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Socioeconomic Disparities in COVID-19 Vaccination Rates in New York City

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By

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ABSTRACT

The Coronavirus Pandemic has exposed mass systemic inequalities experienced by vulnerable populations. Vaccines are critical in protecting people from disease and the rest of the damages COVID inflicted on the world, but vaccination distribution might not be equal. The purpose of this thesis is to discover which factors impact uptake of vaccination in New York City. My empirical analysis combines the data on the earnings, educational attainment, gender, age, population size, access to reliable internet, political leanings, and racial makeup of each ZIP code tabulation area (ZCTA) in New York City. The data on vaccination rates is collected at two points of time (May 22, 2021 and February 28, 2022). The two time periods examine the factors of those who had greater access at the beginning of the rollout and then those that are hesitant later in the rollout. Using regression analysis and descriptive statistics, I find that age, earnings, population size, race, and education were significant predictors of vaccination in the earlier rollout phase. Later in the rollout phase, I found that earnings and race were significant predictors of vaccination. ZIP codes that are older, more educated, wealthier, less crowded were more likely to have more vaccinations. As the rollout continued and restrictions on who could be vaccinated lessened, these factors were less significant (if at all) by February 2022. Still, earnings were a highly significant predictor of vaccination.

1. INTRODUCTION

COVID-19 has drastically changed what was considered "normal" since its emergence in late 2019 and early 2020. As of late May 2022, and in the United States alone, there have been 83.8 million confirmed cases, and roughly one million deaths (Johns Hopkins University, 2022). The health crisis depleted hospitals of their resources to treat infected people, and also put staff in constant danger. The stock market took one of the largest downfalls since the economic recession in 2008, which left businesses scrambling, laying off workers or even closing their doors completely. Industries took massive hits to their revenue due to the lockdown protocols and fear of getting sick, and the unemployment rate hit its highest level in decades, at 14.7% in April 2020 (Domestic Social Policy Division, 2021). Besides being a major health crisis, COVID-19 also created an economic and social crisis (United Nations: Department of Economic and Social Affairs, 2020). The stress that this pandemic has waged on individuals, communities, and organizations, put a safe and effective vaccine in high demand to return to normal as soon as possible.

The pandemic also exacerbated economic and social inequalities pre-existing in our society. Marginalized people, whether it be due to financial status, minority status, or old age, suffered worse from the impact of COVID-19. Whittle and Diaz-Artiles (2020) found that the most determining factors of contracting COVID-19 are race, household income, population density, and the number of dependent children a person has. Research has also demonstrated that Black and Latino people in the United States are three times more likely than white people to contract the virus, and also three times more likely to die from the virus (*COVID-19 deaths analyzed by race and ethnicity*, 2020). Not only are minorities contracting and dying at a quicker rate from

COVID, but research also shows they are being vaccinated at a slower rate than white people too (Closson, 2021). There are many factors why this can be happening; research has shown that there were many obstacles to obtaining a vaccination, such as finding reliable and safe transportation, having the ability to find time off work to attend the appointment, and navigating a primarily online only scheduling service (Goodnough & Hoffman, 2021). These challenges are only heightened by having a lower income, but there is also a potential hesitancy issue. There are many different factors as to why minorities are being vaccinated at a rate slower than white people, but there is no debate that this disparity is occurring.

A *New York Times* article (Goldstein & Sedacca, 2021) reported a major cause of the racial divide between which groups of people are getting the vaccine. The report interviewed multiple Black New Yorkers about why they had not gotten the vaccine, attempting to explain why only 28% of Black New Yorkers ages 18-44 were fully vaccinated, compared with 52% of White New Yorkers in the same age group as of August 2021. The interviewees expressed hesitancy to trust the government's motives, especially because some politicians had prioritized minority communities for vaccination since they had a higher transmission and death rate, a policy action that was met with suspicion. They expressed feelings of distrust towards medical professionals, citing their personal experiences with medical racism, and historic experimentation such as the Tuskegee syphilis experiment. There was also anxiety surrounding the speed of the vaccine and how long other vaccines have taken to develop, like the HIV vaccine. COVID has impacted everyone, while HIV predominantly impacted Black Americans, so there was frustration that the HIV vaccine took 40 years to develop, while the COVID vaccine took less than a year (Goldstein and Sedacca, 2021).

While vaccine hesitancy is a major issue, this is not the sole factor as to why COVID vaccination uptake has not been equal amongst different races and social classes. Research has suggested that the amount of vaccination clinics available within a ZIP code is also a factor (Williams et. al, 2021). Research also demonstrates that those without internet access, did not get vaccinated as quickly as those without, even as the supply of COVID vaccinations increased with time (Michaels et. al, 2021). There is also evidence of those with a lower average income level and less educational attainment (Herman, 2021).

In this thesis, I examine how sociodemographic and economic factors may affect vaccination against COVID-19 in New York City. Specifically, I choose to focus on the vaccine uptakes during two different time periods in the rollout (May 2021 and February 2022). The purpose of using two different time periods in my empirical analysis is to examine the difference between when the vaccine was very high in demand, but low in supply, and then again in February once the supply had increased and eligibility requirements had lessened. Those that received the vaccine earlier on may have not just met the eligibility requirements, but had greater accessibility to the vaccine since there were more barriers with the supply being so low. Those that got vaccinated later on in February may have been inhibited by these barriers and only been able to get vaccinated later.

I find that age, earnings, population size, race, and education were significant predictors of vaccination in the earlier rollout phase. Later in the rollout phase, I found that earnings and race were significant predictors of vaccination. ZIP codes that are older, more educated, wealthier,

less crowded were more likely to have more vaccinations. As the rollout continued and restrictions on who could be vaccinated lessened, these factors were less significant (if at all) by February 2022. Still, earnings were a highly significant predictor of vaccination.

These findings can inform policymakers about which communities need more aid in receiving preventative healthcare against potential pandemics or health emergencies in the future. The approach of this thesis is distinguished from many prior studies that examine vaccination rates at only one time point with no examination of different policies at the time. Many reports used county boundaries as well, while this thesis will look at even smaller boundaries (ZIP code tabulation areas) to acknowledge the vast differences that can be occurring within a county. New York City is a small geographic area, but very densely populated with racial, cultural, and economic diversity. The vaccination policy is the same within New York City since all five boroughs were under the same governing body, so socioeconomic factors are the only variable being investigated in this thesis.

The remainder of this thesis is organized as follows: In Section 2 I discuss the policy background of vaccine development policies. Section 3 is the literature review and is split into three sections one on COVID-19 and how the virus exacerbates already existing inequalities, the next on factors that influence general vaccination uptake (not limited to COVID-19), and the last part specifically concerning the COVID-19 vaccination and which socioeconomic factors influenced deciding to vaccinate. Section 4 is my theory and hypotheses. Section 5 describes my data sources and empirical model. In Section 6 and 7, I report the regression results and discuss the implications of my findings. Lastly, Section 8 concludes.

2. POLICY BACKGROUND

Covid vaccine development & Operation Warp Speed

As mentioned earlier, there was an extreme push to get "back to normal" as quickly as possible. Lockdown strategies were essentially ineffective in containing the virus since they were decentralized and enforced by each individual state, and masks became a highly polarizing and political symbol that led to a lot of states either not enforcing them or people disregarding mandates. The next method to protect the public was mass vaccination.

Operation Warp Speed (OWS) was a federal program that aimed to accelerate the production of 300 million safe and effective COVID-19 vaccinations and deliver multiple options to the American public. The program partnered with the Department of Health and Human Services (HHS), the Center for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), the National Institutes of Health (NIH), the Biomedical Advanced Research and Development Authority (BARDA), and the Department of Defense (DoD). Roughly $10 billion was allocated in various contracts to biopharmaceutical companies by Congress through the CARES Act (Department of Health and Human Services, 2020). There were six companies who received funding: Pfizer, Moderna, Novavax, Sanofi-GlaxoSmithKline, AstraZeneca, and Johnson & Johnson. The difference between Operation Warp Speed and typical private-public partnerships with vaccine companies was that steps in the production process occurred simultaneously;vaccines were being mass produced as they were also being tested for safety and efficacy. This is a high-risk policy decision, because if these tests failed, the United States would have wasted billions of dollars. But, if the vaccine passed the tests, the government would then own the doses, and be able to administer them quickly at no charge to the public (Congressional

Research Service, & Siddalingaiah, 2021). To minimize the risk, there were three different kinds of vaccine technology invested in, mRNA, viral vector, and protein-based vaccines. There were two vaccines invested in each category.

The operation was a success, as Pfizer, Moderna, and Johnson and Johnson were all administered to people in the United States. Pfizer's vaccine was approved for Emergency Use Authorization on December 11, 2020 and then received full approval on August 23, 2021 by the FDA. Moderna's was approved for Emergency Use Authorization one week later, and then was fully approved by January 31, 2022 (Katella, 2021 & FDA, 2021). They both had similar efficacy rates, well above 90% (Katella, 2021).

Johnson and Johnson was approved for Emergency Use Authorization in February 2021, but its use has since been paused, and now restricted. A new risk analysis report of developing thrombosis with thrombocytopenia syndrome (TTS) conducted by the FDA revealed that while the side effect is not common, it is still alarming. Sixty people developed the syndrome and nine people died from complications. The FDA decided that it would now only be administered to people who have a severe allergy to mRNA vaccines, or would rather be unvaccinated than receive an mRNA vaccine. This is because the only other two options in the United States are Pfizer and Moderna, both using mRNA technology. The decision was ultimately made because of the abundance of Pfizer and Moderna vaccines that the United States has, and the risk of keeping Johson and Johnson as a prominent option no longer outweighed the benefits (Foley & Gardner, 2022). This pause and restriction was disappointing news in terms of improving vaccine access equality, because it is a single-shot and much easier to store than both Pfizer and

Moderna. It did not require a second appointment or advanced refrigeration, so it was more successful in vaccinating groups that are more difficult to reach, as shown by the racial makeup it was vaccinating was consistent with the actual U.S. population (Oliver, 2021).

COVID Vaccination Rollout

COVID vaccination rollout has been highly decentralized, because each state has taken its own jurisdiction regarding how it is administered. In this thesis, I focus solely on New York City. This maintains policy as a constant, but still has plenty of racial and economic differences to examine. The NYC Health Department submitted a *COVID-19 Vaccine Equity Strategy* that addresses that the rollout of the vaccines need to be accessible, equitable, and ethical, while addressing issues of systemic inequality against marginalized groups (people of color, sexual minorities, people with disabilities, people who are undocumented, etc.). The action items were, among other things; to prioritize marginalized communities and those with the highest risk of death and negative health conditions, increase education about the vaccine, and establish partnership with communities (NYC Health Department, 2021). The NYC mayor at the time of the initial rollout, Bill de Blasio, responded by opening more vaccination centers in areas that suffered the most from the pandemic (Closson, 2021).

There was never a federal vaccination mandate for the general public, so decisions on how to vaccinate were left to the states. Different vaccine mandates imposed by New York state and city started becoming more prevalent the longer the vaccine was available. New York State mandated that all healthcare workers must have received their first dose or face dismissal as of October 7, 2021. Religious exemptions are not allowed, and medical exemptions must come from a licensed

physician or certified nurse practitioner that states that the COVID vaccine would have a detrimental impact on the recipient's health due to pre-existing conditions (Spina et. al, 2021). More specifically, New York City began to mandate proof of vaccination (policy referred to as "Key to NYC") for everyone 12 years of age and older as of September 13, 2021, to enter into many frequented spaces, such as bars, gyms, theaters, clubs, restaurants, and museums. A vaccine card or mobile vaccination pass with matching identification must be shown to enter these spaces. Employees at all these locations are also required to be vaccinated (City of New York, 2021). Mayor Bill de Blasio signed Emergency Executive Order 250 into law, which outlined these strict vaccination requirements for New York City into action. The order declared that no one, whether it be a "patron, full - or part-time employee, intern, volunteer, or contractor" is to enter the spaces listed before without proof of vaccination (de Blasio, 2021).

Vaccination rates early in the rollout (May 2021) will be compared with vaccination rates later in the rollout (Late February 2022). Over a year into distribution of vaccine rollout, the expansion of where to get the vaccine, and mandates put in place by the city and state have increased access and uptake. Comparing data from May 2021 to February 2022 will show who was vaccinated early, likely due to easier access and who was vaccinated later, likely due to possible hesitancy or other barriers.

3. LITERATURE REVIEW

COVID-19 and Inequality

The spread of COVID-19 had drastically exacerbated already existing inequalities that were occurring throughout the United States and the world (Domestic Social Policy Division, 2021).

There were multiple studies from the initial breakout concerning the effect of demographic factors on the rate of COVID infection. It is important to first address the issue that COVID created within communities throughout the world to understand how critical the vaccine was to restoring some sense of normalcy and safety again. This literature review will first discuss the research conducted on COVID-19 and inequality to frame the problem that led to the production and distribution of the vaccinations.

Whittle and Diaz-Artiles (2020) examined the effect of various factors on COVID infections by ZIP code in New York City including demographics (age, population density, race, male: female ratio), economics (measured economic inequality from 0-1, by looking at income, unemployment rates, poverty rates), and health factors. They found that there were higher COVID positive cases amongst those that are low income and Black. There were also significant associations between COVID positive cases and in dense populations (Whittle and Diaz-Artiles, 2020). This study is similar to this thesis because it examined New York City and used ZIP code as the unit of measure, but in COVID cases, not vaccinations.

Maroko et al (2020) compared the COVID hot and cold spots in zip codes of New York City and Chicago using ArcGIS in April 2020. They found that cold spots, where infection rates were lower than average, consisted primarily of people with higher income, higher education attainment levels, and had a higher proportion white (non-Hispanic) residents. They also tended to have managerial level jobs. Hot spots, where COVID infection rates were higher on average, had higher proportions of Black and Hispanic residents, higher concentration of service workers, and lower rates of college graduates. This study found that the most impactful variable was the

ratio of people per household; more overcrowding in homes seemed to have higher COVID infection rates (Maroko et al., 2020).

Both studies demonstrate that lower income people were more susceptible to contract COVID-19. Lower income people tend to work more service level jobs and were not able to shelter in place since they still needed to go to work in person (US Bureau of Labor Statistics, 2020). This meant that they were still traveling to work and interacting with people, increasing their likelihood of infection. Having a higher level of education attainment was also correlated with less COVID infection rate in a ZIP code, likely because having more education is correlated with having a higher paying job that can be performed from a computer at home. Service workers were left more vulnerable since they were more likely to be essential, requiring them to still work (like grocery store workers, fast food workers, and delivery drivers). Also, lower income people are more likely to live in more crowded settings, increasing risk to everyone in the home. Black and Hispanic people on average tend to have less income than white people (Pew Research Center, 2021), and therefore were put at greater risk of infection.

There were already deep inequalities that existed well before the pandemic, and many were exacerbated by the economic crisis in the early 2000s (Perry et al., 2021). Again, those that have higher income also typically have higher levels of education, so they also tend to have jobs that can accommodate working from home, decreasing their risk of contracting COVID (Torpey, 2018). White and wealthier people might have less risk of complications after contraction because they are more likely to be insured (Grooms et al., 2020), tend to have more trust in their doctor (Boulware et al., 2003), and can afford experiences and habits that keep you healthier, like

exercising in a gym and eating fresh food (Hilmers et al., 2012). Older people also are more likely to have higher earning jobs and be at a more senior level, so they have greater job security (Palmer, 2020). This literature review demonstrates that how disease interacts with inequality is also a global issue, not just isolated to one country.

Blundell et al. (2020) conducted a literature review on the interaction of pre-existing inequalities and the impact of COVID-19 in the United Kingdom (2020). They found that people that live in poorer neighborhoods and identify as an ethnic minority had higher death rates after contracting COVID. Female, lower income, minorities were more likely to have health complications after contracting COVID. There was also a high correlation of being lower income and having a health condition, whether it be mental or physical, so this puts lower income people at higher risk of complications when contracting COVID, and at higher risk of social isolation (Blundell et al, 2020).

Vaccination policies are mainly developed to reach a large percentage of the population to protect people against diseases. With these persistent issues of inequality stressed by the pandemic, vaccination was seemed to be the best way to stop the pandemic, and "return to normal," but there are also inequalities existing within vaccination campaigns and protocols for different diseases, such as influenza. Influenza, or more simply known as, "the flu" is an illness that is predominantly spread through the air by infected droplets (through a cough or a sneeze) (Hall, 2021). There are new strains very frequently which makes building an effective vaccine every year a challenge. Every year, the CDC estimates that there have been anywhere from 9

million to 41 million people sick with the flu each year, and children, the elderly, and immunocompromised people are at risk of complications and hospitalizations (Reed et al., 2021).

Factors influencing vaccination uptake

This subsection discusses research on factors that affect influenza vaccination uptake. A 2008 study analyzed flu vaccination coverage in the United States by conducting a random phone dialing survey of about 250,000 people that were 50 years of age or older (Linn et al., 2010). The researchers found a significant positive correlation between age and vaccination coverage. Black and Hispanic people had lower vaccination rates than white people, Asian Americans, and Native Americans. Older people are more likely to get vaccinated most likely due to their higher risk mitigation (Linn et al., 2010). Black and Hispanic people having lower rates of vaccination can be caused by not having insurance, fears about vaccines, or not having access to resources to learn that it is useful.

Sanders-Jackson et al. (2021) used the National Health Interview Survey Data for 2017 and 2018 across racial/ethnic groups in the US and performed logistic regression on this data. Overall, they found that regardless of race or ethnicity, being over 65 was positively correlated with vaccination uptake. Men had lower rates of vaccination than women. There was a positive correlation between higher education and higher uptake, except the inverse effect was seen for Asian people and it was not significant within Hispanic/ Latino people (Sanders-Jackson et al., 2020). Income had a significant positive correlation with vaccination rates only within white and Black people, it was not significant for Hispanic/ Latino and Asian people (Sanders-Jackson et al., 2020). This finding tells policymakers that just targeting lower income people for vaccination

campaigns might not be as useful as they might think. This difference may exist due to cultural differences, and views and norms around healthcare and vaccination.

Endrich et al. (2009) researched vaccination uptake and demographic trends in other countries to figure out if vaccination inequality is an American problem, or a worldwide one. The main findings of this study were that gender, number of residents in a household, education level and income level show a significant impact on vaccination uptake, but in varying levels based on country. Overall, the strongest predictor of someone being immunized against the flu is if they were a part of a "risk group" (being 65+, having a chronic illness, working in the medical field) (Endrich et al., 2009). These countries all have varying structures of government and differing healthcare policies, and this study demonstrated varying results of some factors being significant or not depending on the country, verifying that policy action can make a difference when combatting vaccination inequality.

Sato et al. (2020) analyzed if bolstering their vaccination campaign reduced inequalities previously seen in uptake of the flu vaccine. In 2013, before Brazil revitalized their campaign, a Black person with a lower education level was most likely to not have been vaccinated against the flu. People 80 years and older were the most common to be vaccinated which is a common trend seen throughout multiple studies. However, by 2015, there was no statistical significance between vaccination coverage based on socioeconomic status (income and education level), skin color and sex. (Sato et al., 2020). This study demonstrated the importance of having a national health care system and free access to vaccination.

Galarce et al. (2011) conducted an online survey of 1569 people 18 years of age and older to examine which sociodemographic factors influence vaccination against H1N1 amongst US adults. Black people were the most likely racial group to express difficulty in finding access to a vaccination, and that people with a high school diploma showed the lowest rates of vaccination. Those with a bachelor's degree were 70% more likely to trust that the vaccine was safe than those with a high school diploma. 18–29-year-old people were the most likely age bracket to have gotten vaccinated against H1N1. When surveyed about the seasonal flu, females were more likely to get vaccinated than males, and people over 60 years old were six times more likely to be vaccinated than 18-29 year old people (Galarce et al., 2011).

Understanding which people are not vaccinating can give health experts and policymakers greater insight into how to better tailor the rollouts, as they can learn how to better target these groups to go out and get vaccinated. For example, Black people that have lower education and already vaccinated against the flu were the most likely demographic to want the vaccine but could not find availability (Galarce et al., 2011). This may be occurring because lower education is likely to mean that they also have a lower income, so they may live in poorer, densely packed neighborhoods that do not have as many vaccination sites per capita. It may also be harder for lower income people to find time to go get vaccinated since service level jobs that tend to be lower wage have unpredictable schedules and it is more difficult to take time off. They might be overwhelmed by other issues too, like childcare. This means that neighborhoods that consist of this demographic should be the first to have more vaccination sites and greater resources on how to find an appointment, since they would be the easiest to help to get vaccinated since they already expressed interest.

H1N1 research was also conducted in France. Vaux et al. (2011) conducted a cross-sectional survey which studied which factors were the most impactful in getting vaccinated against the seasonal flu and H1N1. France offered free vaccinations to combat the H1N1 pandemic in 2009, and this study was analyzing who got vaccinated and what were the most important determinants. Overall, uptake was the highest for both vaccines when the head of the household had a college degree and had a higher-level managerial job (Vaux et al., 2011). There were certain factors that led to someone being more likely to get vaccinated, such as education level and profession level. Education and higher level profession status may have positively influenced the vaccination rate because the person may be more educated on health issues and be more cautious and because they likely have a higher paying job, so they likely have access to insurance, and more time to go to a health office and get vaccinated.

Influenza is not the only vaccine before COVID that is demonstrating an unequal rollout, research has also been conducted on tetanus and shingles and similar results have been found. In 2022, Vogelsang and Polonijo (2022) studied over 200,000 United States adults (60 years and older) through the Behavior Risk Factor Surveillance Systems survey from 2017. The purpose was to analyze which socioeconomic factors and health history factors are correlated with shingles vaccine uptake. They found that lower uptake was associated with having a job or career, living with dependents, and poor rated self-health. Non-Hispanic older white people are almost 50 times more likely to vaccinate against shingles than Black and Hispanic older people (Vogelsang and Polonijo, 2022).

In Germany, Böhmer et al. (2011) examined the most impactful factors of the uptake of the tetanus and flu vaccine among German adults. This was assessed by conducting 21,162 telephone interviews of the German adult population. They found that older people were much more likely to be vaccinated against both tetanus and the flu, and those of a lower socioeconomic status were less likely to be vaccinated. Also, those with health insurance had a greater rate of vaccination, however, if the insurance did cover the vaccine and an out-of-pocket cost was required, the likelihood of vaccination decreased. Those that said they felt they had a lack of knowledge about the vaccine also reported lower uptake (Böhmer et al., 2011).

Those that have a higher income have more time available to take off work, make a doctor's appointment, and the means to go to the health office (Graf, 2020). Having access to a trusted physician boosts vaccination uptake, and higher income people are more likely to have a trusted physician. White people are more likely to get vaccinated for shingles than any other group (Vogelsang and Polonijo, 2022). White people on average have a higher income and education level in the United States, (Chetty et al., 2020) so this may make accessing vaccines easier. This presents income and health inequality that has been seen in multiple countries across different kinds of vaccinations.

COVID-19 Vaccination Uptake

As demonstrated by various vaccination campaigns across the world, vaccines seem to be struggling to reach people with less money and education (Böhmer et al., 2011). COVID-19 is no different. Research has been conducted on willingness to vaccinate, before the vaccine was

released, and then on who was being vaccinated once the rollout started. This literature review will be discussing both.

Willingness

Nikolovski et al. (2021) surveyed US adults who are 65 and older via a mobile application about their willingness to get vaccinated against COVID in November 2020, attempting to examine the demographic and economic factors that were the most correlated with willingness. The majority of people surveyed expressed that they were willing to get the COVID (91.3%). When asked why, they most mentioned the safety and efficacy of the vaccine and with vaccines in general. However, women and Black people reported overall less willingness, and 66.2% out of these groups said that they would want to consult their doctor before making their final decision. White people were the racial group most likely to report willingness to vaccinate, along with those that had a higher income and higher educational attainment levels. Positive news about vaccine development and trials increased willingness to vaccinate across all demographic factors (Nikolovski et al., 2021).

People with a higher income and higher education are more willing since they have learned how to quickly access reliable information (Jansen, 2020). A large part of having higher information is knowing how to access information, and they were more likely to find trusted sources discussing the efficacy of the vaccine. As previously discussed, they also likely have more time to make and go to an appointment that lower income people (that are predominantly people of color) may not have. White people tend to have more money and higher education than ethnic minorities, accounting for the difference in willingness. As for women, they tend to make less

money than men, and potentially less time to seek out an appointment because of this (Bobbitt-Zeher, 2007), which may be why they were less willing. Overall, it is important for news about the vaccine to be reliable and accessible since reporting about the positive progress increased willingness.

Similarly, researchers studied which factors were linked to COVID-19 vaccine willingness in the United States by surveying 1012 adults in July 2020 (before the vaccines were available) (Viswanath et al., 2021). 68% of people agreed to vaccinate themselves and 65% of people agreed to vaccinate their dependents. Black people with low levels of education were significantly less likely to be willing to vaccinate. This can be caused by medical trust due to prior experimentation on Black people by the US government, lower levels of education making literature of the vaccine less accessible or having a lower income that makes finding time to go to a vaccination appointment more challenging. Republicans, people that watched conservative media news outlets, and those who expressed a lack of trust in scientists were the least likely to be willing to get vaccinated. This can be caused by political efforts to curtail COVID spread being viewed as by an infringement of freedoms by right-leaning people. Those that viewed themselves as potentially being more susceptible or more likely to experience complications upon contraction can explain why those with more education are more likely to vaccinate (Viswanath et al., 2021). They are more likely to be reading studies discussing the harmful potential consequences of having COVID, they may be older and more anxious about the risks, or immunocompromised, or other reasons as well. Overall, these studies expressed the importance of an educated public to keep each other healthy.

Malik et al. (2020) used an online platform to survey 672 US adults in May 2020 before the release of the COVID vaccine, and asked questions about perceptions of the pandemic, how likely they would get vaccination, and their trust in information sources. 67% of respondents said they would get vaccinated. Older adults (78%) were more likely to express willingness than younger people, again, likely due to perceived risk and having greater access to medical care out of necessity. Males (72%) were more willing than females, and Asian people (81%) were the most likely racial group to be willing to get vaccinated. Those with an undergraduate college degree or higher (75%) were more likely than those with less than a college degree (Malik et al., 2020).

The researchers also examined current influenza vaccination status and compared that with willingness to get the COVID vaccine. Those without a high school education had very low flu vaccine uptake (10%), but 60% did say they would be willing to get the COVID vaccine. Out of all the other racial groups, Black Americans were the least likely to be vaccinated against the flu and the least willing to get the COVID vaccine (Malik et al., 2020).

This study furthers the point that low income, lower educated, and minority communities (particularly the Black community), is in greater danger of COVID infection and complication. Later data proved that lower income, lower educated, and minority communities were not getting vaccinated at the same rate as wealthier, higher educated, white people (Kaiser Family Foundation, 2022), and are therefore at greater risk. This study demonstrates how interconnected these socioeconomic and demographics are. Finding that Black people were also less likely to get vaccinated against the flu demonstrates that medical mistrust may be a factor, along with not

having as accessible health services as people with more money and resources. People with less money and resources and communities with a higher proportion of minorities are at greater risks of outbreaks and may need more extensive policy options to protect them.

In Australia, Wang et al. (2021) conducted a study in South Australia from May – July 2021 to assess which factors are associated with COVID-19 vaccination uptake, intentions, and community acceptance. All 3003 participants were 18 and over and were interviewed via telephone. 30% of those surveyed were already vaccinated, and vaccination rates were lower amongst those that were younger, without chronic illness, of a non-English speaking culture, and did not have a child less than 16 years old. Of those that were not yet vaccinated, 39.3% expressed that they would be willing to get vaccinated. 8.1% were not willing at all. People that tended to be more willing had the highest socioeconomic status of the respondents had more than a high school level of education, while people that were the least willing had the lowest socioeconomic status, and had a high school education or less. Indigenous Australians were more likely to be undecided or unwilling than non-Indigenous people (Wang et al., 2021). Also, younger people with low education were yet again seen with lower uptake than those that were older with more education.

People with a higher SES were more likely to be willing to get vaccinated, most likely for similar reasons that have been discussed throughout this literature review, being more knowledgeable about the benefits of vaccination, and having the time and resources to go get one. It is interesting to see this trend persist even in Australia, demonstrating that this issue is not at all localized to America. Married people may be more likely because they are older and more

cautious, or also may feel a greater obligation to not only protect themselves from COVID, but also their partner. This study found that vaccinated parents were more likely to vaccinate their children, and this happening can be caused for similar reasons as why married people are more likely. They want to protect their family along with themselves from disease and may have more resources to do so.

COVID Vaccination Rates and Socioeconomic Patterns

Studies have also been conducted to examine COVID-19 vaccination rates and the socioeconomic patterns on who was being vaccinated during the rollout. One study (Agarwal et al., 2021) examined the differences between the uptake of the COVID-19 vaccine and the influenza vaccine in April 2021. County level data (n=756) was analyzed to calculate COVID-19 vaccination disparities (CVD), which was defined "as the rates of those receiving at least one vaccination dose for Whites less than for Blacks, where a higher value suggests greater disparities for Blacks." This was then contrasted with flu vaccine disparities (FVD).

The researchers found that the average percentage of CVD was 16%, and that vaccine hesitancy was not significant in causing this disparity. The higher the proportion of Black residents in the county, the higher the levels of Disparities, even when controlling for hesitancy was negatively correlated with median income and education level. Political ideology is strongly correlated, with communities that had a greater proportion of voters of Republican candidates. When examining flu vaccine disparities (FVD), education and the proportion of Black residents was unrelated to the level for disparity (Agarwal et al., 2021). The researchers found that the most impactful variables that determined disparities of receiving a COVID-19 vaccination were "median

income, education, and political ideologies." The researchers also determined that the most significant reason for Black people not getting vaccinated at a slower rate than White people is due to socioeconomic and political factors. Controlling for hesitancy and still finding that more Black residents in a county is strongly associated with higher levels of CVD is important because a main explanation people have used when seeing trends of low uptake among Black people is that they are just hesitant and there are no more systemic reasons for this difference. The researchers also noted that the willingness expressed by Black people to get vaccinated has only been increasing, so this research suggests that there are other reasons that they are not getting vaccinated at the same rate as other ethnic groups (Agarwal et al., 2021). It is possible that there are not as many vaccination sites per capita in Black neighborhoods, Black people are more likely to be lower income and have less education (Pew Research Center, 2020), which can also contribute to being not as knowledgeable about the vaccine, or not having as many resources to make and attend an appointment. Education is once again seen as a strong indicator of uptake. This was not important for flu vaccine uptake, implying that the outreach for the flu vaccine may be better than the one for COVID and policymakers should look to see how they can make COVID vaccine campaigns similar. It can also be because vaccinating for the flu has been common for many years, so people may feel more comfortable. Supply is also higher for the flu vaccine, and many pharmacies can vaccinate people same day without an appointment.

Also, Brown et. Al (2021) uses the data from the CDC Control and Prevention COVID Data Tracker and the COVID-19 Community Vulnerability Index (CCVI) to examine the relationship between socioeconomic vulnerability and adult vaccination rates in 2,415 U.S. counties. Their findings revealed that there were lower rates of vaccination in counties that had lower

socioeconomic status, and in areas that consisted of more Black residents (Brown et. al, 2021). Even more specific, Michaels et. al (2021) found significant associations between lack of internet access and higher rates of being unvaccinated. Using the data collected in April 2021, the authors found that ZIP codes with higher percentages of households without internet access also had lower percentages of adults with greater than or equal to one COVID-19 vaccine dose in New York City. While the report was careful to not imply causation, they did remind that internet access is one of the social determinants of health, and that their findings were consistent with expressing that not having internet is a barrier to vaccination (Michaels et. al, 2021). The rollout plan in the United States made it so the best way to make an appointment was online. It was possible to call, but with demand high and availability low, anything slowing down the process to book the appointment decreased one's odds of securing one. Having a stable internet connection and a device to book the appointment requires money and time, which could be part of the reason why those with lower income and of a minority status are not being vaccinated at the same rate. These studies continue to explain the inequalities within COVID vaccination rollout across the United States.

The Kaiser Family Foundation (Tolbert et. al, 2021) analyzed how vaccination rates differ by counties and what key attributes are associated with higher or lower uptake. The researchers analyzed data from the CDC; the Social Vulnerability Index, and community transmission level and data from the US Census Bureau to find residents' age, race, poverty level, and health coverage status. They found that political ideology is an important factor, as counties that voted for Biden over Trump have higher levels of vaccination rate. Also, there is a negative correlation between vaccination rates and the level of social vulnerability as seen by data supporting that

people that are uninsured and impoverished are more likely to not be vaccinated (Tolbert et. al, 2021). This data is indicative of political and socioeconomic links to vaccine acceptance. The people that need the vaccine most are not being vaccinated and are in greater danger of health complications if they contract the virus.

Researchers examined the Wales Immunisation System (WIS) and the Welsh Demographic Service Dataset and their census data between December 2020 – April 2021 to examine inequalities of COVID-19 vaccination coverage in Wales (Perry et al., 2021). The study had datasets of over 1.2 million people that were all over 50 years of age. Uptake overall was high, but inequalities persisted despite the free healthcare that Wales has. White people were the most vaccinated racial group. Black people were 21% less likely to get vaccinated than white people. While Wales has higher rates of vaccination overall, which can likely be credited to their inclusive healthcare services, there is still disparity between racial groups. This study was early on in the rollout and gave early warning to other nations to watch for disparities as well.

These studies show evidence of disparities in vaccination by socioeconomic and demographic factors. However, most research showed this on a national level. Within a nation are different cultural values, geographic differences, and many other variables. This thesis analyzes COVID-19 vaccination data on a ZIP code level scale within New York City, a much smaller unit that still has a lot of diversity within. The purpose of this is to demonstrate how disparities are occurring within a small scale, under the local policy guidance of just the New York City Government and New York State Government. Many studies looked at county level data as their smallest unit of measure, but this thesis will go even smaller to ZIP code to demonstrate that

there are still differences occurring on this level. This thesis stresses the importance of local government, because there are so many issues that can happen even within a small geographic area.

Table 1 - Summary of Related Literature

A table was created to summarize the findings of the related literature. The variables that I am investigating are at the top, and then the articles in the literature review are along the side. The table is split into three categories, COVID-19 cases (red), vaccination uptake for vaccines other than COVID-19 (blue), and then COVID-19 vaccination uptake (yellow). If there is a plus sign, that means that the article examined this relationship between one of the three categories and found a positive correlation. If there is a minus sign, that means that article examined this relationship and found a negative correlation. If there is no marking in the box, this means that the article did not investigate this variable. I also created a separate category called "Multiple Time Periods?" This means that the article reviewed the relationship during different periods of time. This was a unique element of my thesis, and I wanted to highlight that not many other authors took this approach.

For COVID-19 cases, all the articles I reviewed examined earnings and found a negative relationship between having higher earnings and COVID-19 cases contracted. If the article examined race, it was typically only focusing on the Black population. Some articles focused on education, but not all. Age, population size, sex, internet access, and political affiliation was not examined or mentioned in any of the articles in my literature review. There was only one time period looked at as well.

For general vaccination uptake, all the articles examined age, and found that areas that consisted of older people were also more likely to be vaccinated. About half the articles examined earnings. If the article examined race, it was typically focused on the Black population, some also examined the Hispanic/ Latino population. Only one examined the Asian population. Roughly half examined education and sex. Population size, internet access, and political affiliation was not examined or mentioned in any of the articles in my literature review. Only two of the articles looked at multiple time periods. Sato examined Brazil's vaccination program effectiveness in 2013 and 2015, and Endrich compared National household surveys in Europe from 2001-2002 and 2007-2008.

For COVID-19 vaccination uptake, most articles examined the Black population and all found a negative relationship. Five out of six articles examined the impact of higher education and found a positive relationship. Only two articles examined earnings and found a positive relationship. Only two articles examined age and found a positive relationship. None examined over the course of multiple time periods. Only two articles examined sex and found a positive relationship between being male and being vaccinated. Only one article examined Asian populations and found a positive relationship, none examined Hispanic/ Latino populations. Only two articles examined political affiliation and found a negative relationship between uptake and right leaning ideologies. Population size and internet access were not examined.

Table 1 - Summary of Related Literature

Article	Older Age	Higher Median Earnings	Higher pop. size	Black pop.	Asian pop.	Hispanic/ Latino Pop.	Higher Edu.	Male pop.	Having Internet Access	Political Ideology/ Party affiliation.	Multiple time periods?
COVID-19 Cases											
(Whittle & Diaz-Artiles, 2020)		-		+							☐
(Maroko et al., 2020)		-		+		+	-				☐
(Blundell et al, 2020)		-					-				☐
Vaccine Uptake (general)											
(Linn et al., 2010)	+	+		-	+	-	+	-[1]			☐
(Böhmer et al., 2011)	+	-									☐
(Vogelsang & Polonijo, 2022)	+			-		-					☐
(Sato et al., 2020).	+	+[2]		-[3]			+[4]	-[5]			☑
(Endrich et al., 2009)	+										☑
(Galarce et al., 2011)	+			-		-	-	-			☐
(Vaux et al., 2011)	-						+				☐
COVID-19 Vaccination Uptake											
(Nikolovski et al., 2021)		+		-			+	+			☐
(Viswanath et al., 2021)				-			+			-	☐

Article	Older Age	Higher Median Earnings	Higher pop. size	Black pop.	Asian pop.	Hispanic/ Latino Pop.	Higher Edu.	Male pop.	Having Internet Access	Political Ideology/ Party affiliation.	Multiple time periods?
(Perry et al., 2021)				-							☐
(Agarwal et al., 2021)		+		-			+		NR	-	☐
(Wang et al., 2021)	+						+				☐
(Malik et al., 2020)	+				+		+	+			☐

Key:
A plus sign indicates that there is a positive relationship found by the researchers between the variable listed in the table and the vaccine variable (whether it be COVID case count, vaccine willingness in general, or COVID-19 vaccination willingness).

A minus sign indicates that there is a negative relationship found by the researchers between the variable listed in the table and the COVID variable (whether it be case count, vaccine willingness in general, or COVID-19 vaccination willingness). If the box is blank, the researchers did not cover that variable.

NR: Means the variable was studied, and no relationship was found.

There is a check box in each "Multiple time periods?" box. A checked box indicates that the researchers examined two different time periods and compared results.

Only sources were included in this table if the studies were empirical. Other literature reviews I referenced were not included.

Red: Studies relating to COVID-19 cases directly, not vaccinations
Blue: Studies discussing factors that impacted vaccination uptake (not specifically the COVID-19 vaccine)
Yellow: Studies discussing factors that impacted COVID-19 vaccination uptake

1. Males were found to have less vaccination uptake between ages 50-64, but there was not a significant difference between the ages in people 65+
2. This study compared Brazil's flu vaccination programs in 2013 and 2015 to see if the equitably improved. All the plus and minus signs are for 2013, because by 2015, there was no significance found between flu vaccination uptake and socioeconomic status, race, or sex.
3. See 2
4. See 2
5. See 2

4. Theory & Hypotheses

In this research, I focus on the effect of age, gender, race, earnings, population size, internet access, political leanings, and educational attainment on COVID vaccination rates. The first recorded vaccination rate data was pulled from the New York City Department of Health on May 22, 2021. At this time, supply was low, demand was high, and eligibility requirements were in place. Those not vaccinated at this time either did not qualify, had access issues, or did not want to be vaccinated. Data was then pulled later in the rollout, February 28, 2022 (*COVID-19: Data*, 2022). By this time, supply had increased and eligibility had expanded. Mandates were in place that would have made living in NYC without proof of vaccine challenging, so it is likely those not vaccinated by late February 2022 did so due to personal hesitancy and not accessibility issues. These two vaccination rates will then be compared, to see which socioeconomic factors led to greater access earlier in the rollout versus later.

The difference is though that this thesis will compare all these variables in the same paper, where the other studies did one or two variables together at most. Also, this study examines the COVID vaccine uptake at the ZIP code level, instead of the typical county boundary that is seen in much of the literature. This is to demonstrate that there are still these stark differences seen even in such a small geographic area like New York City. Cities contain much diversity, not just by race, but by socioeconomic factors as well. It is important to recognize that nation-wide disparities can even be seen in counties that are commonly claimed to be homogeneous in ideology.

Young adults became eligible later than older adults, but uptake has still been slower amongst younger people since they may feel less urgency to get vaccinated as young people (Anthes,

2021). Surveys have shown that they are typically less willing to get vaccinated than their older counterparts, with “24.9% of 18- to 39-year-olds surveyed [saying] they would probably or definitely not get vaccinated” (Anthes, 2021). Also, 94.2% of people over 65 years of age have received at least one vaccination, while this only applies to 73.7% of people 18-24 years of age (United States Census Bureau, 2021). The younger generation also has less financial stability than the older generations, despite being better educated than them (Leonhardt, 2019). This might mean that younger people have less time and resources to access a vaccination appointment, than the older generation does. Based on these observations, **I hypothesize that vaccination rates are higher in older populations**.

In multiple studies, education level was found to be one of the most impactful variables concerning COVID-19 vaccination uptake, unexpectedly even more important than race (Agarwal et. al, 2021 & Miller, 2021). Miller’s study found that 76% of U.S. adults with a bachelor's degree or higher either have the vaccine or intend to get it, countered by 53% of those without a college degree (2021). In 3,142 U.S. counties, Van Beusekom found that the absence of a high school education “was the most important predictor of COVID-19 vaccine hesitancy” (2022). **I hypothesize that vaccination rates are higher in populations with higher educational attainment.**

A lack of internet access was found by the CDC to be significantly associated with being unvaccinated (Michaels et. al, 2021). A bivariate choropleth map was used to visualize ZIP code level data on vaccinations and internet access by households, and the biggest disparities were found in the Bronx and Brooklyn. In New York State, the distribution plan was to have

appointment scheduling be predominantly online (more details and examples as evidence). It was advertised as the "quickest way to confirm you're eligible and make an appointment" (*Distribution of the Vaccine*, 2021). This plan also means that people without access to the internet are left behind since appointments need to be scheduled online at the beginning of the rollout. **I hypothesize that vaccination rates will be higher in populations with broadband internet access in the earlier phase of vaccination distribution.**

When data early into the outbreak demonstrated that minorities were more likely to contract the virus, it would be assumed that these communities would be vaccinated the earliest to curtail the strong negative impact COVID was inflicting on minority communities specifically (*COVID-19 Data*, 2022). However, multiple studies revealed that there were significant differences in vaccine uptake based on race, and that areas that consisted of more Black and Hispanic residents had lower vaccination rates (Brown et. al, 2021). This may be due to the fact that Black and Hispanic people on average have lower earnings than white people and therefore less time or lessened access to healthcare (Pew Research Center, 2020). Black people have also been shown to be more hesitant to get vaccinated as well, potentially due to years of medical experimentation on Black people conducted by the US government (Watson, 2020). **I hypothesize that communities with a higher percentage of minorities such as Black or Hispnaic population have lower vaccination rates.**

Research found that crowded areas had a higher rate of infection (Whittle and Diaz-Artilles, 2020). It may also be true that these ZIP codes will be harder to vaccinate since there are more

people to serve. **I hypothesize that communities with larger populations have lower vaccination rates.**

Income level was also determined to be a significant variable by multiple studies. This is potentially due to people with more income having greater access to medical care, having stable jobs, and more time to go and seek out an appointment. Those with a higher income also are likely to have more education, and the skills to research the vaccine. Argarwal determined it to be one of the most impactful variables to predict vaccination uptake and Herman found that 22% of people making less than $25,000 were unvaccinated, but only 7.4% of people making $150k and above were unvaccinated (2021). **I hypothesize that communities with higher earnings levels have higher vaccination rates**.

There have been variances in vaccine uptake based on gender noted by the CDC (U.S. Department of Health & Human Services, 2022). Researchers have hypothesized multiple reasons for this; traditional masculinity has led men to be less likely to seek out medical care, women are more likely to take preventative health measures (potentially because they are more risk averse), and the political gap between men and women (Puzio, 2021). Women are more likely to seek out preventative care, make up the healthcare workforce, and have longer lifespans, so they were more likely to be eligible earlier since they make up a greater proportion of the older population (Ungar, 2021). **I hypothesize that communities with a higher proportion of males have lower vaccination rates.**

Politics has also played a role in the decision to vaccinate because the pandemic has been highly politicized from the beginning. There were political debates over whether or not to mask to protect people against outbreaks, if business should shut down, and if social distancing was necessary conservative leaning people argued that such measures were a restriction on personal liberties, while liberal leaning people argued their necessity to protect people from the outbreak. The decision was made to acquire donor data in 2020 from *The New York Times* because ZIP code political data was not accessible (Shorey & Rebecca, 2019). Donor data was used as a proxy for the political leanings of a ZIP code. **I hypothesize that a community with a higher percentage of Trump donors have lower vaccination rates**.

5. Data and Method

Data Collection

The subject area of this analysis is the New York City area, encompassing all five boroughs (Queens, Brooklyn, Manhattan, The Bronx, and Staten Island). New York City is diverse in many ways, including racially and economically. This means that a sample of people living in a very small area can be used to investigate factors influencing vaccination rates, relatively free of distance or travel time effects. New York City was also quicker than the rest of the United States in terms of vaccinations, largely due to political pressure from the former Mayor Bill deBlasio and former Governor Andrew Cuomo ("New York speeds Up COVID-19 Vaccinations," 2021), allowing access to more data on vaccinations earlier in the national rollout. I choose to use ZIP Code tabulation areas as the unit of analysis because examining such a geographically small, but densely populated area like the New York City area required small areas of analysis. There are 177 ZIP codes within New York City (representative of 99.9% of the population). A more

common measure in current literature is counties when examining the entire country or state, but a small subset of New York required a smaller area of analysis, especially since so much diversity can be found even within a county in New York City.

I collected socioeconomic and demographic data from the American Community Survey dated in 2020. My socioeconomic and demographic variables included population of the ZIP code, age, earnings, percentage male, percentage of white, black, Asian, Hispanic/Latino people, percentages by terminal educational level, percentage with broadband internet, and percentages of Trump donors (Shorey & Rebecca, 2020). I investigated the relationships between these factors and the percentage of people with one or more COVID-19 vaccines, at two separate time points to see if there were differences. Data on vaccinations were collected from the New York City Department of Health for May 22, 2021 and February 28, 2022 (*COVID-19: Data*, 2022).[1]

The first date was chosen because it was the earliest that these data were collected and made publicly available. At that point in time, eligibility had been recently expanded to everyone twelve years and up, and the demand was still high, making it an interesting time to start analysis (Mervosh, 2021). It was competitive to get a vaccination appointment, but most were eligible.

[1]In the vaccination dataset on February 28th, 2022, the column on the percentage of residents who have received at least one or more doses of the COVID-19 vaccine sometimes exceeded 100%. The Department of Health stated that this is caused by the Census Bureau not having updated the population counts at the time this data was taken. To account for this, New York truncated the data at 99%, this same strategy was used for the model of this paper. This was the most reliable source that this specific dataset could have been acquired from, and their solution to this problem was adopted.

The more recent data I obtained in February 2022 could be used for making comparison to the beginning of the rollout. Mandates had increased, and new demand for vaccinations had decreased as more people already received the shots. As of December 27th, 2021, New Yorkers twelve years and up were required to show proof of two vaccines (or one shot of Johnson and Johnson) (City of New York, 2021) for gyms, entertainment and performance venues, and indoor dining. Many employees were also being required by their employers throughout the city.

By late February 2022, I assume that those that do not want to be vaccinated have, for the majority, chosen against it. I compare the vaccination rates at the two different points of time datasets, assuming that those who are not vaccinated are doing so as a personal decision. There is not a way to quantify hesitancy, and surveys were not conducted in this thesis, but this was decided as the best way to navigate that issue. Data for the dependent and independent variables were cleaned and merged (using the ZIP code) for analysis. Table 2 shows the descriptive statistics of the main variables. Table 3 shows the matrix of correlations between the independent variables. The correlation matrix was included to demonstrate the relationship between the independent variables. There was a strong positive correlation between earnings and having a Bachelor's degree *(r = 0.941)*. There was also a strong positive relationship between having a Bachelor's degree or more and having access to Broadband internet *(r = 0.772)*. There was a negative correlation between ZIP codes that had a higher population of residents and earnings *(r = -0.492)*. I wanted to demonstrate that some of these socioeconomic variables are highly correlated, and might interact when running regression.

Table 2: Descriptive statistics of independent variables.

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
May '21: One or more vax	177	52.258	14.25	29.06	99.83
Feb '22: One or more vax	177	89.608	21.216	57.96	234.09
VaxDiff	177	33.177	8.026	-.83	52.53
65 years + (%)	177	14.779	5.16	.7	32.8
Ln (median earnings)	177	10.751	.415	10.052	11.958
Ln(population)	177	10.557	.74	8.039	11.626
Black pop. (%)	177	21.367	24.088	.1	91
Asian pop. (%)	177	15.171	14.211	.2	72.2
Hispanic/Latino pop. (%)	177	26.169	19.088	4.3	77.8
Bachelor's + (%)	177	39.537	21.272	9.9	91.2
Male pop. (%)	177	47.884	2.586	39.2	58.8
Broadband (%)	177	81.814	7.886	58.445	100
Trump Donors (%)	174	11.216	16.504	.022	73.82

Table 3: Matrix of Correlations

Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) 65 years + (%)	1.000									
(2) Ln (median earnings)	0.114	1.000								
(3) Ln (population)	-0.027	-0.492	1.000							
(4) Black pop. (%)	-0.147	-0.390	0.199	1.000						
(5) Asian pop. (%)	0.181	0.036	-0.092	-0.496	1.000					
(6) Hispanic/Latino pop. (%)	-0.342	-0.616	0.265	0.052	-0.247	1.000				
(7) Bachelor's + (%)	0.099	0.941	-0.403	-0.469	0.090	-0.562	1.000			
(8) Male pop. (%)	-0.331	0.038	-0.120	-0.446	0.252	0.192	0.009	1.000		
(9) Broadband (%)	0.061	0.772	-0.430	-0.386	0.221	-0.519	0.732	0.119	1.000	
(10) Trump Donors (%)	-0.031	-0.000	-0.094	-0.132	-0.247	0.182	-0.081	0.060	-0.133	1.000

Empirical model

I performed regression analysis to empirically estimate the effect of different factors on vaccination rates at different points of time. The independent (predictive) variables include the size of population (log transformed), the proportion of the elderly, the Black population, the Asian population, the proportion of people with a Bachelor's degree or more, the proportion of males, the proportion of Trump donors, the proportion of those with Broadband internet access, and the average median earnings (log transformed). The Akaike information criterion (AIC) and

the Bayesian information criterion (BIC) were also calculated to compare the model performance in explaining the data (for either AIC or BIC, the model with the smallest value is the best fit).

Specifically, I estimate the regression equation below:

$$y = \beta_1 Age + \beta_2 Earnings + \beta_3 Pop. + \beta_4 Black + \beta_5 Asian + \beta_6 Hispanic/Latino + \beta_7 Edu. + \beta_8 Male + \beta_9 Internet + \beta_{10} Trump + \varepsilon$$

Age = Percentage of people 65 years of age and older

Earnings = Log of earnings

Pop. = Log of the population

Black = Black population percentage

Asian = Asian population percentage

Hispanic/Latino = Hispanic/Latino population percentage

Edu. = Percentage of those with a Bachelor's degree or more

Male = Percentage of males

Internet = Percentage of those with broadband internet access

Trump = Percentage of those who donated to Trump leading up to the 2020 election

Y = Percentage of those vaccinated in the NYC ZIP code of interest

ε = Error term

6. RESULT

I report the regression results in Table 4. Specifically, column 1 reports the estimates of socioeconomic and demographic variables based on the vaccination rates collected in May 2021. The proportion of white people was omitted, as it was used as the baseline category for race. The proportion of Asian people and Hispanic/ Latino people demonstrated positive statistical significance at the *one percent* level, meaning that these populations have higher vaccination rates than the white population. The proportion of those with a Bachelor's degree or more has a statistically significant, positive impact on the vaccination rates. A one percentage point increase

in the ratio of people with a Bachelor's degree or more is associated with a 0.395 percentage point increase in vaccination rates.

Table 4: Regression Models for May 2021, February 2022, and the "VaxDiff"

VARIABLES (%)	(1) May '21: One or more vax	(2) Feb '22: One or more vax	(3) VaxDiff
65 years +	0.271**	0.190	-0.0816
	(0.116)	(0.124)	(0.0811)
ln(earnings)	11.25**	16.03***	4.773
	(4.524)	(4.868)	(3.175)
ln(population)	-1.902**	-1.230	0.672
	(0.784)	(0.844)	(0.550)
Black pop.	0.000801	0.0772*	0.0764***
	(0.0376)	(0.0404)	(0.0264)
Asian pop.	0.496***	0.501***	0.00427
	(0.0504)	(0.0542)	(0.0354)
Hispanic/ Latino pop.	0.271***	0.386***	0.115***
	(0.0419)	(0.0450)	(0.0294)
Bachelor's+	0.395***	0.119	-0.276***
	(0.0809)	(0.0870)	(0.0567)
Male pop.	-0.178	-0.355	-0.177
	(0.250)	(0.269)	(0.175)
Broadband	-0.0715	-0.0913	-0.0199
	(0.102)	(0.110)	(0.0717)
Trump Donors	-0.0146	-0.0244	-0.00987
	(0.0343)	(0.0369)	(0.0241)
Constant	-68.24	-75.88	-7.633
	(46.70)	(50.24)	(32.77)
Observations	174	174	174
R-squared	0.818	0.587	0.720
AIC	1141.6302	1167.0798	1018.3516
BIC	1176.3798	1201.8295	1053.1012

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Vaccination rates are expected to increase by 0.3 percentage point with a one percentage point increase in the ratio of the elderly population (65 and older). One percent increase in median earnings is associated with 11.25% increase in vaccination rates. Communities with a larger population have significantly lower vaccination rates, which is consistent with my hypothesis.

The proportion of Black people, the proportion of males, the proportion of those with Broadband internet access, and the proportion of Trump donors was not statistically significant in May 2021. A surprising finding of this model was that the proportion of Black residents was not significant. I had initially hypothesized that a ZIP code having more Black residents would decrease the rates of vaccination, but this was not the case according to this model. The final model accounted for 81.8% of the variability in the data *($r^2 = 0.818$)*.

Column 2 shows the regression results for modeling the vaccination rates collected in the later phase (February 2022), after the supply of the vaccine had increased and the eligibility limits were greatly lessened. I find that the earnings variable consistently has a significant, positive effect on the local vaccination rates. One percent increase in median earnings is associated with 16% increase in vaccination rates. Similar to my findings in column 1, communities with high percentages of Asian and Hispanic/ Latino populations have significantly higher vaccination rates. This time, the Black population variable was significant. A one percentage point increase in the percentage of Black people was associated with 0.1 percentage point increase in COVID vaccination rate. I find that the other variables though, age, population, education, gender, internet access and the proportion of Trump donors were not statistically significant. The final model accounted for 59% of the variability in the data *($r^2 = 0.587$)*.

For column 3, I used another dependent variable, called "VaxDiff," capturing the change in vaccination rates between the two time points of interest. This is to identify the factors that influence the increased vaccination uptake between these two times. The final model accounted for 72% of variation in the dependent variable *($r^2 = 0.720$)*.

If a variable has a negative coefficient, this means that it was less represented in the group of people who were vaccinated in between this time period. A possible explanation for this is because these groups already got vaccinated earlier in the rollout before May 2021. A one percentage point increase in the percentage of those with a Bachelor's degree or higher was significantly correlated with 0.28% decrease in vaccination rates in between these two time periods. This result suggests that more people with lower than bachelor's degrees got vaccinated during this time period. The percentage of Black people and the percentage of Hispanic/Latino people in a ZIP code was also significantly correlated with an increase in vaccination rates in this time period. This is possibly due to supply increasing as time went on, and more outreach was done to marginalized communities once the vaccines were able to support more people, especially considering the Black percentage was not significant early in the rollout.

Between May 2021 and February 2022 models, all of the independent variables had the same relationship with vaccination rate (positive or negative), however, the significance sometimes changed. Being 65 or older was significantly correlated with higher vaccination rates in May 2021. In February 2022, it was not significant. Communities with a higher ratio of elderly people have significantly higher COVID vaccination rates earlier into the rollout, but age was not a significant predictor later on. This is likely due to the elderly getting vaccinated earlier on, since they were a prioritized group by New York State's tiered vaccination rollout policy (ABC Inc., 2021). This finding suggests the initial eligibility requirement does affect vaccination uptake because the vaccine was first accessible to the elderly, when a positive significant relationship was found (*COVID-19: Vaccine*, 2020). When the eligibility requirement was removed, more

people of other age groups got vaccinated and that is likely why the variable is no longer significant in the second time period. Older people are more risk averse, and have more time to seek out medical treatment since they are more likely to be retired and not burdened by childcare and careers.

The same effect happened for the population variable and the education variable. An increase in population size was significantly correlated with a decrease in vaccination rates in May 2021. In February 2022, population size was not significant. This may indicate greater outreach happened later in the rollout to more dense neighborhoods. Vaccination sites were strained with high demand and low supply early on, which likely made living in a highly populated area even more difficult to access a vaccine. As the rollout progressed, more vaccination sites were opened, which made population size a non-significant factor in vaccination uptake.

Communities with a higher proportion of those with a Bachelor's degree tend to have higher vaccination rates in May 2021, but education was not a significant predictor in February 2022. Those with a Bachelor's degree may have been more willing to vaccinate earlier in the rollout since they know where to find reliable information on the vaccine. They also tend on average to have higher paying jobs, which increases the likelihood they have the resources to take off work, navigate the scheduling website, and transport themselves to their appointments.

The significance and the magnitude of the coefficient estimate increased for the logged earnings variable and the Black population variable in the second time period. The income variable has greater explanatory power for vaccination in February 2022 than May 2021. The same effect

happened for the Black population variable. The proportion of Black people in a ZIP code was not a significant predictor of vaccination in May 2021. In February 2022, one percentage point increase in the percentage of Black people in a ZIP code was significantly correlated with a 0.1% increase in vaccination rates. The percentage of Black residents in a ZIP code was not a significant predictor of vaccination early in the rollout, but was later. This indicates there may have been accessibility issues for the Black community earlier on, and increased availability and outreach improved access later.

ZIP codes with a higher percentage of Asian people were significantly correlated with increased vaccination rates in both phases, with similar estimated coefficients. Similar results are observed for the Hispanic/ Latino population. The magnitude of the estimated coefficients was lower than that of the Asian population variable. But, in both May 2021 and February 2022, there was a significantly positive correlation between ZIP codes with a higher percentage of Hispanic/ Latino people and vaccination rates. Out of all the race and ethnicity variables, the Asian population had the strongest positive relationship with vaccination rates, then the Hispanic/ Latino population variable, and then the Black population variable.

Lastly, some variables were not significant in May 2021 or February 2022. These variables were gender, broadband internet access, and Trump donors. The proportion of males, those with internet access, and those that donated to Trump was not a significant predictor in either time period.

Lastly, I show Variance inflation factor (VIF) in Table 5 to check for the potential multicollinearity problem. The highest VIF was seen in the logged earnings variable at 15.36, and the overall mean VIF was 4.62. The VIF suggests that there are interactions occurring between the variables, which was expected. Earnings and education seem to be having the most interactions, which was expected and not possible to separate.

Table 5: Mean VIF

Variable	VIF	1/VIF
Ln(Earnings)	15.36	0.065097
Bachelor's +	12.98	0.077052
Black pop.	3.68	0.271616
Broadband	2.86	0.349926
Hispanic/ Latino pop.	2.77	0.360908
Asian pop.	2.26	0.441882
Male pop.	1.86	0.536629
65 and older	1.56	0.639417
Ln(population)	1.44	0.692285
Trump Donors	1.42	0.702808
Mean VIF	4.62	

7. DISCUSSION

The unique element of this research was the use of the two different time periods. In May 2021, I assume that access would be a major barrier to getting the COVID vaccine (or policies that hindered access) since the supply vaccine supply was low and many policies were in place to determine eligibility. ZIP codes with a greater proportion of people 65 and over, people who have higher earnings, people with higher educational attainment, or smaller population sizes have higher vaccination rates. ZIP codes with a higher proportion of Asian people and Hispanic/ Latino people had a higher rate of vaccination uptake in May 2021 as well.

By February 2022, I assume that hesitancy would be the major barrier to getting the COVID vaccine since the supply was much higher and tiered rollouts had been filtered through. Strict vaccination mandates were enacted in NYC. Those without proof of vaccination would be risking their employment, and could not enter fitness, entertainment, and many other establishments throughout the city (deBlasio, 2021). Not being vaccinated at this point would make life in New York City much more difficult, so it is more likely that not vaccinating at this point was a personal choice and not due to barriers. A ZIP code with higher median earnings, a higher proportion of Asian people, a higher proportion of Black people, and a higher proportion of Hispanic/ Latino people tend to have higher vaccination rates at this time. Since the percentage of those who have high earnings and the percentage of Asian and Hispanic/ Latino people were positively correlated with vaccination in May 2021 as well, it seems that these groups did not have strong access or hesitancy issues. The only factor that was not significantly positively correlated with vaccination rates in May 2021, but then was in February 2022, was the percentage of Black people. This may demonstrate an access issue in the beginning, or greater hesitancy at the start of the rollout. There are other potential reasons too, there may not have been as many sites in primarily Black neighborhoods.

My results suggest that earnings is one of the most important determinants for vaccination uptake. ZIP codes with overall higher earnings had the highest significant correlation on COVID vaccination rates. This variable was significant in both time periods, and even increased in significance and magnitude later in the rollout. This was a surprising finding, as I hypothesized that earnings would be less significant as the rollout continued and access expanded.

The proportion of donors for Trump, the proportion of those with access to broadband internet, and the proportion of males did not have a significant impact on vaccination. This might imply that examining donors as a political proxy may not have been the most effective way to analyze political leanings and vaccination, especially since it brings up other issues- like earnings. People with money are more likely to donate, so the donor variable may have been a better indicator of who had more money to donate in the first place. Broadband internet access is also highly correlated with education and earnings, so this variable may not have been the best predictor either. Gender has shown mixed results throughout the literature on vaccination uptake. Some studies have indicated there is no significance, while some have shown that one gender is more likely to than the other. More research is needed on the preventive health habits of males and females.

For the VaxDiff, the regression shows that ZIP codes with a higher proportion of Black people had a significant positive correlation with vaccination uptake. ZIP codes with more Black people were not a significant factor in May 2021, but were significant in February 2022 and during the time period between these two times. This indicates that more Black populations got vaccinated in the later phase as the distribution of COVID vaccine became more accessible and outreach increased. There are many reasons why this may have occurred, and more research on Black people's perceptions of the COVID vaccines is needed. Previous studies have indicated that there may have been potential access issues due to there not being as many vaccination sites in Black communities than there are in non-Black communities (Williams et al, 2021).

ZIP codes that had a higher proportion of people with more than a Bachelor's degree were significantly correlated with decreased vaccination uptake in between the two time periods. This is different than when education had a positive significant relationship in May 2021. This can be due to people with not as much knowledge about the vaccine feeling more comfortable with the rollout as more people got vaccinated. It is also possible that because the relationship between vaccination uptake and higher education was positive and significant in May, that many people with higher education got vaccinated first. This left those who did not, to go and get their vaccine. Education was a positive predictor of vaccination uptake early on, and then a negative predictor later in the rollout.

ZIP codes with more Asian people and Hispanic/ Latino people also have higher vaccination rates throughout all time periods. More research is needed to understand these groups' perceptions of the vaccine and their preventative health care habits, as they are a very diverse group of people that encompass many different cultures and backgrounds.

8. POLICY IMPLICATIONS

Overall, the findings suggest some level of social disparity in COVID vaccination as certain socioeconomic and demographic factors are found to significantly influence the rate of getting vaccinated in New York City. Earnings was the strongest predictor of vaccination in a ZIP code by far in both time periods, this stark wealth gap we are seeing in New York City needs to be rectified.

Education is one of the significant determinants that policymakers have the most control over in expanding access to. Efforts to make education more accessible and affordable can increase the quality of life of New Yorkers. Those with a Bachelor's degree are more likely to have higher earnings, and more likely to get hired in the first place (Schaeffer, 2022). This variable is highly confounded, but regardless, a better educated public is a better protected public from disease. Making higher level education more accessible to those that have had historical barriers to higher education can help keep the public educated and making healthy choices for themselves. New York City has a public university system (City University of New York - CUNY), but they are notoriously underfunded and need more technology programs so the next generation can be ready for that growing sector (Katt & Prashar, 2019).

There were reports that people were crossing into neighborhoods they did not live in to get vaccinated since there were some vaccination sites purposefully set up in underserved areas (Goodnough & Hoffman, 2021). Ensuring that people getting vaccinated at sites, when supply is very low, actually from the area that site serves, can ensure that people are not getting cut in line.

Population size of a ZIP code was also a significant negative indicator of vaccination rates, so more work needs to be done in future vaccination rollouts to ensure that more heavily populated ZIP codes are also getting access to efficient vaccination sites.

Older communities are already likely to get vaccinated on their own, outreach programs to younger groups to emphasize that they are not invincible and should get vaccinated as well might increase vaccination rates among the young. Perhaps establishing COVID-19 vaccination sites

directly on college campuses can help as well, so young people do not need to worry about taking time out of their day, and figuring out transportation to get to a health clinic. College campuses typically already offer the seasonal flu vaccine, so having the COVID vaccine as an option can help protect the younger population and those that interact with them (like family members).

Pandemic readiness plans are needed, unfortunately this will not be the last pandemic NYC and the rest of the world will face, so training more medical staff, using these other strategies listed above, and outlining clear policies and procedures of what to do before the next pandemic can make the crisis feel more manageable. Over the past two years, the government has been making policy in haste. Preparing ahead of time for the inevitable will benefit everyone. Creating policies based on the type of disease (airborne diseases should have policies centered around masking and social distancing at federal level) is important. Just like how there are security procedures in case of different types of emergencies, there need to be pandemic procedures ready as well for different diseases.

9. CONCLUSION

Overall, my findings demonstrate how critical socioeconomic factors are in determining COVID-19 vaccination rates. Socioeconomic status (high earnings and having high educational attainment) are more influential than demographic factors (race and sex) in determining vaccination uptake. Earnings is also the strongest predictor in a ZIP code's vaccination rates, which demonstrates that the growing wealth gap in New York City will become even more

problematic for lower income people. Special attention should be paid to heavily populated ZIP codes, and communities with lower income and education.

This thesis demonstrates that wealth inequality has broader implications. If the vaccine was being accessed earlier by people with higher earnings, this leaves people with lower earnings potentially more vulnerable to disease. These findings could be leverage for different policy options. Smaller impacts might be simpler, like expanding access to the vaccine in areas with lower earnings, lower education levels, and more populated ZIP codes. Increasing outreach and education about the vaccine and tailoring it to those who are more likely to be correlated with those less fortunate or less educated (Agarwal et. al, 2021).

Limitations and Future Work

Finally, it is important to acknowledge the limitations of this study. Political data by ZIP code was not possible to acquire. ZIP codes are not at all commonly used for political data, election districts are. These are much smaller boundaries that do not overlap over ZIP codes, so these boundaries were not able to be overlaid. Ideally, either voting data in a recent election, or party registration by ZIP code would have been acquired to look for correlations of COVID-19 vaccination uptake by political affiliation. Instead, as a proxy, data on which ZIP codes donated to either Joe Biden or Donald Trump was collected by *The New York Times* and used in this model to show some insight on the political leanings of a ZIP Code (Shorey & Rebecca, 2020). This was a fairly sufficient proxy as regions in New York that tend to vote Republican, also donated Republican (such as, Staten Island), and vice versa. While this introduces other

socioeconomic questions, like which ZIP codes have more money to donate, and therefore have a number of donors, this was rectified by using the percentages.

Another limitation of this study is the strictly quantitative nature of it. Reasons that are not able to be accurately measured also play a factor into vaccine uptake and were not accounted for in this study, such as hesitancy. There are a plethora of variables that could have impacted someone's decision to vaccinate or not. Personal reasons to play a role that have not yet been documented, like if someone had a family member that died of COVID and then decided it was time to vaccinate. My model does not account for all the variables that go into the decision to vaccinate, such as religious beliefs, knowing someone who was sick with COVID, distance to a healthcare clinic, etc. More research is needed to determine the intricate variables that could have impacted vaccine uptake, and to find the reasons for hesitancy. More research is also needed to further explain these impacts on attitudes towards vaccination and how future rollouts can be as equitable as possible. More work within the impacted communities needs to be conducted to understand why these trends are occurring and how our healthcare policies can reach everyone.

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