The Effectiveness of Covid-19 Vaccines and Possible New Policies in the United States

Nathaniel Schmidt
Nicholas Hersperger
Sherry Yang
Yumeng Wang
University of Wisconsin-Madison
ECON 695: Data Analysis and Big Data
Professor Friedman
Dec 15, 2021

Introduction

Covid-19 is the single largest economic and social event in the last ten years. It represents a lot of changes to most people's daily routines and the way that they conduct business. Many people's lives were turned upside down during the beginning of the pandemic. Schools were closed, work hours were changed, and small businesses failed. The United States felt a large sense of hope on December 14, 2020, when the first emergency use vaccines became available to the public. This represented hope for a better future and a quick return to normal life. However, after analyzing the data, it is found that the vaccine alone is not sufficient in stopping the spread of Covid-19 in the United States. These findings suggest that even when vaccinations are increasing, the spread of covid is also increasing in the US. For these reasons, policy solutions that would assist vaccination in reducing the transmission would include digital herd immunity, mask mandates, capacity limits in restaurants, restricting public groups, and quarantines. This paper will explain the analysis of how this conclusion was reached and look into some of the costs and benefits associated with these extra precautions taken to decrease the transmission of Covid-19 in the United States.

Background

How does a disease like Covid-19 spread?

Zoonotic (animal to human) diseases like Covid-19 follow the SIR model (Cooper et al., 2020). This model is used to project and forecast how fast a disease will spread, given the population. This model looks at a few simple factors. The number of susceptible individuals, the number of infected people, the number of individuals who are non-spreading (deceased or immune), and the number of individuals that the virus spreads to from one infected person.

These are all factors in the spread of a virus. Many of these cannot be changed due to policy. The best approach would be to minimize the number of individuals that become infected from one infected person. This is the function that should be minimized.

$$F(x) = (\text{contacts per day}) \times (\text{probability of infection given contact}) \times (\text{days infectious})$$

Some of these factors can be addressed by policy. Quarantine measures, contact tracing technology, and capacity restrictions aim to reduce the number of contacts per day. At the same time, the probability of infection given contact is reduced by vaccinations, mask-wearing, and other precautions like plastic barriers in markets.

Why are vaccines not that effective?

In a controlled setting where a population actively seeks vaccination from a deadly virus, it can be seen that there is a negative correlation between the number of infected and the number of vaccines administered. It is also evident that the vaccines that do exist; work at the individual level. The problem with vaccines is that there is a lack of incentives and a plethora of vaccine misinformation that exist for subsets of the population that leads to the positive correlation at the US national level between higher vaccine rate and more new Covid-19 cases. This correlation also translates to the State level. However, it should be noted that six states do have a negative correlation between these variables: Connecticut (CT), Massachusetts (MA), Maryland (MD), New Jersey (NJ), New York (NY), and Rhode Island (RI). These states are all located on the east

coast and have historically had some of the most stringent pandemic precaution policies. This major difference can be associated with levels of precaution, and it would be ideal for the rest of the US to model their policies after these six states.

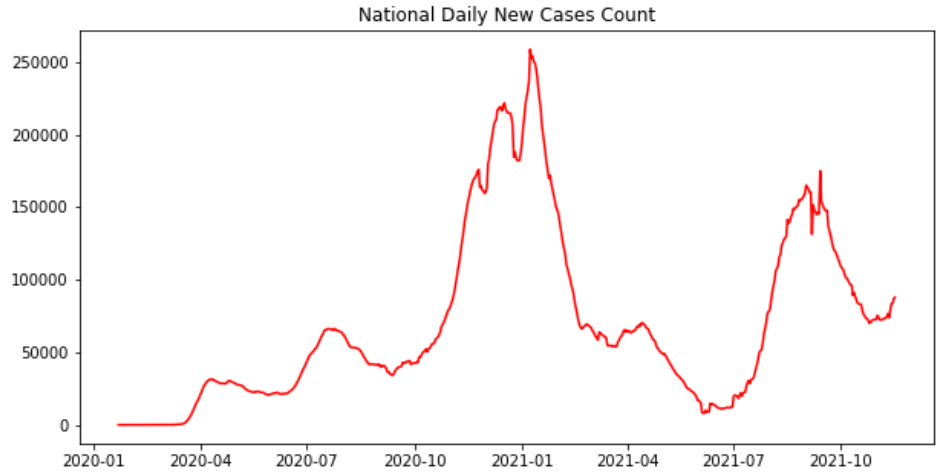
The reason for these policy differences can be explained by the federalist system in the United States, where government authority is separated at the Federal and state level. Each state addressed Covid-19 in its way. Some states like New York had very stringent policy measures, and others like Florida had very few states legislated policies addressing Covid-19. This could be due to large populations of certain religious groups or populations with certain political beliefs about the virus. Many people who are opposed to the vaccine claim that there are unknown side effects and that vaccination is a way for the government to control the population. This misinformation is a key factor in reducing the expected effectiveness of implemented policies and vaccines.

Data Collection

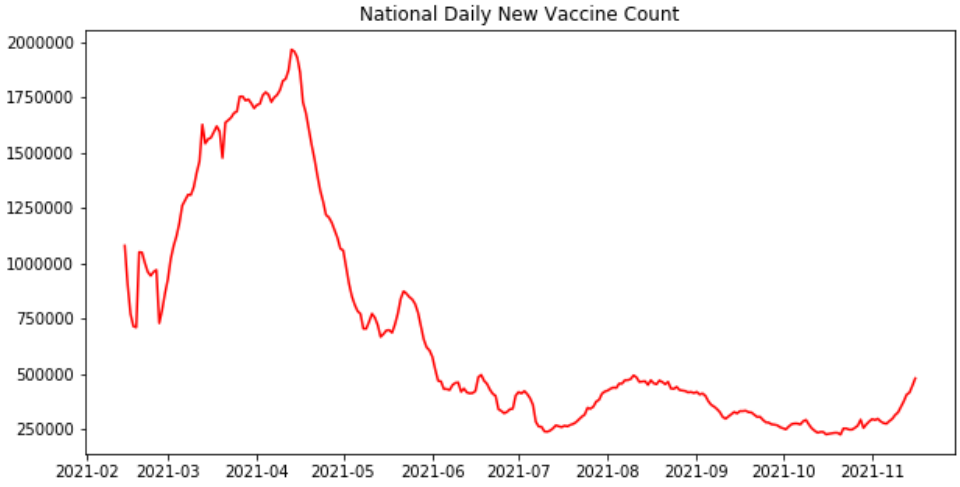
Covid-19 data on the national, state, and county levels in the United States from January 21st, 2020, to November 16th, 2021 was collected from Economic Tracker (2020). This is an aggregated data source provided by Raj Chetty. This data collects information from The World health organization, the CDC, Google data repositories, and other smaller data collectives.

Data Analysis

Graph 1 shows the epidemic has shown a clear "S" curve trend in the United States, with four peaks. Until early March 2020, the United States had only sporadic daily new cases in the single digits. On March 3th, the CDC announced the relaxation of Coronavirus testing standards and the decision to begin large-scale novel Coronavirus testing nationwide. On April 10th, 2020, 31,596 new cases were confirmed in a single day, reaching the first peak. After that, the number of daily new cases started falling slowly. However, due to the control measures of the epidemic deteriorating sharply from mid-June 2020, the number of daily new cases reached the second peak, 66,334 cases on July 19th, 2020. Since the second peak, the number slowly declined but maintained a daily average of tens of thousands of new cases. In October, the epidemic situation was once again out of control, and the number of new cases in a single day began to soar and was continuously above 50,000 new cases for half a year. On January 8th, 2021, the U.S. recorded the highest measurement of 258,888 new cases in a single day, which was the third peak. When Joe Biden took office in January 2021, he announced a goal of administering 100 million vaccine doses within hundred days, which was achieved on March 19, 2021. **Graph 2** shows on April 13rd, 2021, the number of daily new vaccine doses reached a peak of 1,966,127. The increasing number of vaccinations to some degree helped smoothen the new cases in the United States. However, as business reopened and mask policies relaxed in the summer along with the discovery of the even more infectious variant of Covid-19, the delta variant, the number of daily new cases showed a sign of increasing from July 2021. On September 13th, the number of daily new cases reached the fourth peak of 175,209. As some states recovered mask policies indoors, the new cases decreased slowly. Nevertheless, as of November 16th, 2021, the number of daily new cases was still above 50,000, and the new vaccination counts have slowed down to under 500,000 per day.



Graph 1

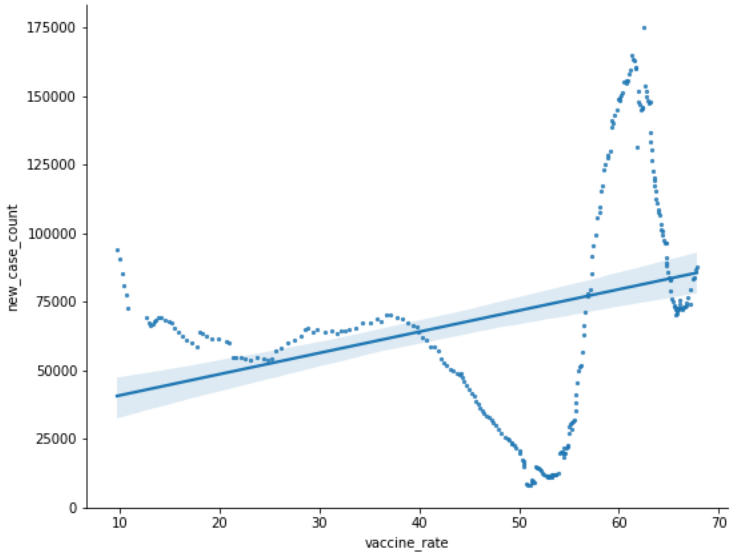


Graph 2

It is generally believed that as the vaccination rate increases, the number of daily new cases would decrease. Many experts previously expected to reach “herd immunity” --- when a sufficient proportion of people are immune to Covid-19, the spread of Covid-19 would be unlikely (Mayo Foundation for Medical Education and Research, 2021). The WHO's Chief Scientist Soumya Swaminathan projected a proportion of 60 to 70% to break the transmission of Covid-19 (WHO, 2020). The most recognized way to create immunity in the human body without infection is vaccination, where antibodies were produced against future infection. Once the number of daily new cases decreases, the economy will recover back to its pre-pandemic level. Therefore, the Biden administration made vaccination free for everyone and encouraged people to get vaccinated. This is because vaccination is seen as a public good that causes a positive externality in society. The private benefit from the vaccination is smaller than the total social benefit of getting vaccinated. Meaning it is likely that the rate of vaccination will be lower

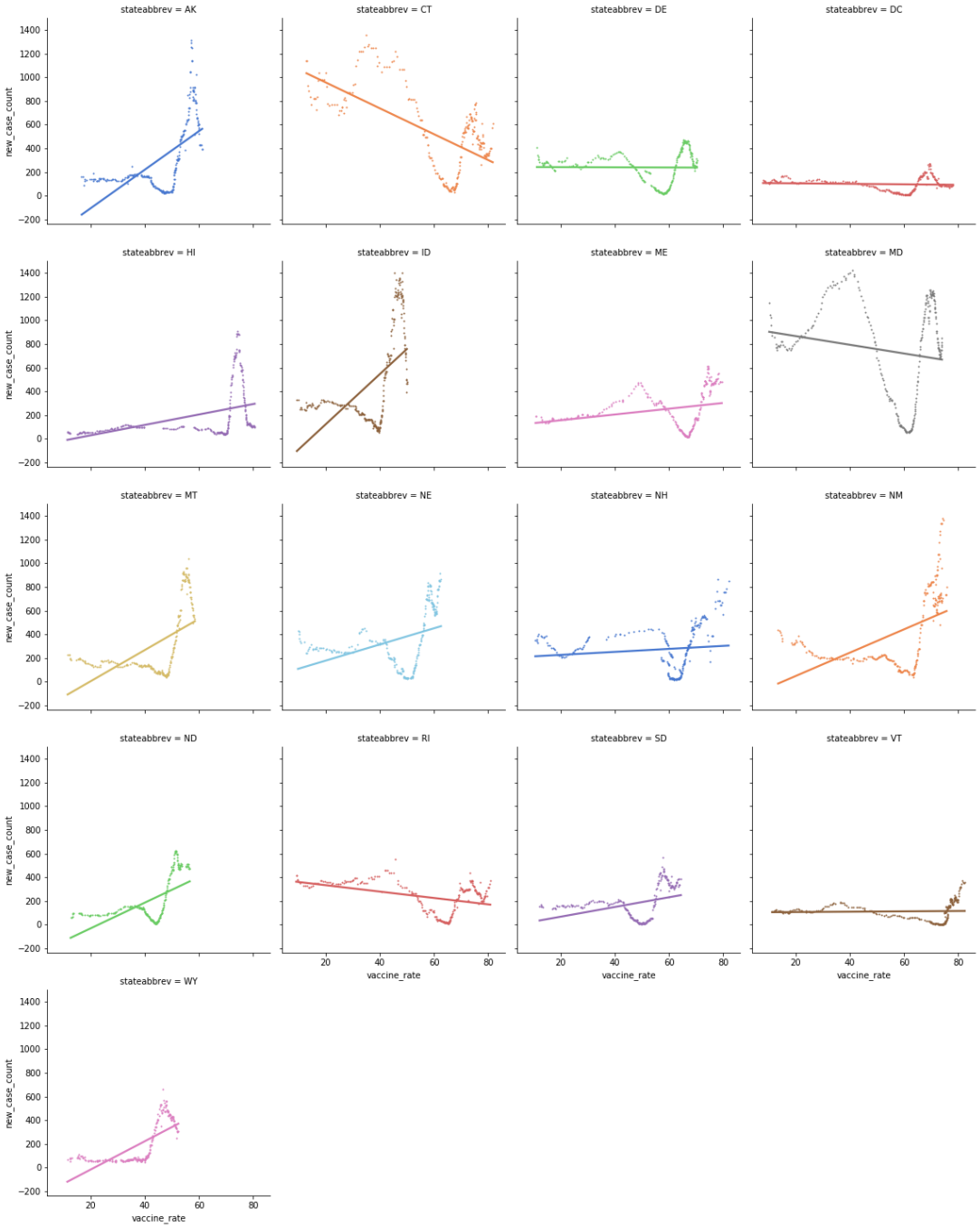
than the socially efficient amount. Therefore a lot of states and local communities incentivized vaccines with rewards or discounts for showing proof of vaccination.

However, through simple linear regression, **Graph 3** shows a positive correlation between the vaccination rate and the number of daily new cases in the United States. Although the actual number of new cases per day decreased to under 25,000 when the vaccination rate was around 50% percent, it jumped to above 150,000 when the vaccination rate was around 60%. Overall, the increasing vaccination rate did not stop the spread of the Covid-19 but instead was correlated with a higher number of Covid-19 new cases.

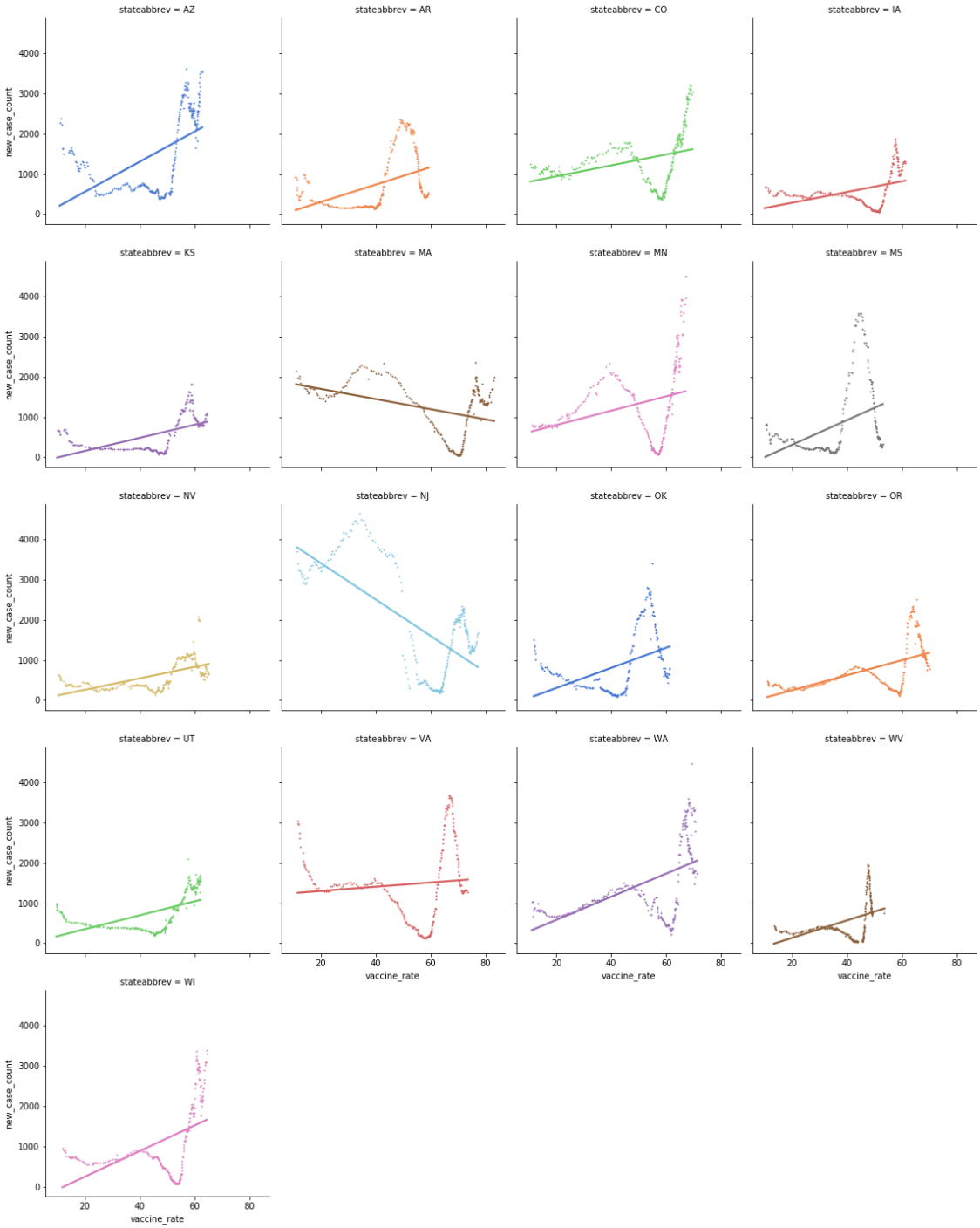


Graph 3

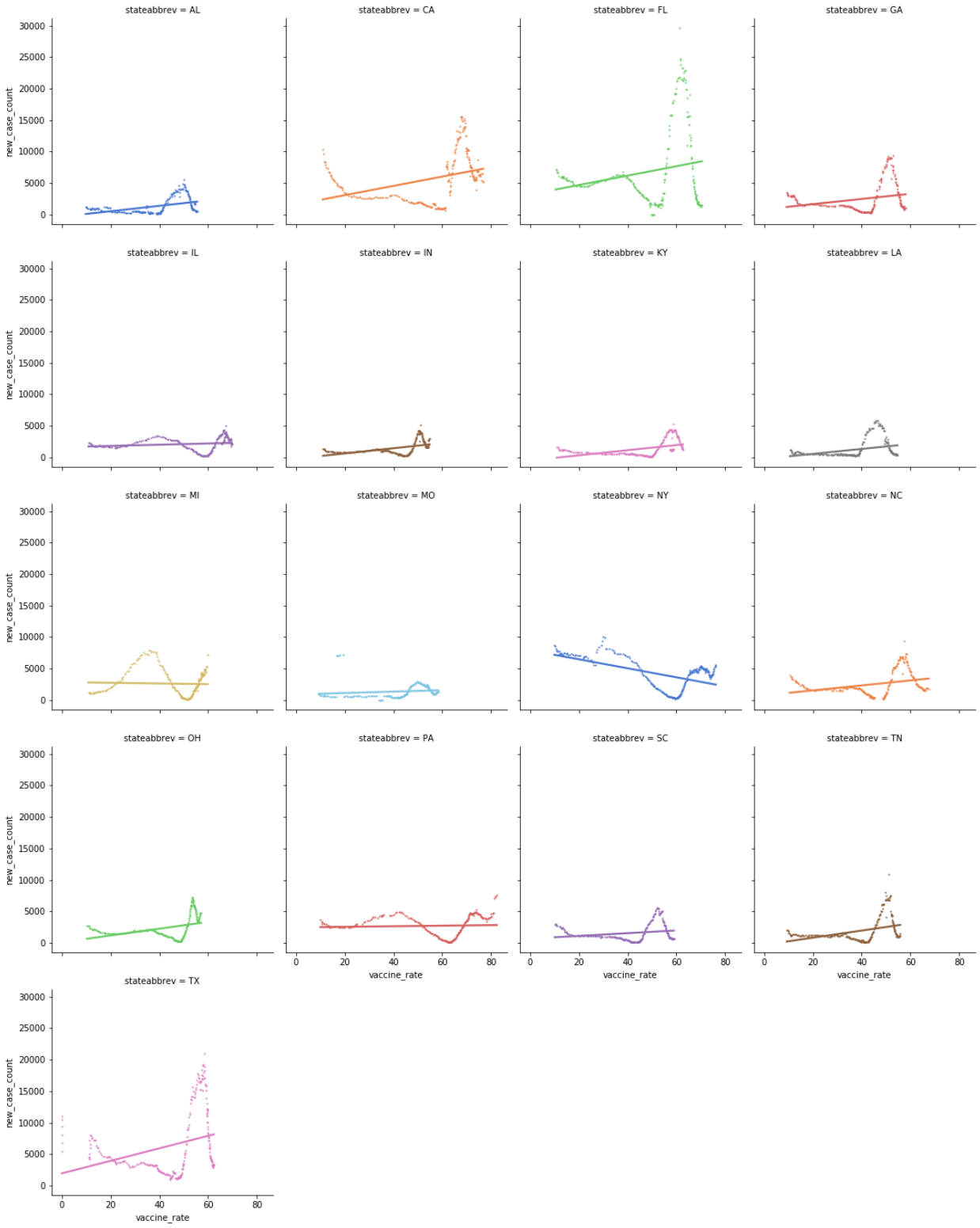
Graphs 4,5,6 show the correlation between the vaccination rate and the number of daily new cases in all states in the United States. The majority of states showed a positive correlation, which was consistent with the national-level correlation. Some states showed no obvious signs of correlation. Only CT, MA, MD, NJ, NY, and RI show a negative correlation between vaccination rate and the number of daily new cases.


stateabbrev = AK
stateabbrev = CT
stateabbrev = DE
stateabbrev = DC
stateabbrev = HI
stateabbrev = ID
stateabbrev = ME
stateabbrev = MD
stateabbrev = MT
stateabbrev = NE
stateabbrev = NH
stateabbrev = NM
stateabbrev = ND
stateabbrev = RI
stateabbrev = SD
stateabbrev = VT
stateabbrev = WY
new_case_count
vaccine_rate

Graph 4

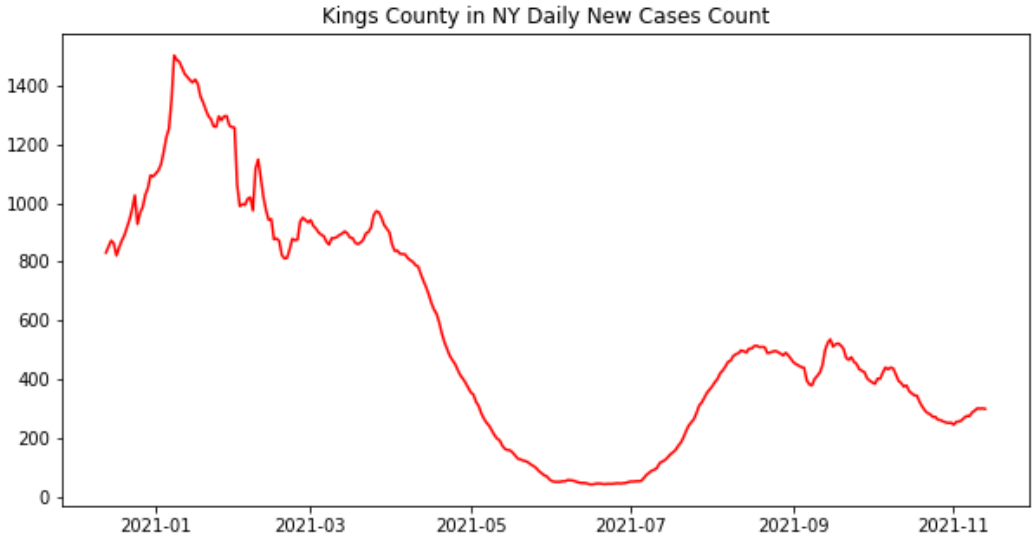

stateabbrev = AZ
stateabbrev = AR
stateabbrev = CO
stateabbrev = IA
stateabbrev = KS
stateabbrev = MA
stateabbrev = MN
stateabbrev = MS
stateabbrev = NV
stateabbrev = NJ
stateabbrev = OK
stateabbrev = OR
stateabbrev = UT
stateabbrev = VA
stateabbrev = WA
stateabbrev = WV
stateabbrev = WI
new_case_count
vaccine_rate
0
1000
2000
3000
4000
20
40
60
80

Graph 5


stateabbrev = AL
stateabbrev = CA
stateabbrev = FL
stateabbrev = GA
stateabbrev = IL
stateabbrev = IN
stateabbrev = KY
stateabbrev = LA
stateabbrev = MI
stateabbrev = MO
stateabbrev = NY
stateabbrev = NC
stateabbrev = OH
stateabbrev = PA
stateabbrev = SC
stateabbrev = TN
stateabbrev = TX
new_case_count
vaccine_rate
0
5000
10000
15000
20000
25000
30000
0
20
40
60
80

Graph 6

Vaccines could be a useful way to fight against Covid-19, as demonstrated in these six states. The vaccination rates in these six states are still not high enough to fully stop the spread of Covid-19. Diving into the county-level data in these 6 states, the actual number of new cases per day increased again in the progress of vaccination. For example, **Graph 7** showed the number of new cases per day in Kings county, the county with the highest population in NY, from December 13th, 2020, to November 13th, 2021, which roughly covers the vaccination timeline. From the graph, the number of new cases showed a trend of decreasing from February 2021 and decreased to the lowest level during June 2021. As of July 1st, 2021, the vaccination rate is 50.3%. However, the number of daily new cases increased again from July in Kings county and remained above 200 cases per day even though the vaccination rate has increased to 68.9% as of November 13th, 2021. This could be partially caused by "breakthrough infections," where fully vaccinated people are still tested positive for Covid-19 more than two weeks after their completed vaccine dose series (Wisconsin Department of Health Services, 2021). But still, scientific research still shows the effectiveness of vaccines against hospital admissions for fully vaccinated people after 6 months of vaccinations, even for new variants like Delta (Tartof et al., 2021). Therefore, vaccines are still important for mitigating adverse impacts that Covid-19 brings. However, more other policies are also necessary to prevent another large outbreak, which will be discussed in the later part.



Graph 7

Solutions and Recommendations

The recurrence of the pandemic in developed economies and its rapid spread in emerging and developing economies is a strong indication that Covid-19 will continue to coexist with humans in all parts of the world for a long time to come. Due to economic pressure, there is a low probability that the United States will resort to a strict general blockade or shut down the economy again. In this context, tracking the infected and their close contacts in isolation remains one of the most effective means of epidemic prevention and control in the present and for some time to come. This is what is called "Digital Herd Immunity."

Thanks to the spread of mobile networks and smartphones, governments and public health authorities in many countries and regions are using digital technology to promptly track infected people and their close contacts and control the timing and scope of infection. According to MIT Technology Review (Johnson, 2021), nearly 50 countries and territories have launched or plan to launch tracking technology. These applications use location-based technologies (such as GPS), Bluetooth, or a combination of the two and are divided into centralized and decentralized application models. Early adopters of tracking technology, including China and South Korea, have focused on location-based centralization. Bluetooth tracking, which greatly protects privacy and battery life on your phone, has received more attention since Singapore first launched the Trace Together Bluetooth tracking app in March 2020 (BBC News, 2020). After Google and Apple jointly developed the discovery notification technology, the decentralized Bluetooth technology has become the mainstream tracking technology in more countries (Apple, 2021).

East Asian countries such as China and the Republic of Korea, which represent strong government capabilities and digital technology, are fully implementing digital tracking technology in the epidemic prevention process (PET Research Group, 2020). China's "Health Code" tracking technology is one of the most critical factors for rapid containment. The South Korean government cooperates with three telecom companies and 22 credit card companies by using mobile phone positioning, the information of credit card records, and interviews with confirmed cases to track contacts. Through the application, residents are reminded to avoid areas prone to infection, and the tracking map update frequency reaches the level of minutes, shortening the tracking efficiency from one day for one patient to an average of 10 minutes (Zeng et al., 2020). The efficient application of tracking technology in East Asian countries has attracted the attention of the World Health Organization and other epidemic areas.

The recent resurgence of the epidemic in advanced economies has created some new opportunities for the adoption of tracking technology. There is a strong need for the United States to use the current short window to find the best tracking technologies and models to increase its capacity to respond to influenza and pandemic pressures in the fall and winter. Achieving this goal will require more decisive policy impetus and applied innovation. The United States, for example, has the highest level of Bluetooth tracking technology. However, adoption is shallow, mainly because federal governments were unable to intervene in the governance of each state. However, the situation has changed due to the efforts of each state. In late July, Google said it was working with 20 U.S. states and territories to launch a Covid-19 contact tracking app that would soon reach 45% of the U.S. population. COVIDWISE, the first application in the United States that uses Google/Apple exposure notification technology first launched by Virginia, has been downloaded by more than 2 million people. In conjunction with states advancing their tracking apps, the American Association of Public Health Laboratories began building a national server to help apps run across state lines.

While Bluetooth tracking is an essential tool in preventing the outbreak of a deadly disease, a vaccine must be introduced and taken by the population for a pandemic to truly end. One prominent issue that became apparent was the lack of willingness to receive the vaccine from some populations. While the vaccine was tested thoroughly before its release and deemed safe for the public, many were not entirely convinced because of the vaccine's rapid development. For example, the US began delivering its first doses on December 14, 2020, to people 16 and older. However, we do not see a major spike in vaccination rates (Graph 2) until late March or early April of 2021, 4-5 months late. That age group accounts for roughly 80% of the US population, and vaccinating that age group would help create herd immunity enormously (Infoplease, n.d.). By using incentives to encourage people to take the vaccine sooner, we can speed up the process of creating herd immunity.

There are many studies already showing this to be effective. The report from Campos-Mercade et al. (2021) explores how monetary incentives increase Covid-19 vaccinations. When vaccines were first introduced in Sweden, they took several groups and analyzed how different encouragement methods affected vaccination rates. It is important to note that *every* group outside the no-reminders groups received two reminders after volunteering for the study, even the control. One group only received the two reminders and analyzed their vaccination rates as a control group. From there, they gave six groups different encouragement techniques: monetary incentives, nudge 1 - a moral call to action using social impact, nudge 2 - argument, nudge 3 - education on the vaccine, nudge 4 - the prior three all employed in one group, and a no reminders group. The monetary incentive given to the Swedish participants was SEK 200 (US$24).

Their findings support the conclusion that monetary incentive has a positive influence on the vaccination rate. They found that the base rate in the control group for vaccination rate was 71.6%. Given monetary incentive, that rate increased by almost 4% with a p-value of 0.009, which supports the conclusion that monetary incentive influences a person’s decision to get vaccinated. Among the nudge groups, none of them increased the vaccination rate from the baseline. The same can be said for the no reminders group. Out of the methods chosen, only monetary incentive was statistically significant in regards to increasing the vaccination rate from the baseline, suggesting it may be a useful tool in encouraging vaccination (Campos-Mercade et al., 2021).

A blaring problem with this solution is the cost. Even just looking at people 18 and older, the cost is enormous. Multiplying the predicted vaccination rate given incentive by 258.3 million (the portion of the population 18 and over), the model suggests 196.3 million people 18 and over would get the vaccine due to the incentive. Given that the incentive used in the model was equivalent to $24, giving all 196.3 million people $24 would cost about 4.7 billion dollars. This also assumes Americans think similarly to the Swedish, and $24 would be enough to convince an American citizen to get the vaccine. However, a solution to this could be reserving incentive-based programs to areas with particularly low vaccination rates.

Another concern is its ethicality. A particular area of concern is coercion. Making the incentive too large to turn down essentially forces people economically into getting the vaccine, which is unethical. It is important to ensure the reward is small enough to be easily turned down. The idea is to find a price level that encourages people already desiring the vaccine to get it sooner than they would without incentive (Erfani et al., n.d.).

Conclusion

The unexpected positive relationship between new Covid-19 cases and vaccination rate requires new policies to be implemented for society to handle efficiently and eradicate not only Covid-19, but any deadly disease mankind encounters. The policies currently in use have, for the most part, failed us. The lockdown was meant to stop the spread of Covid-19 by minimizing contact between people. However, asking people to remain in isolation with little outside contact for an undetermined amount of time was simply too much to ask of society. While the premise is good, it falls apart when a majority of the population does not understand the risk present in their community. In addition to this, the lockdown caused many small businesses to fail and left the economy in an extremely uncertain state. This is why Bluetooth tracking and notification is particularly useful compared to lockdowns. It allows society to remain open, while those who pose a disease risk to society can quickly remove themselves to contain the spread. This buys valuable time for a vaccine to be developed, which is the second step in defeating disease. However, if people do not receive the vaccine fast enough, it allows the virus time to mutate into a strain that is resistant to the current vaccine, restarting the cycle. The use of incentives to encourage people to receive the vaccine can help speed this process up and allow life to return to normal quicker by reaching herd immunity quicker. It is imperative that we take what has been learned from this past year and apply the knowledge gained from it to implement policies even more efficient at wiping out the disease, rather than employing the same policies that have already failed.

References

Apple. (2021, December 2). Apple and Google partner on COVID-19 contact tracing technology. Apple Newsroom. https://www.apple.com/newsroom/2020/04/apple-and-google-partner-on-covid-19-contact-tracing-technology/

BBC News. (2020, June 29). *Singapore hands out coronavirus tracing devices*. https://www.bbc.com/news/business-53216450

Campos-Mercade, P., Meier, A., Schneider, F., Meier, S., Pope, D., & Wengström, E. (2021, October 7). Monetary incentives increase covid-19 vaccinations. *Science.* Retrieved from https://www.science.org/doi/10.1126/science.abm0475

Cooper, I., Mondal, A., & Antonopoulos, C. G. (2020). A SIR model assumption for the spread of COVID-19 in different communities. *Chaos, solitons, and fractals*, *139*, 110057. https://doi.org/10.1016/j.chaos.2020.110057

Erfani, P., & Bourdeaux, M. (n.d.). Can vaccine incentive reward programs increase COVID-19. Retrieved December 15, 2021, from https://ghsm.hms.harvard.edu/sites/g/files/mcu871/files/assets/Programs/PublicPolicy/Vaccine%20Incentives_PGPPSC.pdf

Infoplease. (n.d.). *United States Demographic Statistics*. Retrieved from https://www.infoplease.com/us/census/demographic-statistics

Johnson, B. (2021, October 18). *The Covid Tracing Tracker: What's happening in coronavirus apps around the world*. MIT Technology Review. https://www.technologyreview.com/2020/12/16/1014878/covid-tracing-tracker/

Mayo Foundation for Medical Education and Research. (2021, August 28). Herd immunity and covid-19 (coronavirus): What you need to know. *Mayo Clinic.* Retrieved from https://www.mayoclinic.org/diseases-conditions/coronavirus/in-depth/herd-immunity-and-coronavirus/art-20486808.

PET Research Group. (2020, August 19). *the US is no longer absent in tracking and controlling the epidemic with big data as the global epidemic continues to spread*. Luohan Academy. https://www.luohanacademy.com/cn/insights/be9c93e8098d6443

Tartof, S. Y., Slezak, J. M., Fischer, H., Hong, V., Ackerson, B. K., Ranasinghe, O. N., Frankland, T. B., Ogun, O. A., Zamparo, J. M., Gray, S., Valluri, S. R., Pan, K., Angulo, F. J., Jodar, L., & McLaughlin, J. M. (2021, October 4). Effectiveness of mRNA BNT162B2 COVID-19 vaccine up to 6 months in a large integrated health system in the USA: A retrospective cohort study. *The Lancet, 398*(10309), 1407-1416. https://doi.org/10.1016/S0140-6736(21)02183-8.

The Economic Tracker. (2020). *Opportunity Insights.* https://tracktherecovery.org/

Wisconsin Department of Health Services. (2021, October 20). COVID-19: Illness After Vaccination. https://www.dhs.wisconsin.gov/covid-19/vaccine-status.htm

World Health Organization. (2020, August 28). Episode #1 - herd immunity. Retrieved December 15, 2021, from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/media-resources/science-in-5/episode-1

Zeng, K., Bernardo, S. N., & Havins, W. E. (2020). The Use of Digital Tools to Mitigate the COVID-19 Pandemic: Comparative Retrospective Study of Six Countries. *JMIR Public Health and Surveillance*, *6*(4), e24598. https://doi.org/10.2196/24598