

## *Original Paper*

# An Analysis of the Determinants of Vaccine Hesitancy. Can the World Learn from the US Experience?

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### **Abstract**

*While efforts to vaccinate the general public have been trending in a positive direction, Vaccine Hesitancy is a global issue. Many infectious disease physicians, epidemiologists, and Public Health Authorities fear that Vaccine Hesitancy will indefinitely prolong the pandemic, as the Delta Variant currently ravages through the unvaccinated population. In an attempt to understand this global phenomenon, we looked at the United States' vaccine rollout. In particular, we examined the determinants of vaccine hesitancy in the USA. Our empirical model reveals that Vaccine Hesitancy is significantly impacted by factors such as Median Income, Political Affiliation, Percentage of population that is White/Caucasian, Total Cases, Individuals without Health Insurance, and Education level. We use data from all 50 states in the US. Policy makers in other countries can greatly benefit from the findings of our empirical results. Some incentive structures should be introduced as quickly as possible to achieve a high vaccination rate in the country.*

*Our goal is to use the United State's experience of Vaccine Hesitancy as a baseline of sorts for the greater global community to understand, and reduce hesitancy in their vaccine rollouts.*

### **Keywords**

*hesitancy, median income, political affiliation, total cases, without health insurance, percentage white, delta variant*

## 1. Introduction

Let us imagine that it is currently June 13th, 2023. Karen Smith, a 35 years old white woman stumbles into an emergency room, suffering from a 101 degree Fahrenheit fever. She reports major shortness of breath, loss of taste or smell. She complains of a sore, and irritable throat, congestion, runny nose and she has been nauseated with occasional vomiting for the past few days. She tells her emergency doctor that she had COVID-19 in the month of August 10th, 2021. She is a Republican, high school dropout, residing in a rural area outside of Martins Ferry, Ohio. Martins Ferry has a population of just over 6,000, where she works at a local gas station at minimum wage. Karen had refused to get vaccinated, and ended up contracting the corona virus months after most people got their shots. Why did she refuse? Could it be because of politics? Could it be her stance on government control? Was it a post she saw on social media she was hooked on? She cannot really pinpoint one reason why she chose to not get vaccinated but her lungs which have patchy diffuse interstitial pneumonia are paying the price for her decision to go without vaccination. By the end of the day on June 14th, 2023 she is hooked up to a ventilator in the ICU. What could Karen have done differently to prevent this? How did we fail to provide her with the needed incentives, information and education to get the vaccination? Is vaccination really safe? Would she have prevented her from being in this situation had she been informed about all the facts about vaccines, its efficacy and potential side effects? Who will pay for Karen's decisions? Tax payers will spend billions of dollars on behalf of the vaccine refusers. It could be even more over the next few decades, with all the complications they could develop. How did we arrive at this point? What went so horribly wrong for us to be in this situation? The purpose of this paper is to take a deep, deep dive into the reasoning behind vaccine hesitancy, and inform the true opportunity cost of hesitancy to the average person, as well as relaying the vaccine's technical history.

Specifically, we identified the factors that are important in determining vaccine hesitancy. We then offer policy implications, and recommendations. The paper is organized in the following manner. Section II discusses the historical development of the COVID-19 Pandemic. Section III examines the availability of vaccines throughout the world, their inventors and producers, and countries where these are authorized for use. Next, in Section IV, we discuss the literature review of the issues surrounding vaccine hesitancy. Section V examines the results of our research and empirical model. Section VI reveals our conclusion and potential policy recommendations.

### *1.1 Historical Development of COVID-19*

A novel Coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) called COVID-19 by WHO denoting the year of discovery was discovered in Wuhan, China in late 2019. It rapidly spread across the world and appeared in the United States officially in January 2020, but it is believed by infectious disease physicians to have probably been here since November 2019. This virus first arrived from Wuhan China to California, USA in December of 2019 and the same virus also arrived at NY city from Europe in December of 2019. (Zhu, N. et al., 2021)

Covid-19 had rapidly spread all across the world before the medical professionals could realize that it

was a novel virus. The mechanism of spread was through global travel for both business and pleasure among people who were already infected before developing symptoms and from asymptomatic infections. It is spread through both aerosols from breathing and talking, and respiratory droplets from loud talking, laughing, coughing, and sneezing. (Greenhalgh, 2021) The lack of physical distancing and mask wearing furthered the rate of spread. (Rabi et al., 2020)

Unfortunately, along with the spread of the virus, the world population was divided into three different groups of people. First group believes that in order to combat this global pandemic, we must develop the vaccine as quickly as possible and simply vaccinate as many people in the world as fast as possible. Second group of people were not able to have access to vaccines due to lack of availability and monetary resources. The third group of population simply do not accept the vaccination as the solution to the pandemic problems. We focus on the third group of people and attempt to understand the reasons and factors behind their hesitancy. Specifically, the purpose of this paper is to identify the factors that are important in determining the extent of vaccine hesitancy that exists in the world and offer some sound empirical evidence by evaluating data from the USA from 50 states. We further explore and expose the myth behind some misinformation surrounding different vaccines available today.

### Share of people vaccinated against COVID-19, Aug 8, 2021



**Figure 1. Share of People Vaccinated Against COVID-19. Aug 8, 2021**

Figure 1 reveals the share of people vaccinated against COVID-19 as of August 8th 2021. As you can see from the table, the US ranks 6th on the list of countries with the highest vaccination rate. In the next section, we focus our attention on the types of vaccines available currently at various locations and their production.

### 1.2 Vaccine Development and Availability

In February 2020, The Chinese Center for Disease Control and Prevention released the full generic sequence of the Covid-19 virus to the Global Initiative Sharing All Influenza Data (GISAID) and to the WHO (Zhu et al., 2020). On May 15, 2020, the President of the United States, Donald Trump announced Operation Warp Speed, a team that included the Department of Defense (DOD) and the Department of Health and Human services (HHS) as a partnership for the U.S. vaccine effort. (GAO 2021). Table 1 summarizes the list of current vaccines available in the world, the sources of production information and countries where these vaccines are distributed.

**Table 1. COVID-19 Vaccine Supply Globally**

Name	Type	Inventing Notes institution(s)
Pfizer ((Cominarty or tozingmeron or BNT162b2)	mRNA	<p>Pfizer and more expensive than other types of vaccines and BioNTech extreme cold storage requirements make world wide distribution to poorer countries without extensive cold storage infrastructure impossible Pfizer in New York , BioNTech based in Germany 112 countries North America, northern South America, Europe, Scandinavia, Egyptian - Arabic areas, Australia, Tibet</p> <p>FDA authorization for ages 16 and above granted on August 23, 2021 and E.U.A. in the U.S.A. for children age 12-15 years and for a third dose for the immunocompromised (People receiving cancer)</p> <p>treatment, organ transplant recipients on immunosuppressant therapy, received a stem cell transplant within the last 2 years or are taking medicine to suppress the immune System, moderate or severe primary immunodeficiency such as DiGeorge syndrome or Wiskott-Aldrich Syndrome, advanced or untreated HIV infection, active treatment with high dose corticosteroids or other immunosuppressant drugs)</p> <p>*</p> <p>**</p> <p>***</p> <p>****</p> <p>*****</p>
Moderna (mRNA – 1273 or Spikevax)	mRNA	<p>Moderna Boston, More expensive than other types of vaccines and MA extensive cold storage requirements make world wide distribution to poorer countries without extensive cold storage infrastructure impossible 65 countries North</p>

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		America (Canada and U.S.), southern South America, Europe, Scandinavia. * ** *** ****
Johnson and Johnson-Jansen	Ad26.COVS.2.S	J&J U.S.A. with 38 countries headquarters in USA, Canada, Chile, Mexico, Brazil, Europe Union, Titusville, NJ, Australia, South Korea, a few in Africa Baltimore, MD E.U.A. in the U.S.A. developed at Beth * Israel Deaconess ** Medical Center in Boston, Janssen Belgium
AstraZeneca (AZD1222 or Vaxzeria)	Chimpanzee Adenovirus	University of Poor and middle income countries at cost Oxford (Oxford, 181 countries; England) and North America (excluding USA), South America, Astra-Zeneca-Briti European Union, Scandinavia, Arabic areas, much of sh Swedish Africa, Arabic area, mid-East, India, Australia, Company Argentina. In india it is * marketed and ** produced as Covishied
Gamaleya Sputnik V or Gam-Covid-Vac	Adenovirus 26 as the prime Adenovirus 5 as the Booster	Russia Gamaleya 50 countries Research Institute Russia, old Soviet bloc countries, Some Arabic areas, northern Africa, India, southeastern South America. * **
Convidecia	Ad5-nCoV	Can SinoBIO 10 countries China China, E.U.A., Argentina, Chile, Ecuador, Hungary, 1 Malaysia, Mexico, Moldova and Pakistan * **
Sinophram Sinovac Bharat Biotech	BBIBP-CorVB Whole virus vaccine with adjuvant Corona-Vac Whole virus	Beijing Institute of 64 Countries Biological Products China, Eastern South America, south east Asia, Iran, in China Pakistan, Morocco, Hungary, UAE, several countries in Africa * *** Biotech 38 countries China China, northern Africa, a few old Soviet bloc countries, Mexico, northeastern South America, parts of South Asia *

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	vaccine with adjuvant	*** Bharat Biotech 13 countries India India, Iran, Botswana, Guatemala, Guyana, Covaxin or Mauritius, Mexico, Nepal, Nicaragua, Paraguay, Philippines, Venezuela and BBv152 A,B,C Zimbabwe.
	Whole virus	*
	vaccine with adjuvant	** ***
EpicVacCorona	Adenovirus 5	Vector Institute 2 countries Russia Russia, Turkmenistan
Aurora-CoV	Peptide Viral proteins	*
Soberana 2	Pieces of the spike proteins	Finally Vaccine 2 countries Cuba (Soberana) and Iran (Pasteur). Institute in Cuba *
	Fused to a tetanus vaccine	***
	Also uses Adjuvant	
ZF2001	A section of a spike protein combined with Adjuvant	The Biologic 2 countries Company Institute China and Uzbekistan of Medical Biology * China Academy of *** Medical Science
Abdala	Pieces of the spike proteins	Centro De 2 countries Ingeniería Cuba Cuba and Venezuela *

\* (Zimmer, Carl et al. 2021);

\*\* (Mendonca, S. et al. 2021);

\*\*\* (Pulendran, B. et al. 2021);

\*\*\*\* (FDA News Release 2021);

\*\*\*\*\* (CDC Covid-19, Immunocompromised, 2021).

Only Pfizer-BioNTech have full FAD approval, and two have FDA Emergency Use Authorization (EUA) in the United States. Two manufacturers have applied for full FDA approval. The Adenovirus vectors used an inactivated adenovirus as listed in the table. An adjuvant is a substance added to a virus to enhance the immune response increasing the durability. (Pulendran et al., 2021)

Covid-19 is far more rapidly spread than the original SARS and cases across the world rapidly increased filling up hospitals with high rates of deaths among people age 65 years and older, Blacks, Native

Americans, and among those with other conditions including obesity, diabetes mellitus, advanced kidney disease, autoimmune disease on immunosuppressant therapy which included younger age groups. (Miller et al., 2021) The cumulative case load across the world is **202,608,306 confirmed cases** and the cumulative death rate is **4,293,591 deaths**, reported to WHO (<https://covid19.who.int/>). In the United States the cumulative case load is **35,501,444 confirmed cases**, and the cumulative death rate is **611,504 deaths**, reported to WHO (<https://covid19.who.int/region/amro/country/us/>).

This pandemic has been exacerbated by vaccine hesitancy which depends on a number of variables. Vaccine hesitancy can be divided into several categories; those who are hesitant because they are waiting for more information about vaccine safety and FDA approval, those who mistrust the source of information and those who are unsure about how serious the infection is. These are potentially persuadable if informed by leaders in the community who they know and trust and community outreach among community leaders with portable vaccine vans has led to an increase in vaccination rate in this population.

Vaccine hesitancy is high among conservatives, evangelical Christians, rural population, population with no college education, and those who do not perceive any significant risk for themselves nor for their family. This group is susceptible to the widespread misinformation about both Covid-19 and about the side effects of the vaccines. Many subscribe to conspiracy theories about the vaccine. The last group who cannot be convinced to receive a vaccine are the “Anti-vaxxers” who refuse all vaccines and believe them to be unsafe.

The Delta variant has had a significant impact on those who were both firm vaccine deniers as well as those who didn't believe Covid-19 caused serious illness. This has resulted in many secretly getting vaccinated as loved ones including their children die from the much more contagious Delta (B.1.617.2) variant which originated in India on October 5, 2020. It was identified in the U.K. on February 22, 2021. (Baisheng 2021) The Delta variant was first identified in the U.S. on February 23, 2021. In April 2021, it accounted for 0.01% and has doubled in numbers every 2 weeks and is currently causing 82.2% of infections. As of July 28, 2021, the Delta variant accounted for 92% of Covid-19 infections in the U.S. according to coronavirus.org, a research firm in Bern, Switzerland. (Szabo, 2021). Rachel Maddow, cable news host from MSNBC, interviewed Dr. Anthony Fauci, director of National Institute of allergy and infectious disease (NAID), according to Dr. Fauci, as of August 9, 2021, Delta variant now accounts for 93% of all cases of Covid 19 infections in the USA. According to Dr. Fauci, full authorization of vaccines by the FDA will increase mandates for getting vaccination in the workplace and in schools. He also mentioned that those who are vaccine hesitant because it only has emergency authorization use would likely accept the vaccine once it has full FDA approval.

Most elderly people have been vaccinated so the Delta now accounts for the majority of new Covid-19 infections and is infecting younger patients in their 20s, 30s, and 40s many of which are filling up ICUs. (Yong, 2021). They become very ill for more quickly (within 4 days) and rapidly deteriorate requiring oxygen and intubation. This is because the viral load of this variant is 1000-1260 times higher than the

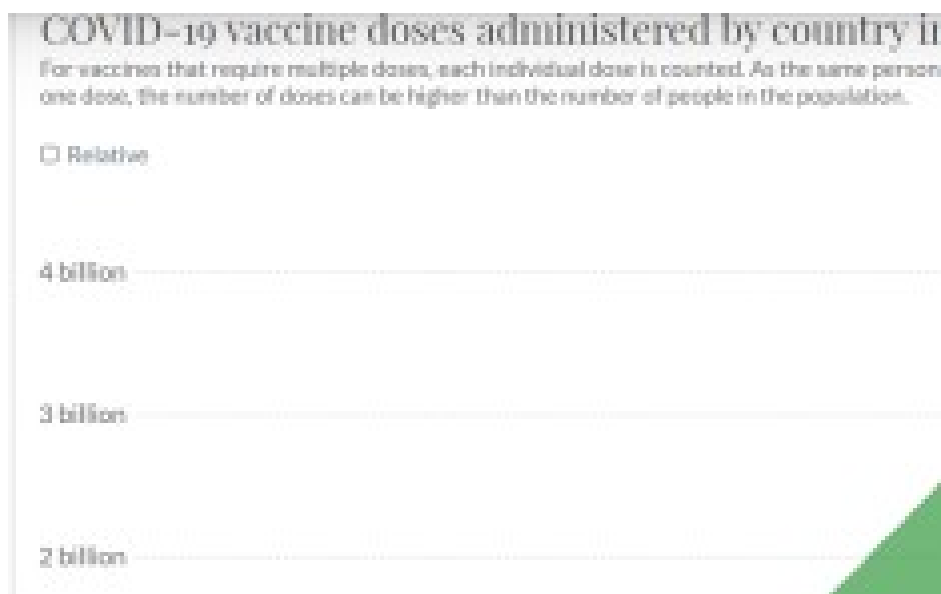
original Covid-19 virus. (Jing et al., 2021) This very high nasal and oral viral load is leading to easier transmission through aerosols from breathing or close physical proximity. Mild to asymptomatic breakthrough infections are occurring among the vaccinated whose nasal and oral viral load is the same as among the infected unvaccinated making the breakthrough infections as contagious. This is why the recommendation to wear masks indoors and among crowds by leading infectious disease physicians, epidemiologists, and Public Health officials has resumed. Children are accounting for 20% of new Delta Covid 19 infections and a substantial number require hospitalization and 1/3 of the hospitalized require ICU admission. (Yong, 2021) New data reported by the CDC on August 24, 2021 from the Los Angeles County Department of Public Health (LACDPH) described age-adjusted Delta variant infections and hospitalizations from May 1 through July 25, 2021 by vaccination status. They found vaccine effectiveness declined from 91% prior to the Delta variant to 66% after the predominance of the Delta variant. The SARS-CoV-2 infection rate among the unvaccinated was 4.9 times and the hospitalization rate was 29.2 times the rates among fully vaccinated people. The decline in vaccine effectiveness may be due to decline in antibodies after a longer period of time since completing the 2 dose vaccine series. The sustained 66% effectiveness in preventing infection and significant lower hospitalization rates shows the continued benefit of the vaccine. (Griffin et al., MMWR from CDC, 2021). The current recommendation is to receive a booster shot 8 months after the second dose. USA Today interviewed Dr. Eric Topol, a professor of molecular medicine and vice president for research at the Scripps Research Institute notes that there is a continued attrition in people who are fully vaccinated. He mentions that the benefit of vaccination remains because those with breakthrough infections have very low hospitalization rates. Dr. Topol thinks that 8 months is too long to wait for a booster because research has shown immunity begins to decline at the five to sixth month mark leaving vaccinated people more vulnerable to infection. This leaves two to three months without adequate protection, He also thinks that the waning immunity over has much to do with the Delta variant's contagious nature. He also notes that relaxation of mitigation actions including wearing the proper type of mask indoors or in a crowd, physical distancing, may be contributing, but are harder to measure (CSantucci, Jeanine, 2021).

The unchecked spread in multiple states and counties with very low vaccination rates leads to increased replication of the delta variant which creates more opportunities to create more potentially deleterious mutations which are proving to escape vaccine induced antibodies leading to more breakthrough infections in the fully vaccinated individuals. The mRNA vaccines remain the most effective against the delta variants. (Liu et al., 2021). Other factors which will lead to more infections are laws in Florida and Texas against mask and vaccine mandates in Florida and Texas. A lawsuit has been filed by the Missouri attorney general to stop mask mandates in schools. (Gonzales, 2021) These efforts to pass laws against mitigation efforts will lead to more infections and prevent the U.S. from ever achieving herd immunity. By comparison, during the 1918 flu pandemic 50 million people died worldwide and 675,000 in the U.S. Mortality was high in people younger than 5 years old, 20-40 years old, and 65 years and older. The high mortality in healthy people, including those in the 20 to 40 year old age group, was a unique feature of



this pandemic. (Yong, 2021)

Mask wearing was an issue in the 1918 flu pandemic, but there were many local newspapers which listed the people who were ill, which allowed people in communities to see that folks around them were dying. This information made the pandemic more local. Today, there are fewer hometown newspapers and HIPAA restrictions on sharing patient information, and this restricts this knowledge to healthcare workers. (Yong, 2021)



**Figure 2. COVID-19 Vaccine Doses Administered by Country Income Group**

Figure 2 displays that the number of Covid-19 vaccines administered varies by country income group indicating high income countries have larger numbers of vaccines being administered.

## 2. Method

### 2.1 Literature Review

The observational study by the Kaiser Family Foundation (KFF) examines the key characteristics of the adult population in the United States who are unvaccinated (KFF study, June 2021). The percentage of unvaccinated adults in the US is continuously shrinking, but the CDC, and epidemiologists warn that the still large contingent of unvaccinated people is alarming, and a major roadblock in returning to pre-COVID measures. The KFF report details that the average unvaccinated person is younger (typically 18-29), more likely to lean Republican, more likely to have experienced lower levels of education, and has a lower income than that of the average vaccinated person. The study also notes that urban Black and Hispanic people are also less likely to receive the vaccine. The rates of those who are vaccinated, compared to those who are not, is highly partisan, reflecting the political climate experienced about, and around the COVID-19 pandemic. Almost half (49%), of those who identify as Republican, or

Right-Leaning, reported their intentions to not receive the vaccine.

An article from the University of Pennsylvania observes the impact of various Vaccine Incentive Programs operated by different State, and Local governments, as well as private organizations. Iwan Barankay notes that all of these incentive programs sound great, such as Ohio's Vax-a-Million, and New York City's Shake Shack Partnership, but that the real issue of vaccine hesitancy will not be solved with gimmicks. Barankay claims "To raise vaccination rates, we have to engage with the socioeconomic barriers that people are facing." (Barankay, Wharton Budget Model). The article explains how some people will get the vaccine no matter what, and others similarly, will not get it no matter what. Those in the middle are not likely to be moved by monetary incentives, or other prizes. Instead, the focus should be on those who want to receive the vaccine, but are blocked due to socioeconomic factors, and barriers (Barankay, 2021). The initial effect of these incentive programs was a large increase in the number receiving vaccines during the first week, and the numbers rapidly tapered over the next 4 weeks. The longitudinal study, based on surveys of US residents from March 16- August 16, 2020, revealed the attitudes and perceptions of the (then potential) Covid vaccines. Throughout the pandemic, the belief was that the public would overwhelmingly welcome vaccinations, similar to Influenza, and other vaccinations. However, this has not held up. This rise in Vaccine Hesitancy was driven by individuals who identify as Republican, who negatively showed a trend in intentions and attitude. Individuals who identified as Democrats were much more likely to exhibit stable attitudes, and intentions of receiving the vaccine. Those who were less likely to receive the vaccine attributed their response to risk perception, as many saw the vaccine as untested, as others did not view the virus' impact as serious as had been reported (Fridman, 2021). This spread has widened as vaccine misinformation has proliferated both on cable news, social media, and conspiracy theories.

A study by the International Monetary Fund examines the phenomenon of Vaccine Hesitancy, and its impact on the prolongment of the Pandemic, and associated health restrictions. Using individual-level surveys developed by YouGov and Imperial College London, this study aimed to reveal the determinants of Vaccine Hesitancy on the global, and national levels through their empirical findings. The first major factors relating to vaccine hesitancy were examined through a demographic lens, as age, gender, race, and socioeconomic status all contributed to an individual's willingness, or lack thereof, to receive the vaccination. Unsurprisingly, political leanings, as well as perceptions of the virus, also were shown to be heavy determinants of vaccine hesitancy. Government and scientific trust, misinformation, and fear of side effects all accumulated a large degree of hesitancy in this area of focus. Using this accumulated data, the study also revealed through its SIR model, that the present, and future rates of vaccine hesitancy can severely impact the future trajectory of COVID-19 case counts, and subsequently, restrictions to mitigate the spread. This model forecasted, with the current rates of vaccine refusal, and hesitancy, that the count of cases, as well as deaths, and hospitalizations, will rise in the coming fall/winter months (Khan, 2021). The report from the Journal of Community Health uncovers the breakdown of those hesitant to receive the COVID-19 vaccination. Those who are less likely to receive the shot are typically young,

conservative leaning, with little education, and less disposable income. However, the greatest denominator actually is not entirely observable through a demographic breakdown. This article argues that perception is the greatest indicator of vaccination, or not. The perceived threat of COVID-19, and its symptoms are not viewed equally. Some do not feel that it is as serious as advertised, and that the Vaccine's unproven long-term effects are more of a concern. Through a multi-item valid, and reliable questionnaire published by mTurk, this study revealed that lower-income, less educated individuals were far more likely to not receive the vaccine due to fear of side effects, or perceptions of the virus not being that serious. Vaccine Hesitancy was also higher in African-Americans, and Hispanic communities, as well as those in rural areas, especially in the Northeastern United States. A large contingent of those who identified as Republican (29%) also reported that they would not likely be vaccinated (Khubchandani, 2021).

The report, developed by AARP PA, and Drexel University, highlights the growing disparities in healthcare access during the COVID-19 pandemic based on geographic, racial/ethnic, and socioeconomic factors. This study, and report revealed that these health inequalities are the most pronounced in rural, or low resourced areas of the Commonwealth of Pennsylvania. In particular, underrepresented populations, such as Black/African Americans, and Latino communities, are disproportionately affected by these acute disparities in healthcare access, and affordability. PA's vaccination plan is heavily affected by these inequalities, as the study notes "The report finds that each of Pennsylvania's 67 counties has at least one "pharmacy desert," such with few to no pharmacies available. With local pharmacies serving as a key component of Pennsylvania's COVID-19 vaccine distribution plan—especially in rural areas of the state—pharmacy deserts directly impact access to vaccines for those at high risk." (Drexel, AARP) Since this report, Health insurers Highmark Blue Shield and Independent Blue Cross have partnered with Penn State Health and the Pennsylvania Department of Health have helped deploy the mobile vaccination effort. They have successfully deployed mobile vaccine vans with trained professionals including nurses into remote communities, senior apartment buildings, schools, door-to-door, corner grocery stores, bodegas, and community events to answer questions about the vaccine. Taking the vaccine to the people has improved the numbers of vaccinated since these mobile units consist of people trusted by the community.

The study produced by Penn Wharton's Budget Model, analyzes the effects of vaccine hesitancy, and forecasts the economic impact of receiving, or refusing the vaccine. PWBM projects that by reducing vaccine hesitancy, 8.3 million cases of infection could be avoided, as well increasing employment by 2.6 million by December of 2021.

10 These forecasts emphasize the importance of reducing vaccine hesitancy, and ominously warn of a possible future. If Vaccine Hesitancy is not reduced substantially, along with the increasing laxing of social distancing, and other health restrictions, cases are projected to skyrocket to an additional 4.6 million cases (Paulson, 2021).

One of the studies by the Kaiser Family Foundations examines the Vaccination Rates by county,

throughout the United States, and looks to establish the key characteristics that under-vaccinated areas share. The article notes that the Biden Administration has placed Vaccine Equity as a priority in their rollouts of the different vaccines, however, the issue is more tangible at a local level. The study points out that earlier in 2021, the CDC determined that areas with higher social vulnerability were more likely to have below average vaccination rates. Notably, the study observed that vaccination rates do not necessarily correspond with COVID infection rates, and impacts. In fact, counties with higher transmissions rates, surprisingly, saw higher vaccination rates. This led to the KFF brief to examine population density, and observe that more urban, metropolitan areas saw greater vaccination rates than the more rural, desolate counties (Tolbert, 2021).

An article published by the University of Minnesota's Center for Infectious Disease Research and Policy reports that vaccine hesitancy in the United States has declined, but warns that this is not necessarily something to celebrate. According to this article, the decrease in vaccine hesitancy can be observed throughout different demographic groups, in particular, Hispanic and African Americans dropped 15.8 percentage points in regards to their intentions of being vaccinated, or not. In general, the United States' hesitancy fell around 10 percentage points from 46% in October 2020, to 35.2% in March 2021. However, CIDRAP warns that roughly 35% of the population can seriously disrupt attempts at herd immunity through widespread vaccination. With the fall, and winter months looming at the time of this article's release, concerns are mounting that a new wave of transmissions could spark returns to 2020 lockdowns (Van Beusekom, 2021).

A research report featured in the New England Journal of Medicine discusses how the supply of vaccines in the U.S. has exceeded their demands, and how some certain policies, and programs could improve the vaccination rate. The NEJM targets herd immunity around 80% of the population receiving the vaccine, however, the nation currently sits at just under 50%. The growing concern is that this level will stagnate without a large push to nudge those in the middle into receiving the shot. Monetary incentives, such as a lottery program, have been noted to be not impactful at worst, and provided middling returns at best. This article notes that a key component of incentive programs needs to address those who are hesitant, not simply just to those who would have received the vaccine to begin with. In order to significantly impact the vaccination rates in a positive direction, these programs and strategies should aim to instill public confidence in the vaccine, and its rollout systems. Importantly, these strategies should aim to remove barriers that have kept poorer populations, people of color, minorities, and those in rural areas from receiving the vaccine (Volpp, 2021).

## *2.2 Empirical Model*

The vaccine hesitancy varies greatly in the country. The data shows that even within counties where hesitancy overall is low, there are ZIP codes where a much larger proportion of the population is unsure about getting a COVID-19 vaccine. In northeastern Washington state, county-level hesitancy hovers at about 20 percent, but some ZIP codes have hesitancy as high as 50 percent. In almost all states, neighboring ZIP codes show wide disparities. In Minnesota, for example, two adjacent ZIP codes have

hesitancy of 9 percent and over 60 percent. In order to address the disparity in the rate of vaccine hesitancy, state officials need available data to target incentive programs where vaccine hesitancy rate is significantly higher.

In our empirical model, we first identify the factors that determine vaccine hesitancy in the United States. The model specified to estimate the coefficients associated with the determinants are given in the equation 1 below. The cross sectional data set used to estimate the model is for 50 states in the US. We utilized the most up to date data as of Aug 9, 2021. The definitions and sources of the variables used in our model are presented in Table 5.

$VH_i = \beta_0 + \beta_1(MEDINC)_i + \beta_2(POLAF)_i + \beta_3(\%WH)_i + \beta_4(TPC)_i + \beta_5(W/HI)_i + \beta_6(EDU)_i, \dots, \dots$  Equation 1 2.3  
 Dependent Variable: Vaccine hesitancy (VH)

11 The dependent variable (VH) in this model measures the extent to which the population within the state is hesitant to be vaccinated. Specifically, the Center for Disease Control considers individuals as hesitant if they indicate that they would “probably not” or “definitely not” receive a COVID-19 vaccine when available. We utilized estimates of hesitancy, as well as the data of the unvaccinated population of each state provided by the CDC. At this current point in time, vaccinations are readily available to very nearly every individual in the United States, which has resulted in the current unvaccinated population to be deemed “hesitant”. Hesitancy has been divided into three separate distinctions: Hesitant, Unsure, and Very Hesitant. Most of the unvaccinated population lies within the Hesitant portion, and thus, is the pocket we focused on for our analysis.

The independent variables included in the model represent the factors that are important in determining the extent of vaccine hesitancy and are listed below.

- *Median Income (MEDINC)* measures the Median Income of people living in each state. We expect a negative coefficient to be associated with this variable, indicating that individuals from States with a higher median income are less likely to be hesitant. According to the Kaiser Family Foundation, unvaccinated individuals, on average, have lower amounts of disposable income.
- *Political Affiliation (POLAF)* measures the individual states political affiliation. Utilizing Politico’s reports of the Electoral College from the 2020 Presidential General Election, we determined which states voted Republican or Democrat. We expect a negative coefficient to be associated with this variable, indicating that Republicans are more likely to be hesitant. According to PLOS One’s report on the demographics of the unvaccinated, 49% of all unvaccinated people identified as Republican. 29% of that group reported that they were “Hesitant to Very Hesitant”. We have identified Republican states as (0), and Democratic as (1) in our data.
- *(%WH)* measures the percentage of population within the state that is White/Caucasian. We expect a positive coefficient to be associated with this variable, indicating that White people are more likely to be more hesitant. According to the KFF’s report on unvaccinated individuals, White adults account for the largest share of the unvaccinated population (57%).
- *(TPC)*- This variable measures the state’s total confirmed positive cases as of August 3rd, 2021. We

expect a negative coefficient to be associated with this variable, indicating that individuals from states with a higher number of confirmed cases are more likely to be hesitant. Studies from the KFF have pointed to

population density being a contributing factor to total cases, especially in areas with higher hesitancy. • (*W/HI*) represents the percentage of the population that is currently without any health insurance within the state. We expect a positive coefficient to be associated with this variable, indicating that individuals without Health Insurance are more likely to be hesitant.

• (*EDU*) represents the percentage of the population with a bachelor's degree or higher within the state. We expect a negative coefficient to be associated with this variable, indicating that individuals with at least a bachelor's degree or higher are less likely to be hesitant.

**Table 2. Variable Definition and Sources of Data**

Name of the variables	Definition Sources	Notes
VH	Vaccine Hesitancy 1 & 4	As of 8/3/21
MEDINC	Median Income by State 3	As of 2020
POLAF	Political Affiliation 2	Nov, 2020
TPC	Total confirmed cases by state 1	As of 8/3/21
W/HI	Percentage of Individuals w/o Health 3 Insurance or coverage	By State
EDU	Percentage of Individuals with a 3 bachelor's degree or higher	By State
%WH	Percent of population that is 3 white/caucasian	By State

Sources of Data:

1) Center for Disease Control and Prevention

-<https://data.cdc.gov/stories/s/Vaccine-Hesitancy-for-COVID-19/cnd2-a6zw/>

2) Politico- <https://www.politico.com/2020-election/results/president/>

3) U.S. Census Bureau

<https://data.census.gov/cedsci/table?q=United%20States&g=0100000US&tid=ACSDP1Y2017.DP05&>

vint age=2017&layer=state & cid=DP05\_0001E

4) USA Fact- <https://usafacts.org/visualizations/covid-vaccine-tracker-states/>

### 3. Result

The results of our regression analysis were mostly similar to our expectations beforehand. Five out of six of our independent variables have the expected signs and their coefficients are significant. It indicates that the variables chosen to estimate the equation are useful in predicting the extent of Vaccine Hesitancy (VH), our dependent variable. Table 6 summarizes the results from estimating using a simple linear regression model for equation 1. As expected, higher the median income, the lesser the VH. The states with higher total number of cases are associated with higher VH. Republicans are more likely to be more hesitant to accept vaccines than the Democrats. As the literature suggests our results are consistent with the idea that white/caucasian race tends to be more hesitant to become vaccinated. Individuals with no health insurance are likely to refuse to take the vaccine even though these vaccines are offered at no charge in the United States.

**Table 3. Regression Results**

	Coefficient	T-Stat	P-Value
Intercept	0.5341861017	5.871395206	0.0000005623280215
MEDINC	-0.0000030428166330543	-3.13878407750077	0.003062
	****		
POLAF	-0.07664	****	-4.00964 0.000238
%WH	0.115542	*	1.59469 0.118106
TPC	-2.20102678256513E-08		-1.73311 0.090242
		**	
W/HI	0.723723	****	2.191009 0.033918

EDU 0.000359 0.280398 0.780517

\*\*\*\* Significant at 0.01 level

\*\*\*Significant at .05 Level

\*\* Significant at 0.10 Level

\* Significant at 0.12 level

R=Square 0.701652

Number of Observations 50

F 16.85453

Significance F 6.87697097681E-10

#### 4. Discussion

With only 50% of the population in the United States being fully vaccinated, the development of mutations has spread among the unvaccinated who tend to be concentrated especially in the southern states. This rapid replication, through the rapid-fire spread of infection could lead to more dangerous variants that may be resistant to all vaccines that we have currently available. This mutation and spread of variants could easily outpace vaccinations, and swamp the health providing systems. The only solution worldwide, as well as in the United States, is to vaccinate as many people as rapidly as possible. There are efforts being made by the United States, the European Union, specifically the United Kingdom, as well as other countries with more developed vaccine access to send vaccines to low and developing countries to help speed up the process of getting people vaccinated. However, given the scope of this task, as well as most nations lagging behind their vaccination goals, this effort appears to be in vain.

There are many counties with extremely low vaccination rates as low as 20% adjacent to more urban areas which may have 40% or more vaccinated, which has led to widespread infection in a large geographic area as demonstrated by many of the Southern and conservative states and counties throughout the rest of the U.S. Most people in much of the U.S. have discontinued mitigation strategies such as wearing a mask and practicing social distancing which has facilitated the rapid spread of the delta variant. India is an example of a dense unvaccinated population due to a lack of access to vaccines. This widespread unchecked infection in a dense population has given the Covid-19 virus ample opportunity to form many mutations from the many replications as it spreads to new hosts leading to delta variant which has rapidly spread across the world. (Young, p. 2921)

The delta variant has a number of mutations that increase the viral load in the oropharynx by 1,000-1,260 times the original virus with the effect of increased transmission, shorter incubation period, and more severe illness in those who become ill. (Jing et al., 2021) The result of this continued widespread low vaccination rate will lead to the

virus becoming endemic. This will allow a more rapid evolution of variants with mutations which are likely to escape both convalescent and vaccine immunity. (Liu et al., 2021) Herd immunity is unlikely to ever be achieved since the medical community is unable to vaccinate as many people as possible in a short period of time in both the U.S. and all across the world. (Aschwanden, 2021)

Given the results from estimating the empirical model specified in equation 1, we are in agreement with the current literature regarding the factors that determine the variation of vaccine hesitancy in different states within the United States. Policy makers around the world must pay particular attention to these factors identified in our findings.

In this section, we move forward to evaluate the economic consequences of persistent vaccine hesitancy.



As the world tackles this pandemic, and inch toward the goal of herd immunity, we must compose incentive structures targeted at hesitant individuals. Using the results from our empirical model, and regression, we can determine multiple factors that can help identify potential hesitant individuals. We believe that this focused strategy would be much more effective at increasing the vaccination rate, compared with more general incentive strategies that encompass most citizens.

Increasing the overall vaccination rate throughout the United States, as well as throughout the world must be the number one priority, and to do so, vaccine hesitancy must be greatly decreased. Through our variables that we identified correlating with vaccine hesitancy, we can identify individuals more likely to be vaccine hesitant, and target them with positive messaging, information/education, and incentives.

A possible policy recommendation could utilize partnerships between private institutions and government agencies by incentivizing vaccinations through monetary rewards, similar to Vanguard's strategy (see below). Cooperation between government agencies and private businesses could stem the tide of vaccine hesitancy, whilst simultaneously incentivizing private employees, and reducing government spending.

Another important economic issue to note relates to the immediate, and long term financial responses undertaken by the Trump and Biden Administrations. Trillions of dollars were allocated for fiscal relief through Stimulus Packages, rent moratoriums, relief funds, as well much more dedicated to vaccine research and development through Operation Warp Speed, testing applications, and personal protective equipment. (IMF) While these endeavours provided immediate relief to millions of people, reports of financial hardships still flourish. Compounding this, the United States is currently experiencing one of its largest labor shortages in recorded history. The Business Insider reports that wages are up and there are more open positions than current job seekers, yet, many individuals are sidelined by health risks due to the Delta Variant, guardian and caregiving responsibilities due to many children still not being physically in school. (Business Insider, Kaplan)

What can be done to counter some of these economic effects that are severely hampering the nation's economic ability? We believe a complete perspective change is required. To combat vaccine hesitancy, and its resulting loss in economic output, we must begin to view Vaccine Hesitancy as a negative externality that must be addressed by providing economic incentives to reduce the externalities. One recommendation is directed at the Public Sector, and has been shown to be incredibly fruitful when utilized: incentivizing employees to receive the vaccine. Achieving herd immunity is critical according to the Journal of American Medical Association (JAMA). Robert Litan, a non-resident Senior Fellow in the Economic Studies Program at the Brookings Institution, believes that the COVID vaccine can be observed as a positive externality. He believes a solution could be to compensate every vaccinated individual with \$1,000. Harvard economist, and former chair of Economic Advisors for the Bush administration, Gregory Mankiw, champions this position as "textbook" economics. (Forbes, 2020)

Vanguard, an asset management giant, followed this strategy, proposing a \$1,000 incentive to any employee that receives the vaccine. Vanguard has given their 16,500 eligible employees until Oct 1, 2021

to receive the shot (CNBC, Macheel). Many others, including State governments, have attempted to incentivize the vaccine. Krispy Kreme offered free daily donuts to anyone showing proof of inoculation, Ohio had offered a Vax-A-Million lottery system, promising scholarships and monetary rewards, and President Biden has called on states to offer \$100 for full vaccination.

Using the United State's experience as our template for the greater world, we can look at similar variables from different nations to predict, and identify potentially hesitant individuals. We would assume the variable Political Affiliation (POLAF) would have to be tweaked, understanding that the rest of the world does not necessarily abide by the two party system that the States do. Health coverage would similarly need to be reevaluated, given the vast differences in European and American Health Systems. However, education, median income, total cases, and percent white could all be used as indicators of potential hesitancy throughout the world. Vaccine Hesitancy is the single greatest roadblock on the path to a return to normalcy. Without serious policy, societal, and administrative changes the costs of prolonging the COVID-19 pandemic could be momentous. In order to minimize vaccine hesitancy, and its consequences, we must again look at the determinants to understand where it comes from. There is no one singular reason for the majority of vaccine hesitant individuals, in many cases, it is a perfect storm of the determinants we quantified, compounded by misinformation, and a divided societal climate. As seen in our empirical model: median income, political affiliation, education level, total cases, and percentages of the population that is white and without health insurance, all are defined as determinants of vaccine hesitancy.

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## References

- Adolph, C., Amano, K., Bang-Jensen, B., Fullman, N., & Wilkerson, J. (2021). Pandemic Politics: Timing State-Level SocialDistancing Responses to Covid-19. *Journal of Health Politics, Policy and Law*. U.S. National Library of Medicine. <https://doi.org/10.1073/pnas.2109720118>
- Rasmussen, A. L. (2021). *Vaccination Is the Only Acceptable Path to Herd Immunity*. Med (New York, N.Y.), U.S. NationalLibrary of Medicine, 2021. Retrieved from <http://www.pubmed.ncbi.nlm.nih.gov/33521750/>
- Anita Milicic Head of Vaccine Formulation and Adjuvants Group. (2021). Adjuvants: The Unsung Heroes of Vaccines. *The Conversation*. Retrieved from

- <http://www.theconversation.com/adjuvants-the-unsung-heroes-of-vaccines-156548>
- Aschwanden, C. (n.d.). *Five Reasons Why COVID Herd Immunity Is Probably Impossible*. Nature, U.S. National Library of Medicine. Retrieved from <http://www.ncbi.nlm.nih.gov/33737753/>
- Barankay, I. (2021). Will COVID-19 Vaccination Incentives Work? *Knowledge@Wharton*. UPenn Wharton: Budget Model, 24 May 2021. Retrieved from <http://www.knowledge.wharton.upenn.edu/article/why-incentives-wont-raise-covid-19-vaccination-rates/>
- Center, Therapeutic Research. (2021). Communicating about Covid-19 Vaccination. *Pharmacist's Letter*. 14 July 2021, [pharmacist.therapeuticresearch.com/Content/Segments/PRL/2021/Jan/Communicating-About-COVID-19-Vaccination-S2101002](http://pharmacist.therapeuticresearch.com/Content/Segments/PRL/2021/Jan/Communicating-About-COVID-19-Vaccination-S2101002).
- Corum, J., & Carl, Z. (2021). "How GAMALEYA'S Vaccine Works." *The New York Times*. Retrieved from [www.nytimes.com/interactive/2021/health/gamaleya-covid-19-vaccine.html](http://www.nytimes.com/interactive/2021/health/gamaleya-covid-19-vaccine.html)
- DeSai, A., & Maimuna, M. (2020). "What Is Herd Immunity?" *JAMA Patient Page*. *Journal of the American Medical Association*. Retrieved from <http://www.jamanetwork.com/journals/jama/fullarticle/2772168>
- Edwards, D. A. et al. (2021). *Exhaled Aerosol Increases With Covid-19 Infection, Age, and Obesity*. *PNAS*, National Academy of Sciences, 23 Feb. 2021. <https://doi.org/10.1073/pnas.2109720118>
- FDA New Release, "Coronavirus (COVID-19) Update: FDA Authorizes Additional Vaccine Doses for Certain Immunocompromised Individuals." For Immediate Release, 12 Aug 2021 <https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-authorizes-additional-vaccine-dose-certain-immunocompromised-individuals> 12 Aug 2021.
- FDA News Release, "FDA Approves First Covid-19 Vaccine." For Immediate Release, 23 Aug 2021, <https://www.fda.gov/news-events/press-announcements/fda-approve-first-covid-19-vaccine>
- French, Paul. "In the 1918 Flu Pandemic, Not Wearing a Mask Was Illegal in Some Parts of AMERICA. What Changed?" *CNN*, Cable News Network, 5 Apr. 2020, <http://www.cnn.com/2020/04/03/americas/flu-america-1918-masks-intl-hnk/index.html>
- Fridman, A. et al. (2021). *COVID-19 and Vaccine Hesitancy: A Longitudinal Study*. PLOS ONE, Public Library of Science, 16 Apr. 2021. <https://doi.org/10.1371/journal.pone.0250123>
- Gonzales, O. (2021). *Missouri attorney general files lawsuit to stop school mask mandates*. <https://www.axious.com/missouri-lawsuit-stop-school>
- Greenhahgh, T. et al. (2021). *Ten Scientific Reasons in Support of airborne transmission of SARS-CoV-2*. 15 April, 2021. [https://doi.org/10.1016/S0140-6736\(21\)00869-2](https://doi.org/10.1016/S0140-6736(21)00869-2)
- Graham, D. A. (2021). *It's Not Vaccine Hesitancy. It's Covid-19 Denialism*. The Atlantic, Atlantic Media Company, 27 Apr. 2021, Retrieved from <http://www.theatlantic.com/ideas/archive/2021/04/its-not-vaccine-hesitancy-its-covid-denialism/618724/>

- Griffin, J. et al. (2021). *SARS-CoV-2 Infections and Hospitalization Among Persons Aged  $\geq 16$  Years, by Vaccination Status—Los Angeles County, California, May 1–July 25, 2021*. CDC MMWR Early Release/Vol 70, 24 August 2021. <https://doi.org/10.15585/mmwr.mm7034e5>
- Jing, L. (2021). Viral Infection and Transmission in a Large Well-Traced Outbreak Caused by the DELTA SARS-CoV-2 Variant. *Virological*. <https://doi.org/10.21203/rs.3.rs-738164/v1>
- Khan, H. et al. (2021). Who Doesn't Want to Be Vaccinated?: Determinants of Vaccine Hesitancy During COVID-19. *International Monetary Fund*. <https://doi.org/10.5089/9781513573717.001>
- Khubchandani, J. et al. (2021). COVID-19 Vaccination Hesitancy in the United States: A Rapid National Assessment. *Journal of Community Health*. <https://doi.org/10.1007/s10900-020-00958-x>
- Liu, Y. et al. (2021). The SARS-CoV-2 Delta variant is poised to acquire complete resistance to wild-type spike proteins. <https://doi.org/10.1101/2021.08.22.457114>
- Korp, A. (2021). New Research Shows Disparities Limiting Access to Health Care Services, Including COVID-19 Vaccines, in Pennsylvania's Underserved Communities. In *DrexelNow*.
- McAlpine, K. L. (2021). *Why Global Vaccinations are Dangerously Lagging: Six Things to Know as Delta variant spreads rapidly, BU-led panel explains why vaccination rollout isn't keeping pace*. Retrieved from <https://www.bu.edu/articles/2021/why-global-vaccinations-are-dangerously-lagging>
- McMorrow, M. (2021). Improving Communications around Vaccine Breakthrough and Vaccine Effectiveness. *Center for Disease Control and Prevention*. Retrieved from <http://www.context-cdn.washingtonpost.com/notes/prod/default/documents/8a726408-07bd-46bd-a945-3af0ae2f3c37/note/57c98604-3b54-44f0-8b44-b148d8f75165>
- Mendonça, S. A. et al. (2021). Adenoviral Vector Vaccine Platforms in the Sars-Cov-2 Pandemic. *Nature News*. <https://doi.org/10.1038/s41541-021-00356-x>
- Miller, S. (2021). Estimated Mortality Increases during The Covid-19 PANDEMIC by Socioeconomic Status, Race, and Ethnicity: *Health Affairs Journal*. *Health Affairs*. <https://doi.org/10.1377/hlthaff.2021.00414>
- Paulson, M. (2021). Health and Economic Effects of Reducing COVID-19 Vaccine Hesitancy. In *Penn Wharton Budget Model*. University of Pennsylvania: Wharton School, 22 Mar. 2021. Retrieved from <http://www.budgetmodel.wharton.upenn.edu/issues/2021/3/22/health-and-economic-effects-of-reducing-covid-19-vaccine-hesitancy>
- Pulendran, B. et al. (2021). Emerging Concepts in the science of vaccine adjuvants. *Nature*, 20. Retrieved from <http://www.nature.com/nrd>
- Psychology Research: Antivaxxers Actually Think Differently than Other People*. (2021). MedicalXpress, MedicalXpress, 2021. <https://doi.org/10.1038/s41573-021-00163-y>
- Rabi, F. A. et al. (2020). SARS-CoV-2 and Coronavirus Disease 2019: What We Know so Far." *MDPI, Multidisciplinary Digital Publishing Institute*, 20 Mar. 2020.

- <https://doi.org/10.3390/pathogens9030231>
- Rasmussen, A. L., & Saskia, V. P. (2021). Sars-Cov-2 Transmission without Symptoms. *Science*. American Association for the Advancement of Science, 19 Mar. 2021, <https://doi.org/10.1126/science.abf9569>
- Reed, T. (2021). *CU beds are running out again” 25 August 2021*, Retrieved from <https://www.axios.com/covid-hospitals-icu-beds-vaccines-sick-pandemic-48996586-e2fd-4180-af21-dfa3228e6f4.html>
- Rushing, E., & Goodin-Smith, O. (2021). *Mobile vaccine clinics ramp up efforts to reach Philly’s most vulnerable communities: Let’ bring vaccine to them*. Retrieved from <https://www.inquirer.com/health/coronavirus/mobile-covid-vaccine-philadelphia-coronavirus-20210323.html>
- Santucci, J. (2021). *Keep Your Guard Up: CDC studies show waning Covid vaccine efficacy as delta variant sweeps U.S.* Retrieved from <https://www.usatoday.com/story/news/health/2021/08/24/covid-vaccine-efficacy-delta-variant-cdc-study=los=angeles/5578703001/>
- Smith, J. (2021). Here’s How THE Astrazeneca Covid-19 Vaccine Compares to Those Available in the U.S. *Prevention*. Retrieved from <http://www.prevention.com/health/a35118263/astrazeneca-vs-pfizer-vs-moderna-covid-19-vaccine/>
- Sridhar, D., & Deepti, G. (2021). Herd Immunity by Infection Is Not an Option. *Science, American Association for the Advancement of Science*. <https://doi.org/10.1126/science.abf7921>
- Stadnytskyi, V. et al. (2020). *The Airborne Lifetime of Small Speech Droplets and Their Potential Importance in Sars-Cov-2 Transmission*. *PNAS*, National Academy of Sciences, 2 June 2020. <https://doi.org/10.1073/pnas.2006874117>
- Szabo, L. (2021). *Unraveling the Mysterious Mutations That Make Delta the Most Transmissible Covid Virus Yet*. Kaiser Health News. 28 July 2021, [https://www.medscape.com/viewarticle/955583\\_print](https://www.medscape.com/viewarticle/955583_print)
- Tolbert, J. et al. (2021). *Vaccination Is Local: COVID-19 Vaccination Rates Vary by County and Key Characteristics*. *KFF*, Kaiser Family Foundation, 12 May 2021. Retrieved from <http://www.kff.org/coronavirus-covid-19/issue-brief/vaccination-is-local-covid-19-vaccination-rates-vary-by-county-and-key-characteristics/>
- Thompson, D. (2021). “Millions Are Saying No to Vaccines. What Are They Thinking?” *The Atlantic*, Atlantic Media Company, 4 May 2021, Retrieved from <http://www.theatlantic.com/ideas/archive/2021/05/the-people-who-wont-get-the-vaccine/618765/>
- Thompson, D. (2021). The Surprising Key to Combating Vaccine Refusal. *The Atlantic*. Atlantic Media Company, 4 Mar. 2021, Retrieved from <http://www.theatlantic.com/ideas/archive/2021/02/vaccine-hesitancy-isnt-just-one-thing/618164/>
- Tufekci, Z. (2020). This Overlooked Variable Is the Key to the Pandemic. *The Atlantic*, Atlantic Media

- Company, 1 Oct. 2020, Retrieved from <http://www.theatlantic.com/health/archive/2020/09/k-overlooked-variable-driving-pandemic/616548/>.
- United States Government Accountability Office (GAO) Report to Congressional Addressees. (2021). Operation Warp Speed.” Accelerated COVID-19 Vaccine Development Status and Efforts to Address Manufacturing Challenges. February 2021
- Van Beusekom, M. (2021). COVID-19 Vaccine Acceptance Rises but Needs Boost. *CIDRAP*, University of Minnesota, 25 May 2021. Retrieved from <http://www.cidrap.umn.edu/news-perspective/2021/05/covid-19-vaccine-acceptance-rises-needs-boost>
- Volpp, K. G., & Carolyn, C. (2021). *Incentives for Immunity - Strategies for Increasing “Viral Vector Vaccine.”* *Wikipedia*, Wikimedia Foundation, 11 July 2021, Retrieved from [http://www.en.wikipedia.org/wiki/Viral\\_vector\\_vaccine](http://www.en.wikipedia.org/wiki/Viral_vector_vaccine)
- Volpp, K. G., & Carolyn, C. C. (2021). Incentives for Immunity—Strategies for Increasing Covid-19 Vaccine Uptake.” *New England Journal of Medicine*, 385(1), 2021. <https://doi.org/10.1056/NEJMp2107719>
- Wenner, D. (2021). *Mobile Covid-19 vaccination clinic heads for minority neighborhoods in Pa.* *Patriot NewsPennLive*. [dwenner@pennlive.com](mailto:dwenner@pennlive.com). 12 April 2021. Retrieved from <https://www.pennlive.com/news/2021/04/mobile-covid-19-vaccination-clinic-heads-for-minority-neighborhoods-in-pa.html>
- Wickramaratchi, Manohari Meegahawattage et al. (2020). Review on Identification of Major Infectious Site and Disease Progression Pathway for Early Detection of Novel CoronaVirus Covid-19. 2020. <https://doi.org/10.31222/osf.io/fu9p8>
- Yong (Ed., 2021). America Is Getting Unvaccinated People All Wrong. *The Atlantic*. Retrieved from <http://www.theatlantic.com/health/archive/2021/07/unvaccinated-different-anti-vax/619523/>
- Zimmer, C. et al. (2020). Coronavirus Vaccine Tracker. *The New York Times*. Retrieved from <http://www.nytimes.com/interactive/2020/science/coronavirus-vaccine-tracker.html>
- Ziv, S. (2020). Economists’ Solution: Pay AMERICANS \$1,000 to Get Covid-19 Vaccine. *Forbes*. Retrieved from <http://www.forbes.com/sites/shaharziv/2020/12/01/proposal-pay-americans-1000-to-get-covid-vaccine/?sh=617e11d264bf>
- Zhu, N. et al. (2020). A Novel Coronavirus from Patients with Pneumonia in China, 2019.” *N Engl J Med*, 382(8), 2020, <https://doi.org/10.1056/NEJMoa2001017>