The Impact of Covid-19 Vaccination on Consumer Behavior in the United States

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Abstract

This paper investigates the existence of correlation and causation between US vaccination rates and economic indicators. Specifically, it focuses on the vaccine rollout's impact on the accommodation and food services (AFS) sector as well as the nation's overall gross domestic product (GDP). In order to conduct statistical analysis, this paper uses quarterly state-wide data containing vaccination rates and sector-specific GDP from 2019:Q1 to 2021:Q2. To begin, this paper calculates a Pearson correlation coefficient (r) to quantify the relationship between vaccination rates and economic indicators. The data revealed a high correlation between full vaccination percentages and the aggregate amount the AFS sector contributed to states' GDP ($r = 0.727$, $p < 0.01$). The data also revealed a low, yet nonetheless statistically significant, correlation between full vaccination percentages and the national overall GDP ($r = .287$, $p < 0.05$). Next, in order to understand the underlying causality behind the rise in economic indicators from 2020:Q4 to 2020:Q2, two tests were performed. To begin, a difference in differences analysis was conducted to denote the varying levels of impact vaccination rates had on consumption within the AFS sector. While states such as North Dakota and Florida reflected relatively low difference-in-differences values, California and New York showed much higher values. Furthermore, a regression discontinuity design reveals that factors outside of vaccination rates cause changes in consumption. Ultimately, this paper reveals that while vaccination rates correlate with economic indicators, their effect has so far been limited to certain demographics and is reliant on additional government action.

I. Introduction

Data provided by Our World In Data[1] in December 17, 2021 reported 5.34 million deaths due to the pandemic accross the world. However, the global pandemic caused by the coronavirus disease is not only a human tragedy but also an economic disaster. A joint analysis by the Brookings Institute and the International Monetary Fund projected the 2024 World GDP to be 3% lower than pre-pandemic rates.[2]

After receiving approval from the United States' Food and Drug Administration (FDA), the first vaccine was distributed on December 14, 2020.[3] While the human benefit of the Covid-19 vaccine has been widely publicized, the economic impact of vaccination has remained largely unquantified. Existing literature has investigated the economic impacts of vaccines for diseases such as malaria and influenza.

A study conduted by Barham and Calimeris found that children who were vaccinated as part of a Bangladesh family planning program showed increased cognitive ability due to increased school attendance, which translates to increased future economic productivity.[4] However, a meta-analysis of twenty-six studies examining the impacts of vaccines for different

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[1] Ritchie, H., Mathieu, E., Rodés-Guirao, L., Appel, C., Giattino, C., Ortiz-Ospina, E., Hasell, J., Macdonald, B., Beltekian, D., & Roser, M. (2020, March 5). *Coronavirus (COVID-19) cases - statistics and Research*. Our World in Data. Retrieved December 4, 2021, from https://ourworldindata.org/covid-cases.

[2] Brookings, "Social and economic impact of covid-19," The Brookings Institution, https://www.brookings.edu/wp-content/uploads/2021/06/Social-and-economic-impact-COVID.pdf.

[3] Peter Loftus and Melanie Grayce West, "First Covid-19 Vaccine given to U.S. Public," The Wall Street Journal (Dow Jones & Company, December 15, 2020), https://www.wsj.com/articles/covid-19-vaccinations-in-the-u-s-slated-to-begin-monday-11607941806.

[4] Barham T, Calimeris L: Long-term effects of family planning and child health interventions on adolescent cognition: Evidence from Matlab in Bangladesh. 2008, University of Colorado: Health and Society program, Working paper

diseases found little correlation between vaccination and macroeconomic effects aside from lowered health costs.[5]

However, to the knowledge, this type of causal analysis has not yet been applied to the impact of SARS-CoV-2 on immediate economic indicators and behavioral patterns. A recent analysis conducted by Dongwar *et al*. used the Spearman correlation coefficient to find a moderately significant relationship ($p = 0.05$) between countries' GDP per capita and their vaccination rates.[6] However, their study does not provide insight into the causality of this relationship. For instance, a if GDP rates in respective countries were already increasing, a high GDP might not be caused directly by the vaccine. Furthermore, the causality might be reversed: countries with high GDP per capita will likely invest more in vaccines.

To the knowledge of the author, this study is the first to investigate if Covid-19 vaccination actively change consumer behavior and influences macroeconomic indicators such as GDP and spending in the Accommodation and Food Services industry. This paper is organized as follows: Section 2 presents the data used in this analysis. Section 3 details the methodology for measuring correlation and causation. Section 4 showcases the results. Section 5 provides major conclusions and implications.

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[5] Deogaonkar, R., Hutubessy, R., van der Putten, I. *et al.* Systematic review of studies evaluating the broader economic impact of vaccination in low and middle income countries. *BMC Public Health* 12, 878 (2012). https://doi.org/10.1186/1471-2458-12-878

[6] Dongarwar, Deepa, Brisa Garcia, Sitratullah Maiyegun, Korede Yusuf, and Hamisu Salihu. "COVID-19 Early Vaccination Rates and Gross Domestic Product Per Capita." International Journal of Translational Medical Research and Public Health . Accessed December 18, 2021. https://www.ijtmrph.org/index.php/IJTMRPH/article/download/329/51.

II. Data

In order to understand the methodology behind this paper, it remains important to first understand the data being used. This analysis incorporates state-specific time-series-based vaccination data recorded by Our World in Data[7], which collaborates with the CDC to provide the public with SARS-CoV-2 related information. Relevant variables include the specified state, total vaccinations within the state, the number of people fully vaccinated per 100 people, and daily vaccination count. More importantly, this is a time-series-based data set beginning from December 2020, meaning one can track how vaccination data has changed over time.

The second data set used in this analysis was provided by the Bureau of Economic Analysis (BEA)[8]. This data gives the quarterly GDP per state and presents each sector's respective contribution to the overall GDP in a hierarchical fashion. In other words, a state's GDP is split up into "Private" and "Public" sectors before being divided into smaller and smaller areas of economic transaction. Importantly, one of the sectors provided is titled "Accommodations and Food Services," which is the sector this paper focuses on. Furthermore, the GDP is chained to 2021:Q2 dollar values.

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[7] Ritchie, H., Mathieu, E., Rodés-Guirao, L., Appel, C., Giattino, C., Ortiz-Ospina, E., Hasell, J., Macdonald, B., Beltekian, D., & Roser, M. (2020, March 5). *Coronavirus (COVID-19) cases - statistics and Research*. Our World in Data. Retrieved December 4, 2021, from https://ourworldindata.org/covid-cases.

[8] *GDP by State*. GDP by State | U.S. Bureau of Economic Analysis (BEA). (n.d.). Retrieved December 4, 2021, from https://www.bea.gov/data/gdp/gdp-state.

III. Methodology

Data Preprocessing

Before conducting further tests, it remains important to first preprocess the data in a fashion that aids data analysis. The BEA data set begins in 2005:Q1, however, this paper only deals with quarters starting from 2019:Q1 because any earlier date is not relevant to vaccination, which only happens in significant quantities from 2021:Q1 to 2021:Q2. Thus, the first step of preprocessing is to filter for values within the relevant timeline within the BEA data set. Next, this paper filters the "description" column for the following values: "All industries total" and "Accommodations and food services." These represent, respectively, a state's total consumption and its consumption within the AFS sector.

To prepare the vaccination data for analysis, this paper converted all dates into Python DateTime objects. Next, it applied the Pandas Python library's "groupby" function to calculate the maximum quarterly values of the following categories: "people_fully_vaccinated_per_hundred," "total_vaccinations_per_hundred," and "distributed_per_hundred." By taking the maximum value, one can find the overall vaccination rates by the end of a quarter. Ultimately, this analysis found the highest correlations with "people_fully_vaccinated_per_hundred," so the other columns were eventually removed from the data set. After preprocessing, the BEA economic indicator data set was merged with the Our World in Data vaccination data set through an inner join.

Correlation Analysis

To calculate the correlation coefficient, a Pearson correlation coefficient (r) was calculated to find the correlation between economic indicators and the percentage of fully vaccinated individuals in a state. The economic indicators used included overall GDP growth (GDP of a state divided by its GDP a quarter before) as well as AFS consumption growth. Because the correlation analysis utilizes growth rates instead of a metric such as GDP per capita, the value does not need to be standardized on a per-capita basis as the result is algebraically the same. Growth is the most important metric because a state could have high a GDP per capita despite low vaccination rates simply due to the state's economic health before the pandemic. To measure correlation, the Pearson correlation coefficient values were calculated using the following formula:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

This calculates the correlation for linear relationships between two normally distributed variables. The values x and y represent the x and y pairs of points within the data with size N. The $\bar{x}$ and $\bar{y}$ variables represent the mean value for their respective axis. After calculating the Pearson correlation coefficient, this analysis involves finding the p-value for statistical significance using the following formula:

$$t = \frac{r \times \sqrt{n-2}}{\sqrt{1-r^2}}$$

The p-value takes the Pearson correlation coefficient and N number of samples as inputs to calculate the overall significance of the results. The lower the p-value is, the higher the statistical significance. In the field of economics, a p-value less than 0.05 is generally accepted as a low enough value, representing a 95% confidence in statistical significance.

Causation Analysis

However, correlation alone does not imply causation. Thus, this paper uses two tests to analyze the causal impact of vaccination rates on consumption in the economy, and more specifically, the Accommodations and Food Services industry. These two tests include a difference-in-differences analysis as well as a regression discontinuity design.

The difference-in-differences analysis assesses the causal impact of the *entire* vaccine rollout effort from the end of 2021:Q1 to 2021:Q2, which was the time period in which most individuals received vaccines (see section 4). It remains important to note that this analysis assesses the impact of vaccine distribution as well as the implementation of incentive mechanisms, the reduction of restrictions, and the presentation of persuasive information to increase vaccine confidence. To begin, the difference in consumption within the AFS sector between 2021:Q1 and 2020:Q4 was calculated. This value is the equivalent to the slope between these two quarters and can thus be used to estimate the 2021:Q2 AFS contribution to GDP assuming the same rate of economic growth. By comparing the actual 2021:Q2 AFS contribution to GDP to the projected value, one can reasonably assess how the vaccine rollout effort actively impacted the economy. A choropleth plot is used to compare the relative impact the vaccine rollout had on consumption in the AFS industry. However, to account for states with varying populations and GDP values, the difference in differences values are divided by the 2021:Q1

GDP to allow for a standardized comparison. The result of this operation is mathematically equivalent to the difference in projected GDP growth and actual GDP growth. Similar to a simple difference-in-differences calculation, if the difference between projected GDP growth and actual GDP growth is large, one can infer that the treatment period (2021:Q2) caused a change in GDP.

The difference-in-differences analysis only assesses the causal impact of the vaccine rollout and does not isolate the causal link to the vaccination rate itself. For instance, perhaps the primary cause of economic growth is simply the reduction of lockdowns and not only vaccinations directly affecting people's spending behavior. To assess whether additional factors impacted consumption growth, a regression discontinuity design is conducted with the x-axis being the percentage of fully vaccinated people and the y-axis being the AFS contribution to GDP. A threshold is drawn at a vaccination rate which separates all points from 2021:Q1 and 2021:Q2. A linear regression line is fitted to both sides. If the two lines roughly match each other's slope and threshold intersection, there is likely no additional factor other than vaccination that causes changes in consumption. However, if a discontinuity exists, that suggests additional factors, or treatments, caused economic impacts from 2021:Q1 to 2021:Q2.

IV. Results and Discussion

Change in Vaccination Rates

To contextualize the impact of vaccination rates on the economy, this paper will first present changes in vaccination rates across different states. Figure 1 depicts the state-wide percentages of fully vaccinated individuals within the United States at the end of 2021:Q1 and

2021:Q2. Note, 2020:Q4 is not included because the number of fully vaccinated individuals is too minimal to be counted.

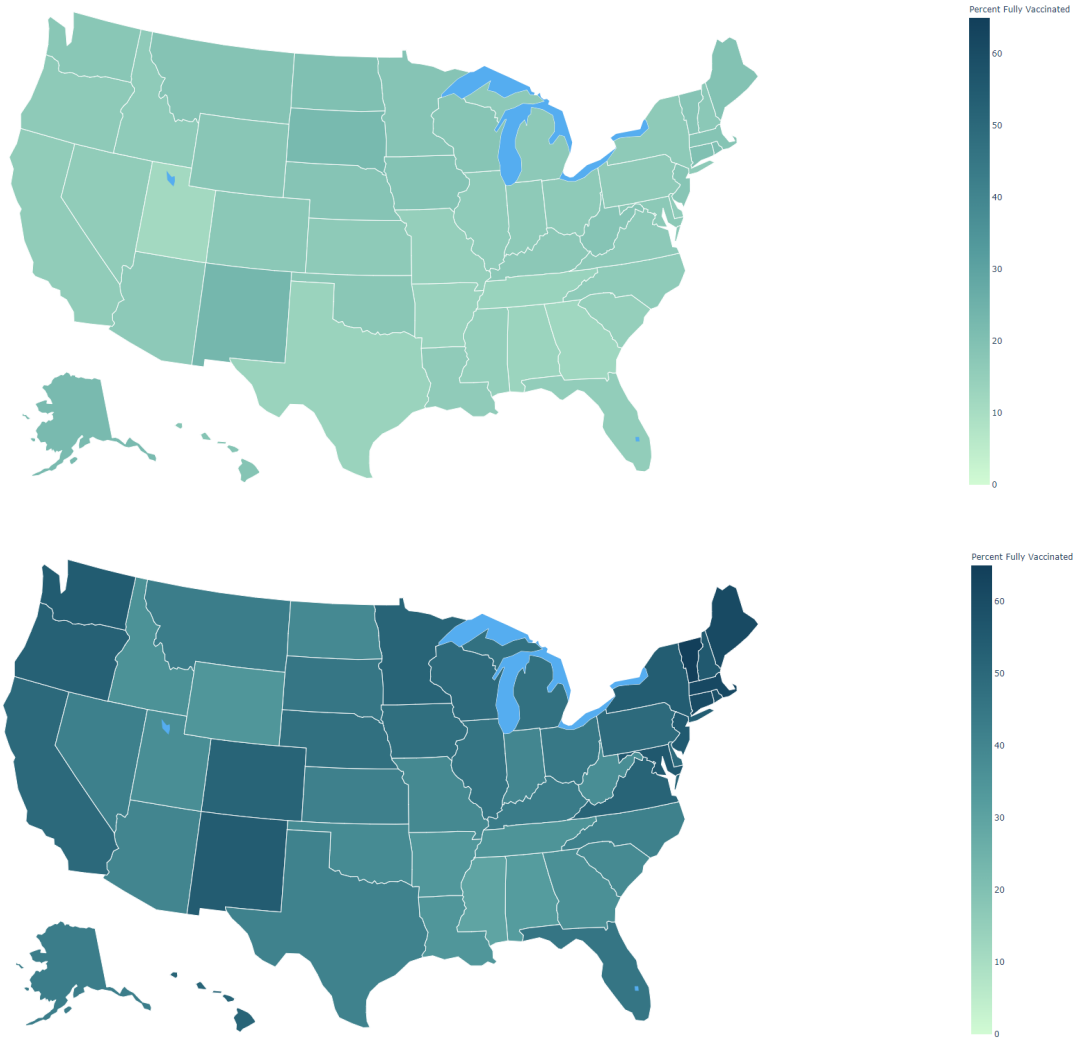

Figure 1: This is chloropleth plot of the percentage of individuals that are fully vaccinated in the United States in 2021:Q1 (top) and 2021:Q2 (bottom). Darker colors correspond to higher full vaccination rates.

In 2021:Q1, the average full vaccination percentage is 17.27%. States such as New Mexico, South Dakota, and Alaska lead full vaccination rates by reaching 23.51%, 22.39%, and 22.30% respectively. In 2021:Q2, however, the average vaccination percentage increased to 46.12%, reflecting improvements in distribution logistics, vaccination advertising campaigns,

and regional vaccine incentivization. 2021:Q2 also represents the time period in which the vaccine was made available to a majority of the public. These factors are important, as they characterize how the majority of the vaccination campaign occurred during the second quarter of 2021. Thus, 2021:Q2 is referred to as the treatment period in the difference-in-differences analysis explored later in this paper.

Correlating Vaccination Rate to AFS Consumption

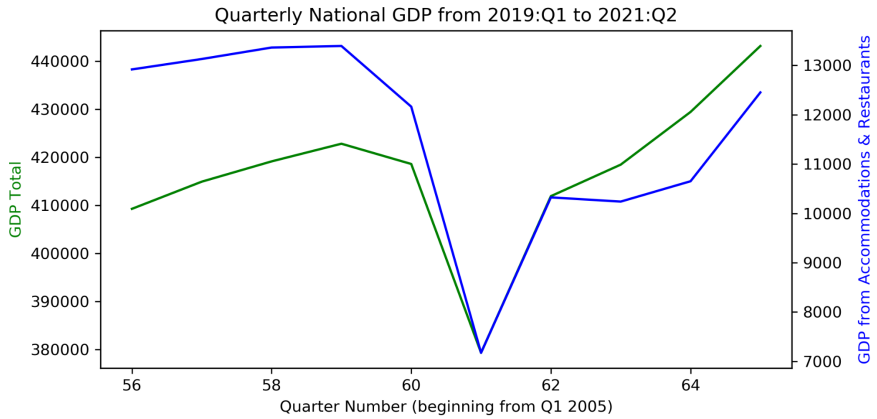

Figure 2: The overall GDP and the specific consumption in the Accommodations & Food Services industry from 2019:Q2 to 2021:Q2. Each unit in the x-axis represents the n-th quarter since 2005:Q1, with the value 0 directly correlating to 2005:Q1. The blue line refers to AFS consumption levels (in millions) while the green line refers to total GDP (in millions).

As seen in Figure 2, both the total GDP and the AFS contribution to GDP saw a major decrease during the second quarter of 2020, the time in which SARS-CoV-2 created national lockdowns. This caused a spike in unemployment and a reduction in consumer spending. However, both GDP and AFS consumption rebounded drastically in the following quarter, reflecting the initial reduction in SARS-CoV-2 restrictions before the Delta variant was discovered in October 2020[9]. The nation's consumption in the AFS industry stagnated from

[9] "Tracking SARS-CoV-2 Variants." World Health Organization, December 13, 2021. https://www.who.int/en/activities/tracking-SARS-CoV-2-variants/.

2020:Q3 to 2020:Q4 because of national fears regarding the Delta cariant. At the same time, consumption in the overall GDP continued to increase, reflecting spending in other areas. Importantly, the values in both axes increased dramatically in the second quarter of 2021 as vaccines were distributed to ore individuals.

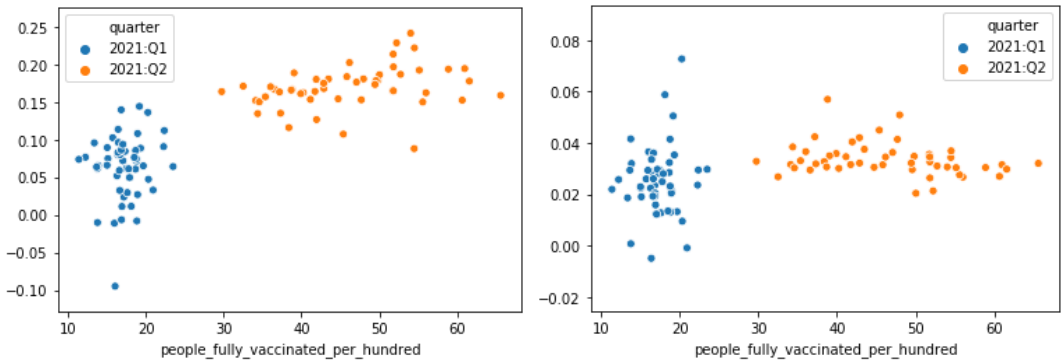

Figure 3: In both graphs, each dot represents a state whose x-value is the percentage of fully vaccinated individuals and whose right value is the quarterly growth rate (not calculated in percentages, so a growth rate of 1 = 100%). The left graph represents the growth rate for consumption in the AFS sector from 2021:Q1 to 2021:Q2, while the right graph represents the growth rate for the total GDP in the same time period.

Figure 3 supports the results presented above, as higher vaccination rates generally saw higher growth rates in both AFS consumption and total GDP. After calculating Pearson correlation coefficients between both economic indicators, it remains clear that a statistically significant correlation exists within the AFS sector ($r = .727$, $p < .01$). However, a statistically significant correlation also exists between GDP and the rate of full vaccination ($r = .287$, $p < .05$)

Difference-in-Differences Analysis

The difference-in-differences analysis was conducted for all with respect to the AFS industry's contributions to GDP for states using the methodology outlined above. A difference-in-differences analysis was conducted specifically for the Accommodations and Food Service industry primarily because of its high correlation with the percentage of fully vaccinated

individuals. The most immediate result is that the vaccine rollout had a positive economic impact on some states while the rollout had minimal impact in other states. For instance, in states such as California and New York, the vaccine rollout directly led to increased consumption in the AFS industry. However, in states such as North Dakota and Montanna, the vaccine rollout had minimal impact on consumption. In these states, individuals continued to attend restaurants and hotels despite low state-wide vaccination rates. See Figure 4 for a visual representation of these results.

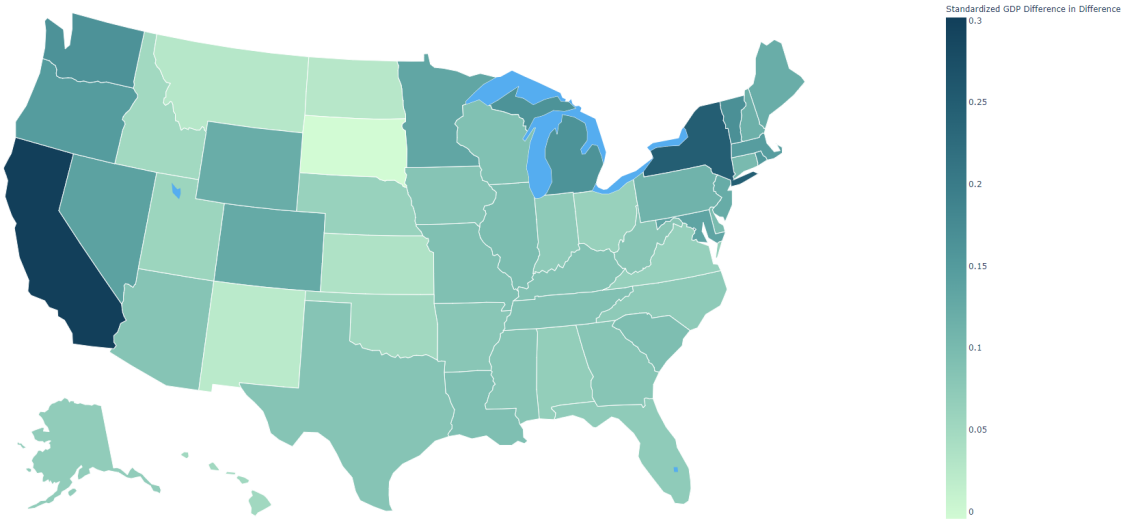

Figure 4: In this choropleth plot of the United States, each state's color corresponds to the standardized AFS difference-in-differences value. A dark value means that a state's AFS consumption has been positively impacted by the vaccine rollout.

One fascinating result is that states where the vaccine rollout impacted AFS consumption tended to learn to lean leftwards on the political spectrum. This result likely reflects differences in social norms and the varying ways officials treated the pandemic in such states. For instance, in North Dakota, individuals had relatively high AFS consumption even before the vaccine rollout.

Regression Discontinuity Design

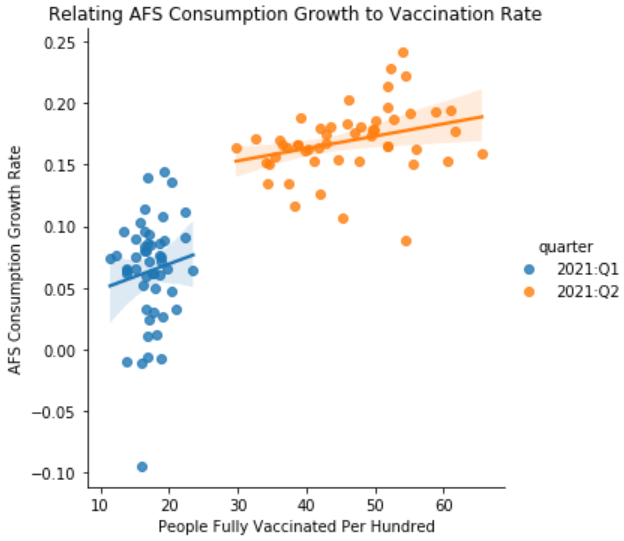

Figure 4: This graph is used for the regression discontinuity design analysis. A linear regression line is fit to data points belonging to the first and second quarter of 2021, respectively.

As outlined in the methods, a regression discontinuity test was conducted to assess whether factors beyond the vaccination rate impacted the AFS contribution to state-specific GDP. Figure 4 fits a linear regression line to each quarter in which vaccination rates were above zero. The major assumption behind this analysis is that if vaccination rates are the only cause of increased AFS consumption, the difference between the two lines' intercept would be minimal at a threshold that separates the two quarters. In this case, such a threshold can be drawn between 23% and 29% in the x-axis. If the threshold is drawn at a full vaccination rate of 29%, the difference between the two lines' intercept with the threshold is ~0.07, or a 7% difference in consumption growth rate. If the threshold is drawn at 23%, the difference grows closer to 8%.

Ultimately, given the fact that the distribution of growth rates within a quarter generally stays within 15%, the differences outlined above are significant. This means that additional factors have indeed caused a large portion of the change in AFS consumption growth. In other

words, the economic rebound in 2021:Q2 can be explained by additional factors such as reduced lockdowns and increased confidence in going outside safely. This also explains why the impact of vaccines on the economy varied among the different states.

V. Conclusions

In this paper, an analysis was conducted to investigate the correlation between the percentage of fully vaccinated individuals within a state and the state's GDP and consumption in the accommodations and food services sector. Overall a strong correlation ($r = 0.727$, $p < .01$) was found between the percentage of fully vaccinated individuals and consumption in the AFS sector. A weak, but still statistically significant, correlation exists between the percentage of fully vaccinated individuals and states' overall GDP ($r = .287$, $p < .05$). To explain the high correlation between the percentage of fully vaccinated individuals and spending in the AFS sector, two tests were conducted to deduce the causality between vaccination rate and AFS consumption. To begin, the difference-in-differences analysis found varying causal impacts of vaccination rates on AFS consumption. Interestingly, states where vaccines had the highest impact on consumption generally happened to lean Democratic in terms of political affiliation. The opposite was also true. Afterwards, a regression discontinuity design found that additional factors contributed to changes in AFS consumption that occurred from 2021:Q2 and 2021:Q1. In conclusion, vaccination rates have varying impacts on the consumer spending in the accommodation and food services industry.