, since our aim is to have the least cases as possible. While increased testing will invariably lead to an increase in documented cases, increased testing also allows for the early identification and tracing of patients. This allows the state to ensure that every COVID case has the proper attention and care it requires. All COVID case number data is from the U.S. Centers for Disease Control and Prevention (CDC, 2020).

4.3. COVID Deaths

The reported number of COVID deaths is considered to be a reciprocal output of the system. The ultimate goal of a states' response to the pandemic is the welfare of its citizens and minimization of deaths. All COVID case number data is taken from the U.S. Centers for Disease Control and Prevention (CDC, 2020).

4.4. Change in GDP

Behind ensuring the physical health of the citizenry, the states' response also has the direct effect of slowing the productivity of the local economy. One measure of the productivity of a states' economy is the total Gross Domestic Product (GDP). It is expected that, without the pandemic, the GDP for each state would have remained relatively stable throughout 2020. Therefore, we considered the percentage change in GDP in 2020 to be a reciprocal output of the system, since the least GDP decline is a better output. All GDP data is taken from the U.S. Bureau of Economic Analysis (BEA, 2020).

4.5. Change in Unemployment

Another key indicator to economic health is the unemployment rate. Again, it is expected that without the pandemic, the unemployment rate for each state would have remained relatively stable throughout 2020. For this analysis we used percentage-points change in unemployment rate, 10/2019-10/2020, seasonally adjusted as a reciprocal output of the system. All unemployment data is taken from the U.S. Bureau of Labor Statistics (BLS, 2020).

4.6. Output Summary

All output values used in this analysis are compiled in Appendix Table 2. Reciprocals are taken for all values except for Test Performed due to the inverse relationship between these values and efficiency.

There are seven states which have the highest value for any output, and therefore are unable to be properly assessed using DEA:

- NY performed the most COVID-19 Tests
- ME reported the fewest cases of COVID-19
- AK reported the fewest COVID-19 deaths
- NE and SD reported no change in seasonally adjusted unemployment rate, which is a reciprocated output and therefore undefined. IA reported the lowest non-zero change for unemployment rate
- DE reported the smallest decrease in GDP

5. Parameter Relationships

The relationships between each input and output parameter are very complex, but do not need to be identified or analyzed in DEA analysis. An increase in population, for example, can simultaneously increase the number of tests (beneficial) and the number of cases (detrimental).

Similarly, there are relationships between different input parameters. Broadly speaking more federal funds went to more populous states, for instance, and healthcare infrastructure and expertise is also correlated with population size.

Furthermore, there are relationships between output parameters. As mentioned previously, an increase in the number of tests performed can lead to an increase in the number of cases. Certainly, unemployment rates and GDP are correlated.

These complex relationships need not be considered while performing DEA, which makes this method particularly suited for this problem.

6. Formulation of the Linear Program

DEA is a common analytics tool to identify which systems within a group of systems are performing relatively inefficiently with a given set of inputs and outputs (I/O). In order to define the system, we must first assign a unique weighting variable to each of the 50 states. It is logical to use each state's two-letter abbreviation for the weighting variable. For example:

$$AK = weight\ applied\ to\ I/O\ for\ Alaska$$
$$\vdots$$
$$HI = weight\ applied\ to\ I/O\ for\ Hawaii$$
$$\vdots$$
$$WY = weight\ applied\ to\ I/O\ for\ Wyoming$$

By doing this, the linear program employed in DEA can weight each system appropriately to determine an average composite system, subject to a variety of constraints.

6.1. Objective Function

The DEA linear program attempts to find a weighted composite system which allows for the smallest value of the composite system efficiency index, *E*. If a solution can be found such that $E<1$, it can be interpreted that the composite system requires less input to generate the same output as the system being analyzed. This would mean that the composite system is more efficient than the system (state) being analyzed Therefore, the objective function can be simply stated as:

$$Minimize\ E$$

6.2. Constraints

Constraints serve to limit the governing equations in order to best address the target problem. A DEA performed without constraints would simply set $E=-\infty$ and be finished with the analysis. Instead, mathematical relationships are required which associate the various inputs and outputs with *E*. Additionally, it is vital to define each weighting variable to be non-negative, as no input or output can conceivably be negative. Additionally, all constraint equations were scaled to avoid floating point errors in LINDO which occur for values below 10^{-5} (LINDO, 2003).

6.2.1. Non-negativity Constraint

If weighting variables are allowed to be negative, the analysis will fail to converge. Therefore, it is critical that each is defined as such:

$$AK, AL, AR, AZ, \ldots, WA, WI, WV, WY \geq 0$$

Owing to the structure of LINDO, each variable must be individually assigned a non-negativity constraint in the set of input equations. This may make the equations bulky, but they do the needed work.

6.2.2. Weight Constraint

In order to form the composite system, the DEA adjusts the weighting variables such that the sum of the weighting variables is equal to 1. This is easily understood by the fact that the entire system constitutes the composite system. This constraint allows the composite system to be directly compared to any other system in the analysis. The equation governing this constraint can be stated:

$$AK + AL + AR + \ldots + WI + WV + WY = 1$$

6.2.3. Input Constraints

Generally speaking, input constraints to a DEA take the form:

$$ax + by + \ldots + nz \leq nE$$

where *z* is the weighting variable being analyzed against the composite system and *n* is the value of that constraint applicable to *z*. For example, the constraint equation for the input of Federal Funds Received when analyzing Alaska's relative efficiency takes the form-

$$2.8AK + 4.3AL + \ldots + 2.2WV + 1.6WY \leq 2.8E$$

where the dollar input of federal dollars to Alaska was $2.8 billion. The values for all states are available in Tables 1a and 1b of the Appendix.

The linear programming software being utilized to perform this DEA, LINDO, has a specific syntax which requires that all variables be on the left hand side of the comparator. Also, LINDO interprets a '<' sign to be the same as '≤', and similarly for greater-than. Therefore, each input inequality is rearranged to take the form:

$$2.8AK + 4.3AL + \ldots + 2.2WV + 1.6WY - 2.8E < 0$$

Our analysis for each state requires eight input constraint equations, two of which are reciprocated: population density, and average age.

6.2.4. Output Constraints

Generally speaking, output constraints to a DEA take the form:

$$ax + by + \ldots + nz \geq n$$

where, again, *z* is the weighting variable being analyzed against the composite system and *n* is the value of that constraint applicable to *z*, the weighting variable for the system being analyzed. For example, the constraint equation for the output of Total COVID Tests Performed when analyzing Alaska's relative efficiency takes the form-

$$2.49AK + 72.4AL + \ldots + 14.4WV + 4.3WY > 2.49$$

Where 2.49 represents the 249,000 tests performed in Alaska. The values for all states are available in Tables 2a and 2b of the Appendix.

Our analysis requires five output constraint equations, only one of which is not reciprocated – the one for total tests performed.

Hence, there were a total of 101 input equations and 50 output equations for each DEA run.

7. Results

DEA was performed using a distinct linear program for each state based on that state's input- and output-constraint equations as defined previously. Forty-three (43) DEAs were performed in total, as it was already deemed unnecessary to examine New York (NY), Maine (ME), Alaska (AK), Nebraska (NE), South Dakota (SD), Iowa (IA), and Delaware (DE). Each of these states has a maximum quantity for some output and therefore the DEA will trivially find an optimal solution at $E=1$. These states are however still included in the analysis of every other state, contributing their weight to the composite state.

Forty-three (43) non-trivial states analyzed and twenty-two (22) states were deemed to be relatively inefficient, $E<1$, and twenty-one (21) were deemed to be not relatively inefficient, $E=1$. Seven (7) states cannot participate in this exercise owing to the limitations of DEA.

7.1. Relatively Inefficient States

The twenty-two states deemed to be relatively inefficient are shown in Table 2, in ascending order of *E*. Any state that does not appear in Table 2 was identified as $E=1$, not relatively inefficient.

Table 2. States for which E<1

State	E
TX	0.828
NV	0.87
CO	0.88
OK	0.881
MS	0.882
KS	0.893
AR	0.901
LA	0.902
IN	0.911
MN	0.917
PA	0.92
AZ	0.921
TN	0.923
KY	0.926
OR	0.939
OH	0.95
NC	0.955
WA	0.958
MI	0.96
SC	0.962
MA	0.964
WI	0.982

7.2. Slack/Surplus

Slack/surplus quantities identify underutilized input and output resources. For each state where $E<1$, the slack or surplus of each constraint was briefly analyzed and, along with basic knowledge of U.S. geography and culture, commented upon in Table 3. For example, it is noted that Texas has highly populated urban areas (Houston, Dallas/Ft. Worth, San Antonio, Austin) which, when combined with vast tracts of sparsely populated areas, skews inputs out of Texas' favor.

Slack/surplus quantities for those states not identified as relatively inefficient are all 0 and therefore provide little by way of insight into that state's underutilized resources.

8. Analysis

Of the forty-three (43) non-trivial states analyzed, twenty-one (21) were deemed to be relatively efficient, $E=1$, and twenty-two (22) states were deemed to be relatively inefficient, $E<1$. This result is expected as roughly half of all states should be worse than average and half should be better. Due to the large sample size, $n=50$, any one state which is significantly more- or less-efficient than any other state should be averaged out and a largely normal distribution is expected. If, contrarily, it was determined that a significantly different number of states were relatively efficient versus relatively inefficient, this might indicate an error in the input/output data.

Unfortunately, there do not seem to be obvious systemic inefficiencies identified by this analysis which might be able to be addressed at a federal level. The DEA indicates that it is up to each state, relatively inefficient or otherwise, to recognize, analyze, and address their own inefficiencies if the impacts of the COVID-19 pandemic are to be tempered.

Table 3. Analysis Results, sorted by increasing values of E

State	E	Notes
TX	0.828	Highly populated urban areas combined with vast tracts of sparsely populated areas skews inputs out of TX's favor
NV	0.87	Las Vegas: densely populated, tourist based economy
CO	0.88	No obvious reason
OK	0.881	No obvious reason
MS	0.882	Relatively high COVID deaths
KS	0.893	Very low COVID tests
AR	0.901	Relatively high COVID deaths, relatively low COVID tests
LA	0.902	Relatively high COVID deaths
IN	0.911	Very high COVID deaths
MN	0.917	No obvious reason
PA	0.92	Highly dense urban areas.
AZ	0.921	No obvious reason
TN	0.923	High change in GDP
KY	0.926	No obvious reason
OR	0.939	No obvious reason
OH	0.95	Relatively high cases, deaths, and relatively low testing. Relatively high PCPs.
NC	0.955	Highly dense urban areas
WA	0.958	No obvious reason
MI	0.96	Relatively high cases, deaths, and relatively low testing. Relatively high PCPs.
SC	0.962	Relatively low testing.
MA	0.964	Very high COVID deaths
WI	0.982	No obvious reason

9. Summary and Conclusions

DEA has been employed to analyze each of the fifty (50) U.S. states to determine their relative inefficiencies in reacting to the SARS-CoV-2/COVID-19 pandemic which has consumed the world in 2020. The analysis described herein considered only the following variables as inputs:

- Federal Funds Received
- State Population
- State Population Density (reciprocal)
- Average Age (reciprocal)
- COVID-Applicable Primary Care Physicians
- Total Staffed Hospital Beds
- Total ICU Beds
- Total Critical Care Healthcare Professionals

The analysis performed in this study considered the following variables as outputs:

- Total COVID-19 Tests Performed
- Total COVID-19 Cases (reciprocal)
- Total COVID-19 Deaths (reciprocal)
- Percent Change in State GDP (reciprocal)
- Percentage Point Change in State Unemployment (reciprocal)

Correspondingly, this analysis concluded that twenty-two (22) states are relatively inefficient with regards to the amount of input required to produce a given amount of output. Twenty-two (22) states represent 51.2% of the total analyzed states, which is expected by nature of DEA, as well as in a normal distribution. Moreover, twenty-one (21) states were deemed to not be relatively inefficient and an additional seven (7) states produced a maximum quantity for a given output and could not be meaningfully analyzed using DEA.

The goal of this investigation was to determine if there are systemic inefficiencies at the state level contributing to the inefficiencies associated with the United States at a country level in other studies. This analysis was unable to identify a specific factor at the state levels which might be causing this anomaly. However, this study was able to discover several areas for improvement, identified by the input parameters, and measured by the output parameters, in states identified as relatively inefficient.

This study is beneficial for improving medical response in future for oncoming diseases and health emergencies. Hospital administrators and state agencies will know what to look for to improve the performance of their response. Hence, the study has practical implications for the future.

Appendix

Table 1a. Raw Inputs for States AK-MO

State	Federal Funds ($x10^9$)	Population	Pop. Density	Average Age	ICU Beds	1st & 2nd Line HCPs	Staffed Beds	COVID-App. PCPs
AK	$ 2.80	731,545	1.3	34.6	130	543	1274	10441
AL	$ 4.30	4,903,185	95.8	39.2	1870	4393	15322	2119
AR	$ 2.40	3,017,825	60.1	38.3	856	2131	7968	13861
AZ	$ 8.10	7,278,717	57.2	37.9	1742	5277	13426	5980
CA	$ 44.30	39,512,223	251	36.8	8131	23510	74180	78738
CO	$ 5.70	5,758,736	52.6	36.9	1770	4434	8132	12756
CT	$ 3.60	3,565,287	741.2	41	731	3465	8798	12627
DE	$ 2.30	973,764	484.1	40.7	249	1025	2072	2285
FL	$ 21.80	21,477,737	375.9	42.2	6226	17053	56106	56210
GA	$ 16.80	10,617,423	176.4	36.9	2703	7432	22547	23833
HI	$ 2.70	1,415,872	222.9	39.2	219	811	2583	2059
IA	$ 2.50	3,155,070	20	38.2	622	2227	6428	3588
ID	$ 2.00	1,787,065	231.4	36.6	333	1128	2487	31754
IL	$ 20.70	12,671,821	184.6	38.3	3426	9567	28906	11946
IN	$ 5.70	6,732,219	55.9	37.9	2358	4679	15874	7937
KS	$ 2.90	2,913,314	35.6	36.9	878	2581	6467	6249
KY	$ 3.80	4,467,673	111.4	38.9	1447	4155	13674	11359
LA	$ 4.70	4,648,794	107.2	37.2	1518	4123	14925	8561
MA	$ 10.10	6,949,503	43.1	39.4	1555	6498	15198	4566
MD	$ 7.90	6,045,680	614.5	38.8	1227	5054	10804	18245
ME	$ 2.00	1,344,212	866.6	44.9	288	1247	2896	26164
MI	$ 10.60	9,986,857	174.7	39.8	2749	8878	23582	28990
MN	$ 5.70	5,639,632	69	38.1	1277	5566	10590	14724
MO	$ 5.00	6,137,428	63.8	38.7	2092	6088	16762	6506

Table 1b. Raw Inputs for States MS-WY

State	Federal Funds ($x10^9$)	Population	Pop. Density	Average Age	ICU Beds	1st & 2nd Line HCPs	Staffed Beds	COVID-App. PCPs
MS	$ 2.90	2,976,149	88.3	37.7	931	2149	10063	15704
MT	$ 2.10	1,068,778	7.1	39.9	248	747	2239	2285
NC	$ 9.90	10,488,084	24.7	38.9	3168	9188	22467	5503
ND	$ 1.90	762,062	26.3	35.2	278	866	2003	5258

State	Federal Funds (x10^9)	Population	Pop. Density	Average Age	ICU Beds	1st & 2nd Line HCPs	Staffed Beds	COVID-App. PCPs
NE	$ 2.30	1,934,408	148.4	36.6	548	1695	4240	3756
NH	$ 1.80	1,359,711	17.2	43	252	1284	2281	23372
NJ	$ 9.50	8,882,190	1207.8	40	1882	5924	20175	4729
NM	$ 2.90	2,096,829	419.3	38.1	460	1206	3884	55256
NV	$ 4.10	3,080,156	206.2	38.1	1118	1842	5837	22393
NY	$ 25.80	19,453,561	421	39	4420	15154	57654	1852
OH	$ 11.10	11,689,100	283.6	39.4	3622	10473	27824	30185
OK	$ 5.50	3,956,971	57	36.7	1164	2762	38591	8309
OR	$ 4.10	4,217,737	42	39.4	837	2999	6172	9833
PA	$ 12.80	12,801,989	285.7	40.8	3643	13212	34841	34844
RI	$ 2.10	1,059,361	1,010.8	40.1	279	754	2440	3981
SC	$ 4.00	5,148,714	162.6	39.6	1459	4160	11770	8132
SD	$ 2.00	884,659	11.3	37.1	150	939	2741	2124
TN	$ 6.00	6,833,174	160.1	38.8	2309	7004	18638	18070
TX	$ 37.50	28,995,881	104.9	34.8	7149	20645	58423	55385
UT	$ 104.40	3,205,958	36.5	31	687	2010	4640	4700
VA	$ 11.90	8,535,519	67.7	38.4	2007	6274	17840	2003
VT	$ 1.70	623,989	211.7	42.8	94	388	835	18785
WA	$ 9.20	7,614,893	107.8	37.7	1493	5216	10312	14933
WI	$ 5.60	5,822,434	76.6	39.6	1506	3169	11048	4797
WV	$ 2.20	1,792,147	106.3	42.7	643	1683	5348	12051
WY	$ 1.60	578,759	6	38	102	244	1261	1003

Table 2a. Raw Outputs for States AK-MO

State	Total Covid Cases (12/3)	Total Covid Deaths (12/3)	Percent Change in GDP	Change in Unempl. Rate	Total Tests (12/3)
AK	32531	121	-33.8	3.5	249054
AL	256828	3711	-29.6	3.1	7240533
AR	340979	6739	-27.9	5.4	1013295
AZ	161521	2522	-25.3	2.7	4307326
CA	1245948	19324	-31.5	3.9	25760389
CO	241172	3193	-28.1	2.3	3590860
CT	121426	5091	-31.1	1.6	3566143
DE	36698	779	-21.9	2.9	801768
FL	1001800	18776	-30.1	3.6	13376764
GA	482139	9567	-27.7	1.3	4597875
HI	17819	242	-42.2	11.6	708502
IA	350970	5973	-28.2	0.8	890139
ID	234810	2449	-32.4	2.6	1581374
IL	104734	991	-29.7	3.1	8818194
IN	748603	13397	-33	1.8	2352170
KS	162061	1679	-30.3	2.2	861845
KY	186765	1980	-34.5	3.1	2785907
LA	241335	6501	-31.4	4.2	3638611
MA	235683	10796	-31.6	4.6	4894187
MD	205399	4764	-27.7	4.4	4773185
ME	12558	220	-34.4	2.4	1766805
MI	402886	9842	-37.6	1.6	7112839
MN	327477	3751	-31.3	1.3	4541990
MO	159036	3879	-32.1	1.2	2454173

Table 2b. Raw Output for States MS-WY

State	Total Covid Cases (12/3)	Total Covid Deaths (12/3)	Percent Change in GDP	Change in Unemploy-ment Rate	Total Tests (12/3)
MS	305370	4043	-32.9	1.8	1569145
MT	64340	713	-30.8	1.4	701129
NC	156996	2201	-30.5	2.6	8014994
ND	673656	34422	-27.6	2.4	441782
NE	371594	5366	-31	0	1245372
NH	132530	1128	-36.9	1.6	969106
NJ	22332	537	-35.6	4.5	7037626
NM	346206	17145	-28.3	3.3	2243523
NV	81105	977	-42.2	8.3	1692269
NY	100963	1629	-36.3	5.7	29087353
OH	437928	6671	-33	1.5	6593237
OK	205999	1752	-31.1	2.7	2267621
OR	78160	953	-31.9	3.5	2189174
PA	375431	10757	-34	2.7	3394959
RI	59005	1391	-32.4	3.5	1666502
SC	220835	4444	-32.6	1.8	2614105
SD	82203	995	-28.8	0	343362
TN	384285	4688	-40.4	4.1	4809666
TX	1200674	21756	-29	3.4	11646776
UT	202220	906	-22.4	1.7	1972081
VA	244503	4409	-27	2.6	8022193
VT	244503	4147	-38.2	0.8	259760.4
WA	170342	2850	-25.5	2	3198027
WI	49905	778	-32.6	2.2	4017188
WV	420930	3703	-29.6	1.3	1441693
WY	34507	230	-32.5	1.8	429925

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