**Comparative analysis of state public health measures and number of COVID-19 cases in
California, Texas, and New York (April to July 2020)**

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Background:

Pandemics are unpredictable and have the potential to cause a significant amount of mortality without adequate public health measures. In the beginning of a pandemic, especially if a virus is a newly mutated strain, there is most likely no vaccine available for inoculation. Non-pharmaceutical interventions (NPIs) or public health measures can help mitigate the damage until a viable cure is found. Common NPIs include wearing a face mask, hand hygiene, contact tracing, travel restrictions, social distancing, and closing public places (WHO). Because approximately 40% of those infected with COVID-19 are asymptomatic, many unknowingly spread the disease making it a challenge to curb the growth of the current pandemic. While the CDC recommends social distancing and wearing face masks to avoid infecting others, individual states in the U.S. have enforced their own statewide public health measures to tackle COVID-19. Many states have online databases containing information about their daily number of COVID-19 cases and when certain policies were implemented. Looking at state policies and trends in statewide cases together can help us identify the effects of enforcing certain public measures on the number of new COVID-19 cases over time.

An early predicting study analyzed the global impact of “large scale anti-contagion policies” on the growth of COVID-19. This study estimated that “interventions delayed on the order of 62 million confirmed cases” and for the US specifically estimated a 34% per day growth in cases in the absence of these policies.⁸ A University of Kentucky study analyzed four separate social distancing measures (shelter in place orders, school closures, closure of entertainment related businesses, and minimizing large social gatherings) at the state and county level from March and April 2020 in the United States. This study found that all of the aforementioned measures were associated with the reduction of the COVID-19 growth rate.⁴ In particular, it was noted that shelter in place orders “lead to statistically significant reductions in the COVID-19 case growth rate” and the percent reduction in the growth rate increased as the duration of the policy in place increased. In order to analyze the effects of in dining operations for restaurants in relation to case growth rate, we utilized a case study from a local outbreak in Guangzhou, China delivered through the CDC illustrating the spread of COVID-19 to ten people from three separate families through the transmission of droplets that was exacerbated by the air conditioning system.¹⁰ For this study, data on daily case numbers from three states in the United States as well as their enforced statewide public health guidelines regarding shelter-in-place, in person restaurant dining, closure of non-essential businesses, and mask mandates from April to July of 2020 will be used in order to better understand the correlation between differing public health measures and the spread of COVID-19. California, Texas, and New York were individually chosen due to the variation in their respective trends of cases as well as their differences in policy implementation. After collecting data on each state's daily cases and the timing of four public health measures we chose (shelter in place, mask mandate, restaurant closure/reopening and non-essential closure/reopening), we superimposed these data points on top of each other to track how cases and policies have changed over time in each of these three states and which factors might have affected the trends of COVID-19 cases in these states. Additionally, we used a report by the American Enterprise Institute to evaluate the appropriateness of each state's policy measures in response to COVID-19 based on features such as testing and tracing capacity and give recommendations for further actions. This information gives us key insights into which policy measures have been effective in preventing the spread of the COVID-19 pandemic, since each state has taken a different approach.

Abstract:

In response to the spread of COVID-19 in the United States, every state has utilized varying degrees of public health policies yielding different trends in the number of cases. Due to the lack of a unified approach taken in response to the global pandemic in the United States, we can look at the general trends in case numbers from different states in the context of the public health measures that have been implemented. Through the use of multiple databases, we collected data from each states health department websites and policy data came from the COVID-19 US State Policy Database on the CDR, as well as the KFF state policy database in order to graph the number of daily new cases in three different states while marking the dates when the certain policies were implemented. The scope of this particular review focuses on California, New York, and Texas, each of which have taken different approaches and are reflective of three different areas of the continental United States. The four policies that are analyzed include shelter in place orders, mask mandates, the closure and reopening of non-essential businesses, and the closure and reopening of restaurants for in person dining. To further understand the reopening strategies of these three states, we have utilized the “National Coronavirus Response: A Roadmap to Reopening” guide to compare the points at which each state decided to open considering testing capacity, contact tracing, and case numbers/trend in cases at that point in time. Based on this data, we comparatively analyzed trends in cases and policy measures, taking into account other factors like tracing and testing capacity to evaluate the appropriateness of each state’s measures in its overall goal of reopening. Overall, we have found New York which began as the hotspot for COVID-19 cases, to ultimately be the most successful state in regard to reducing the number of daily new cases and surpassing goals for contact tracing and testing. Conversely California, which began as a success story, has seen a sharp rise in cases after moving into phases of reopening. Similarly, Texas has also seen a rise in cases over recent months with the relaxation of public health measures before meeting the markers for reopening. Both California and Texas have been far behind on testing and contact tracing capabilities. Not only abiding by public health policy recommendations but also being consistent with these measures throughout the course of the pandemic are correlated with lower numbers of cases when comparing New York with California and Texas. This finding implies that for future pandemics, and moving forward with the current pandemic, extreme caution should be taken in timing public health measures and tracking cases.

Materials and Methods:

METHODS:

We began a literature search for studies that have been published regarding the policy of each US state and the rate of COVID-19 infections in each respective state. Very few studies looked at these two variables closely, but a notable study that guided our approach was the “Strong Social Distancing Measures in The United States Reduced The COVID-19 Growth Rate” from the University of Kentucky. In this study, Courtemanche et al. utilized the event study design to estimate the impact of the policy measures taken by each state to model the reduction in the daily growth of COVID-19 cases. The data in this study included observations from 3,138 counties (New York City counted as one instead of 5) spanning from March 1, 2020 and April 27, 2020 with a total sample size of 182,004 from the fifty-eight days of collected data from each county.⁴ Each observation was weighted by the population of the county. The predictor variable in this study was the adoption of government-imposed measures (SIPOs, school closures, large social

gatherings and closures of entertainment related businesses). For the 4 measures listed above there are also seven variables regarding whether the policy was implemented 1-5, 6-10, 11-15, 16-20 or 20 or more days ago. The daily growth rate in confirmed cases at the county level. Daily exponential growth rate was calculated as the natural log of cumulative daily COVID-19 cases minus the log of COVID-19 cases on the prior day. The study completed a statistical analysis of the relationship between social distancing policies and the exponential growth rate of confirmed COVID-19 cases. Along with having controls, the model had fixed effects such as geography and time. County fixed effects acknowledged the variation that could have been caused by differences in policies, population density, and residents' education, political beliefs, and age. The results on the modeled reduction of daily percent growth of cases included 95% confidence intervals. In their conclusion, they suggest that more data is needed on measures such as mask wearing and the reopening of restaurants.⁴ Following these recommendations we utilized data from openICPSR's online COVID-19 US State Policy Database collected in the COVID-19 Data Repository (CDR), as well as data regarding the daily cases from Texas Department of State Health Services, New York State Department of Health, and the California Government COVID-19 Update websites to make a comparative analysis of states with varying policy measures and cases. We also chose these four measures were based upon the guidelines specified in the "National Coronavirus Response: Roadmap to Reopening" where characteristics of different phases of reopening such as physical distancing and mask wearing. The shelter-in-place, non-essential business closure, and restaurant closure measures we chose are specific examples of physical distancing that we included in addition to the mask mandate policy.

To perform our comparative analysis, we chose the states California, Texas and New York to follow the growth of their COVID-19 rates over time and marked the dates in which each of their policies were passed. We chose these states because of their variation in their timing of policy measures as well as their differences in the progression of cases. We entered the daily cases for each of the states starting April 5th through July 6th, and we chose this three-month period because April 5th is a few weeks after the passing of some of the earliest policy measures and the policy measures database we used included data up until July 6th. The policies included in this graph were the same four selected for Figure 1. shelter in place order, mask mandate, and restaurant closure/reopening. Restaurant closure is defined in the CDR dataset as "closed restaurants except take out", and reopening restaurants ranges from open with "outdoor dining only" or limited to 25-50% capacity, or completely reopening without restrictions. Instead of measuring the duration of the policies like the previous correlation analysis, we recorded the date that each of the policies were passed. The timing of the measures becomes important for our comparative analysis and we will interpret our findings for policies that may be correlated with the trend in cases we observed in the three-month period.

We then used the "National Coronavirus Response: Roadmap to Reopening" report's phases of reopening to classify California, Texas, and New York in their respective phases of reopening according to trends in cases, testing, tracing, and whether or not certain mandates are in place. The information from this table is organized into a table that delineates what characteristics of each phase are and what requirements must be met to move onto the next phase. We used data from The COVID Tracking Project, the Harvard Global Health Institute, Youyang Gu's Covid-19 Forecasts, and the Centers for Disease Control and Prevention which was compiled by the New York Times for data on how much testing is currently available; NPR's survey of state

public health departments, NPR member station reporting, and National Association of County and City Health Officials, to account for the current tracing capacity; and the CDR dataset which specified which policies are in places and which businesses and facilities such as gyms, alcohol stores, movie-theaters, etc. are open. This data is up to date as of July 7th, except the tracer data which is accurate of June 18th. Using the same report, we then evaluate the appropriateness of certain policy decisions and recommend further actions. Lastly, we note the factors of herd immunity, compliance towards regulations, and population density that could additionally explain variations in trends in cases across these states.

Results:

Figure 1. New positive cases per day in California, Texas, and New York over time with markings of when the public health measures of closing restaurants, mask mandates, reopening restaurants, and shelter in place started. A second graph for each state was created replacing restaurant closure/reopening with the closure/reopening of non-essential businesses. Data was gathered from the respective states' health department websites and policy data came from the COVID-19 US State Policy Database on the CDR, as well as the KFF state policy database. According to the CDR database California did not reopen restaurants

however, in the KFF database restaurants were reopened for a brief period between June 17 and July 6. Texas did not have a shelter in place policy according to the data in the CDR. We found that Governor Abbott from Texas declined to call their unofficial stay at home order a shelter in place order, which may be the reason it was not officially recorded on the database. The non-essential businesses reopened in Texas include retail, restaurants, libraries, and malls. In California other non-essential businesses such as manufacturing, offices, outdoor museums, and limited personal services. In New York landscaping/gardening businesses were open and some parts of the state reopened construction, agriculture, forestry, fishing, hunting and other businesses depending on the county.

	Characteristics of Phase I		Triggers for Moving to Phase II			Characteristics of Phase II		Triggers for Moving to Phase III
State	Physical Distancing (includes shelter-in-place and restaurant closures)	Mask Mandate	Sustained reduction in cases for 14 days	Testing is readily available	State is conducting active tracing and monitoring* (data from June 18)	Relaxing physical distancing measures	Allow immune citizens to return to work	Development of a vaccine with proven safety and efficacy
CA	Shelter-in-place, restaurant closures	Yes	No	No (38% of testing target)	15.17 tracers per 100,000	No	Open: Essential businesses, alcohol stores Closed: Gun stores, dine-in restaurants, gyms, movie-theaters, hair salons, bars	No
TX	No shelter-in-place, restaurants open but limited capacity	Yes	No	No (25% of testing target)	10.16 tracers per 100,000	No	Open: Essential businesses, alcohol stores, gun stores, dine-in restaurants, gyms, movie-theaters, hair salons Closed: Bars	No

NY	No shelter-in-place, restaurants open	Yes	Yes	Yes (368% of testing target)	51.68 tracers per 100,000	Yes	Open: Essential businesses, alcohol stores, dine-in restaurants, hair salons Closed: Gun stores, gyms, movie-theaters, bars	No
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*The National Association of County and City Health Officials recommends 15 contact tracers for every 100,000 people as a non-pandemic standard, and 30 such workers during a pandemic.

Figure 2. Phase of reopening of California, Texas, and New York as of July 6th, 2020. This data table compiles data from openICPSR's CDR dataset; the New York Times article "Is Your State Doing Enough Coronavirus Testing" which compiles data from The Covid Tracking Project, the Harvard Global Health Institute, Youyang Gu's Covid-19 Forecasts, and the Centers for Disease Control and Prevention; National Academy for State Health Policy; NPR's survey of state public health departments, NPR member station reporting, and National Association of County and City Health Officials. The data shown here is accurate as of July 6, 2020 except the data for tracers which is accurate as of June 18. The columns are various benchmarks and milestones included in the report "National Coronavirus Response: A Roadmap to Reopening" that characterize various phases of reopening.

Discussion:

Evaluation of trends in daily new cases and recommendations for next steps

First, we will discuss the trends in California, Texas, and New York and their correlation with the various mandates passed as shown in Figure 1. Then we will classify which phase of reopening each state belongs in as of July 6th, recommend next steps, and note extraneous factors that may influence the efficacy of policy measures as shown in Figure 2.

California

California was not a pandemic hot spot initially and began with a very strict approach to controlling the spread of COVID-19 by implementing shelter-in-place and restaurant closure policies in mid-March. However, cases continued to rise steadily, reaching nearly 4000 new cases/day before the state implemented a mask mandate. Around the same time as the implementation of the mask mandate, restaurants were also re-opened despite an unprecedented surge in cases leading up to the decision. After implementing the mask mandate and reopening restaurants, new cases per day began to increase at a much higher rate than before, reaching a peak of 9000 new cases/day before the state closed restaurants once again.

California is still in Phase I of reopening as the state is still under shelter-in-place with restaurants closed for indoor dining. According to "National Coronavirus Response: A Roadmap to Reopening," states in Phase I should move to Phase II when there is a "sustained reduction in cases for at least 14 days," which California has not seen yet throughout the course of this pandemic. Additionally, California needs to increase testing capacity (which is currently at 38% of its target) and the tracer workforce (which was at 15.17 tracers/100,000 people as of June 18, was far under the recommended pandemic standard of 50 tracers/100,000 people). We recommend that the state continues to remain closed and encourage mask wearing and physical

distancing. We also recommend that the state increase testing and tracing capacity through new testing centers and training more tracers. Currently, the trend of new cases seems to be increasing steadily so it is of utmost importance that proper distancing and protective measures are enforced. The fact that cases are still increasing despite there being proper Phase I measures in place indicates that there could be uncontrollable factors in play such as compliance and enforcement that we will mention at the end of this paper

Texas

Texas, much like California, implemented strict restaurant closure policies in mid-March, in the early stages of the pandemic when it was not a hot spot. Despite there being no official “shelter-in-place” mandate, Governor Abbott did order all residents to stay home besides going out for essential tasks from April 2 to April 30.¹⁵ However, before new cases stabilized and decreased, the state lifted the restaurant closures and new cases doubled to approximately 4000 new cases/day from about 2000 new cases/day before a mask mandate was implemented. Thereafter, similar to California, daily new cases increased at a much higher rate than before.

Texas is also classified by Phase I of reopening. While the state has lifted its unofficial shelter-in-place mandate and reopened restaurants, it is still enforcing a mask mandate. As the number of new cases is continuing to rise dramatically and it won't be likely to reach a 14 day decline soon, postponing safely moving to Phase II. Similar to California, Texas also needs to increase its testing capacity (currently at 25% of the target number) and tracer workforce (10.16 tracers/100,000 people as of June 18). We recommend that Texas follow a similar course of action to California: the state should reverse its reopening status by enforcing a shelter-in-place mandate and closing restaurants and gyms and other places where it is indoors with little air circulation and difficult to maintain a safe physical distance.

New York

New York is a much different case than California and Texas. It began with a dramatic surge in cases in February and March and established itself as the biggest COVID-19 hot spot. Like California and Texas, New York also established a shelter-in-place order and ordered closure of restaurants in mid-March. However, it began a mask mandate in late April, almost 2 months earlier than California and Texas who began their mask mandates in late June and early July respectively. Once daily new cases had decreased for 3 months to about 1000 new cases/day did the state end shelter-in-place, reopen non-essential businesses, and reopen restaurants.

New York has moved into Phase II of reopening as it has seen a sustained reduction in cases for the past 3 months with the exception of a few spikes, has reached 368% of its testing target, and has exceeded the recommended tracer goal of 30 tracers/100,000 people with 51.68 tracers/100,000 people as of June 18. It has also lifted social distancing requirements and is beginning to open up businesses cautiously while keeping large indoor entertainment and exercise facilities closed. According to the American Enterprise Institute, states should only move into Phase III of reopening “once a vaccine has been developed, has been tested for safety and efficacy, and receives FDA emergency use authorization;” this will allow states to build “population-level immunity” and “enable the lifting of all physical distancing measures”.⁷

Comparative Analysis

Overall, California and Texas showed similar results despite California having an earlier head start to shelter-in-place orders due to the relaxation of public health measures before seeing a steady decline in cases. New York, however, was successful in seeing a large decrease in the

number of COVID-19 cases and maintaining a low number of cases giving us some insight when comparing it to California and Texas.

If we classify the mask mandate and shelter-in-place order as protective measures and the reopening of restaurants/non-essential businesses as relaxing measures, we can see how the three states differ in their approaches.

Protective:

California, Texas, and New York all implemented some form of a shelter-in-place order within one month of each other, with California's beginning in mid-March, Texas's unofficial shelter-in-place mandate beginning early April, and New York's shelter-in-place order beginning late March.

California, Texas, and New York differed greatly in when they chose to implement a mask mandate as well, with California starting in mid-June, Texas starting in early July, and New York starting in late April.

Relaxing:

California, Texas, and New York differed greatly in when they chose to reopen restaurants, with California reopening mid-June, Texas reopening early May, and New York reopening late June. California, Texas, and New York were similar in that they all reopened non-essential businesses at the same time, around early May.

Waiting for a significant decline in cases to reopen

The American Enterprise Institute recommends that states in Phase I of reopening (California and Texas), should wait for a 2 week decline in new case numbers as one of the signals to move into Phase II. A key difference between these states is that California and Texas began reopening restaurants and non-essential businesses before cases had decreased for 14 days consistently whereas New York waited for 3 months of declining cases to start reopening restaurants. These policies are significant because an early study indicates that droplet transmission can result in a considerable amount of infection in an indoor air-conditioned restaurant.¹⁰ Additionally, Texas reopened restaurants in early May, before they implemented a mask mandate in early July.

California also reopened restaurants relatively early, but around the same time they began the mask mandate. On the other hand, in New York, the state implemented a mask mandate in late April before they reopened restaurants in late June. This may have been a contributing factor in reducing the overall transmission of COVID-19 in restaurants.

Timing of protective and relaxing measures

Looking at the difference between protective and relaxing measures, New York implemented both protective measures (shelter-in-place in late March and mask mandate in late April) before reopening restaurants and non-essential businesses in late June and early May. On the other hand, California and Texas did not prioritize these protective measures. California began their shelter-in-place policy early, in mid-March, but reopened non-essential businesses in early May before they reopened restaurants and implemented a protective mask mandate at the same time in early June. Similarly, Texas began by closing restaurants and non-essential businesses in mid to late March, however, they reopened restaurants quickly, in early May, before waiting 2 months to implement a mask mandate in early July.

Tracing and testing

Another key difference between California and Texas versus New York is that New York greatly emphasized tracing and testing, surpassing the standard of 50 tracers/100,000 people and reaching 100% of its testing target earlier on than California and Texas.

Combined, these factors allowed New York to have a shorter overall shelter in place and thus a quicker and more effective pandemic response. California and Texas are currently still closed despite starting their shelter-in-place policies at around the same time as New York. As a result of this prolonged order, citizens may start breaking those shelter-in-place mandates because of impatience. This may lead to compliance issues that reduce the overall effectiveness of these orders.

Confounding Factors

Next we will discuss some confounding factors that may influence the trends in COVID-19 cases in addition to state measures as well as clear up some public misconceptions.

Compliance

In the future, we highly recommend more research on the public's level of compliance to public health measures and ways to increase that during pandemics. This is critical since the effectiveness of certain public health measures cannot be accurately determined if most of the population fails to comply. In regard to shelter-in-place, the U.S. Bureau of Transportation Statistics found that only 25.5% of Californians obeyed this order whereas 30% of New Yorkers stayed at home.

In regard to increasing compliance levels, there are concerns about strict legal enforcement of public health mandates violating personal freedoms and the precedent that might be set.

According to CNN, in addition to aforementioned reasons, many Americans refused to wear masks due to the CDC's conflicting guidance: it initially stated healthy individuals did not need to wear masks before recommending in mid-April for everyone to wear them. Therefore, another effective approach to increasing compliance is to disseminate information to the public only after thorough research to avoid backtracking.

Population Density

Another factor that may have influenced the effectiveness of the various policy measures is population density. New York saw a large concentration of cases in New York City where population density is greatest. Also, California's beach scene may have attracted many more tourists during holidays like Memorial Day and July Fourth, contributing to a greater rise in cases.

Herd Immunity

Lastly, there's a common misconception that New York's cases are decreasing due to herd immunity. But it is important to realize that in New York, 15-21% of people have been exposed so far. To get to that percentage of exposure, 17,599 of the 8.4 million people in New York City have died. Even though many have died in New York, the state didn't reach herd immunity as for herd immunity to be reached, 70% of the population must be immune. Whether or not 70% of the population is immune will only be concluded when the % exposed increases. However, to mitigate the spread of the pandemic, we all must strive to prevent exposure through social distancing.

From our data, we come to the overall conclusion that the timing of public health measures and tracking of cases is a key factor in handling COVID-19 and other future pandemics. We saw that California and Texas relaxed policies too soon (before they saw a significant decline in cases), didn't prioritize implementing protective measures as strongly as trying to reopen, and didn't prioritize tracing and testing as readily as New York; these were all factors that didn't allow them to reach Phase II of reopening as quickly as New York. States should emphasize

implementing protective measures such as shelter-in-place and mask mandates first rather than try to open up facilities like restaurants or non-essential businesses, meeting testing and tracing goals, and wait until there is a significant decline in cases to reopen. This research lays the groundwork for more detailed research in the future looking at rates of compliance as well as focusing on different county public health protocols to further nuance and understand the case trends we see.

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