

## Introduction

COVID-19 is the first global pandemic that we have faced in recent decades. Various governments and local authorities have promptly reacted to the pandemic by exercising mandates such as masking and social distancing, which has sacrificed the economy and affected local unemployment due to dormant social activities. Its impact to overall unemployment rate is unprecedented and worthwhile to be studied for. However, unemployment rate seems to have improved when vaccination was being introduced in December 2020. The original view was that vaccination could reduce the number of COVID-19 cases and death[1]. This belief and confidence also allowed government to lift lockdowns, eventually leading to daily lives resuming to its normal activity level. Consequently, the economy bounces back, and unemployment rate improves.

This research focuses on the impact of COVID-19, implementation of mask mandate, and vaccination rate, on the unemployment rate in Macomb County, Michigan. In the first part of the research the relationship between mask mandate and number of COVID-19 cases and deaths is being studied. The result from the first part has inspired the research to go into the direction of studying vaccination rate and COVID-19 cases and unemployment rate.

In the second part of the research, the correlations between COVID-19 cases and deaths, vaccination rate and the unemployment rate are being studied. This investigation is interesting because it explores the extent of COVID-19 cases impacting unemployment rate in Macomb County, Michigan, and whether vaccination rate has improved COVID-19 cases and the unemployment rate. This can be an important point for readers, particularly for business leaders, who are interested to see the extent of COVID-19 cases and vaccination towards local economy, which can be proxy measured using unemployment rate.

## Background/Related Work

Given the global impact of COVID-19, plenty of research have been conducted in this area. A few papers and studies have inspired the formation of research question and hypothesis in this research. For part one of the research, the main study that initiated the investigation between the effectiveness of mask mandate is “Maintaining face mask use before and after achieving different COVID-19 vaccination coverage levels: a modelling study”[4]. Bartsch et al shows that masking is a cost effective and efficient way in reducing transmission and hence reducing the number of cases and death. With that in mind, the hypothesis for the first part of the research is that masking is effective in reducing the number of COVID-19 cases and we should see a significant drop or less spiked increase when mask mandate is in effect in Macomb County.

The first study mentioned about masking being an alternative measure to vaccination. Naturally, my study pivoted me to read more about the impact of vaccination in flattening the COVID-19 curve. The paper “Vaccination Rate and Incidence of COVID-19 and Case Fatality Rate (CFR)”[5] claims that a positive correlation was observed between vaccination rate and bi-weekly incidence rate whereas a negative correlation was observed between vaccination rate and

CFR inspired the research to study the correlation between COVID cases and the number of vaccination in Macomb County.

The third study that has shaped this research geared towards investigating the economic growth and unemployment rate is “COVID-19 Vaccines: A Shot in Arm for the Economy”[6]. Hansen et al quantified the effect of vaccination using county-level data from end of 2020 to mid 2021 in the United States. They found that an increase in 1 percentage point of initial vaccination rate reduces weekly unemployment rate by 0.004 percentage points of the 2019 labor force.

Combining the perspectives given by the papers mentioned above, I am interested in finding whether vaccination can really flatten the COVID-19 curve, and hence reviving the economy which is proxy measured by using unemployment rate in the second part of my research.

The followings are the hypothesis being explored in the second part of the study:

- i. Number of COVID-19 cases and deaths are positively correlated with unemployment rate.
- ii. Number of COVID-19 cases and deaths are negatively correlated with number of vaccinations.
- iii. Unemployment rate is correlated with number of vaccinations. The correlation will be part of the research result.

## Methodology

### **Step 1: Data acquisition and construction**

The datasets acquired from the sources that will be mentioned in more details under the Data Sources section of the report. In the first part of the research, I have used the COVID-19 cases and deaths number from Kaggle and the data regarding period of mask mandate. Both datasets are open sourced, and they were used under the MIT Common Creativity license.

In the second part of the research, vaccination record from Macomb County website was downloaded. As vaccination record is related to one's privacy, I read through the methodology of collecting data and ensured that the data is collected ethically, and that the participants voluntarily provide that information to the authority. The second dataset used was the unemployment rate data from the Federal Reserve Bank of St Louis, which is an open-sourced public data set. Both datasets will be used in combination with the COVID-19 cases and death time series from Part 1 of the research.

### **Step 2: Data cleaning and manipulation**

In Part 1, both datasets are clean so not much manipulation was needed to be done. The 5-day moving average of the number of COVID-19 cases was calculated to smoothen the time series. This step is to reduce the impact of missing data in some of the days.

In Part 2, the unemployment rate data is in monthly frequency whereas the vaccination and number of COVID-19 cases are in daily frequency. Consequently, I summed up the vaccination and number of COVID-19 cases into monthly frequency so that all three series can be compared. The vaccination record time series has the shortest time range which starts at December 2020. Therefore, I have filtered the other two datasets such that all data starts from December 2020 to November 2022.

### Step 3: Data visualizations

In Part 1, the 5-day moving average percentage change for number of COVID-19 cases is plotted against date. The beginning and the end of the mask mandate are indicated by two red lines as shown in the chart below.

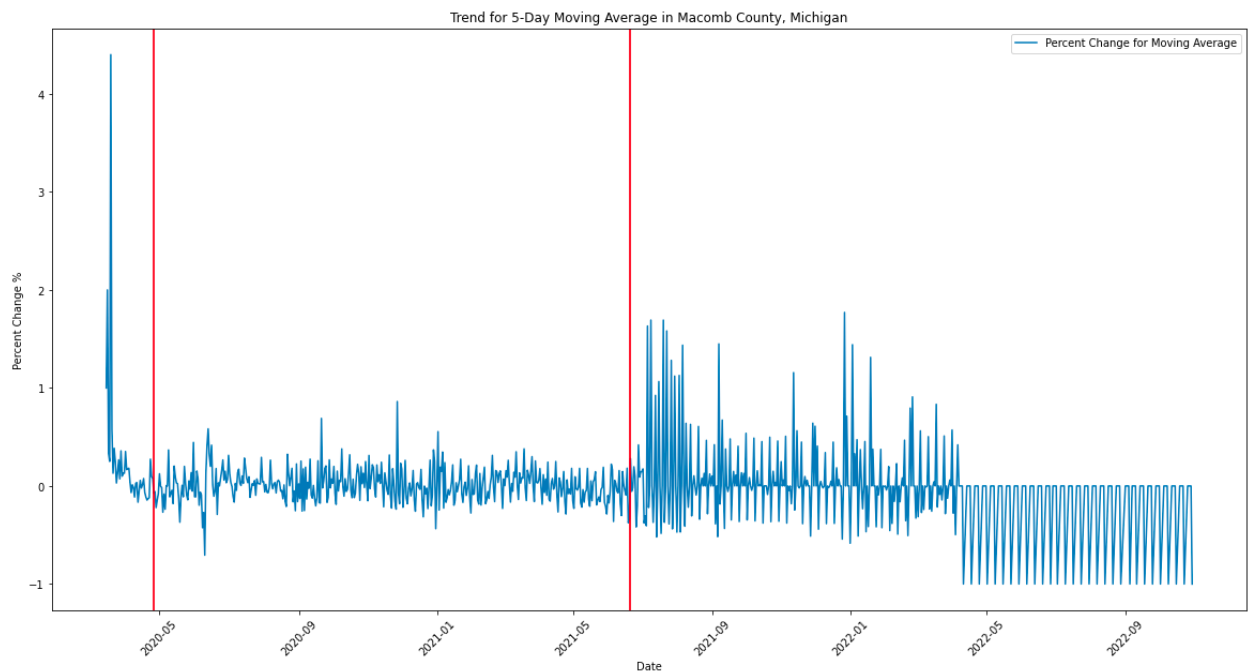


Figure 1: Trend for 5-Day Moving Average. Two red lines indicate the beginning and end of mask mandate in Macomb County.

In Part 2, each time series is plotted in the attempt to uncover any obvious trends. The end of the mask mandate, which is April 21, 2021, is being indicated by the blue vertical line in each of the chart.



Figure 2: Monthly unemployment rate in Macomb County. The blue line indicates the end of mask mandate in Macomb County on April 21, 2021.

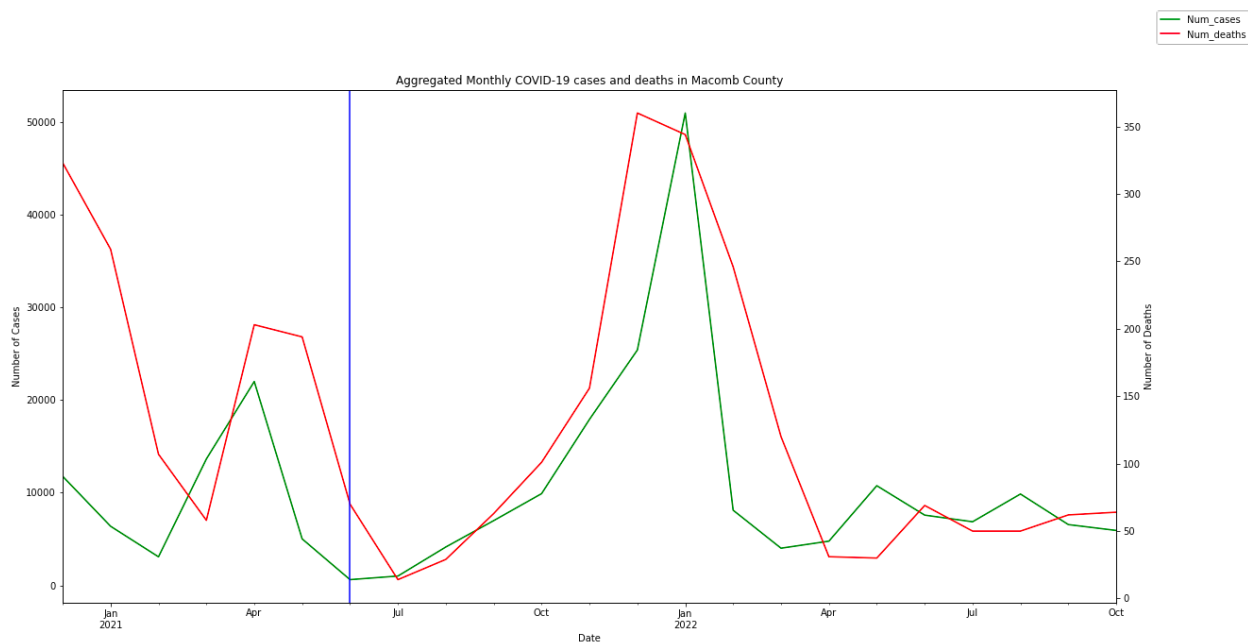


Figure 3: Aggregated monthly COVID-19 cases and deaths in Macomb County. The blue line indicates the end of mask mandate in Macomb County on April 21, 2021.

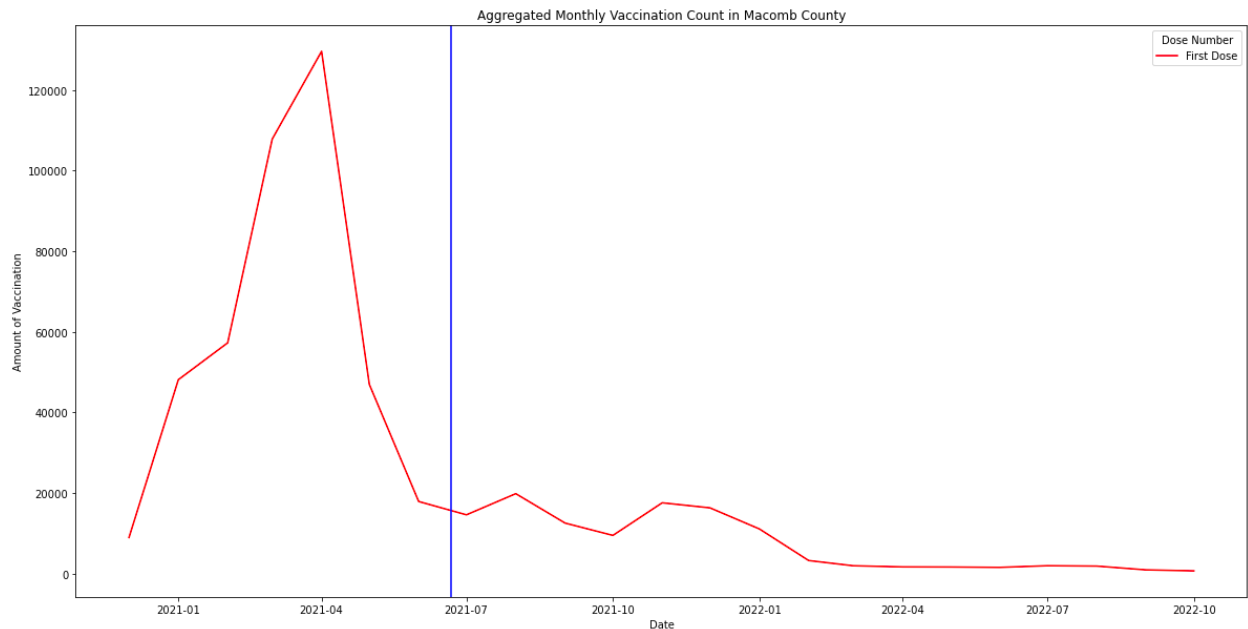


Figure 4: Aggregated monthly vaccination count in Macomb County. The blue line indicates the end of mask mandate in Macomb County on April 21, 2021.

#### Step 4: Statistical Analysis

In order to verify the hypothesis stated earlier, two tests were performed on each relationship. Firstly, the causality of each time series pair was tested with Granger Causality test. This is a statistical hypothesis test for determining whether one time series is useful in forecasting another, which provides early indication whether the two time series are correlated. Then, the pair will be tested using Pearson Correlation test to identify the correlation coefficient. These two tests were chosen because they are suitable for the data set in this research. Before conducting these tests, the time series are being assessed to ensure that they are stationary.

### Findings

In Part 1, we can see from Figure 1 that there is a huge difference in the pattern of moving average of COVID-19 cases between April 21, 2020, and June 21, 2020 and outside of these dates. The moving average fluctuated greatly outside of these dates, indicating that mask mandate has an impact on the number of COVID-19 cases. However, the limitation of the nature of the dataset hindered me from drawing statistical conclusion based on the dates of mask mandates.

In Part 2, a more robust statistical tests are being done on the available dataset. the hypotheses mentioned under Background/Motivation section are being tested and the results are reported below.

Hypothesis 1: Number of COVID-19 cases and deaths are positively correlated with unemployment rate.

Relationship	Granger Causality		Pearson Correlation	
	F-test	p-value	Correlation coefficient	p-value
Number of COVID-19 cases vs unemployment rate	0.6	0.672	0.183	0.401
Number of COVID-19 deaths vs unemployment rate	0.673	0.626	-0.151	0.490

Hypothesis 2: Number of COVID-19 cases and deaths are negatively correlated with number of vaccinations.

Relationship	Granger Causality		Pearson Correlation	
	F-test	p-value	Correlation coefficient	p-value
Vaccination rate vs number of COVID-19 cases	0.247	0.905	0.148	0.4996
Vaccination rate vs number of COVID-19 deaths	1.334	1.334	0.137	0.532

Hypothesis 3: Unemployment rate is correlated with number of vaccinations.

Relationship	Granger Causality		Pearson Correlation	
	F-test	p-value	Correlation coefficient	p-value
Vaccination rate vs unemployment rate	3.548	0.047	0.489	0.017

From the result tables above, we can see that Hypothesis 1 is rejected. Number of COVID-19 cases and deaths cannot be used to explain or predict unemployment rate. Although there is a positive correlation between the relationships, there is no statistical significance between them. Similarly, Hypothesis 2 has been rejected as well; vaccination rate cannot be used to predict the number of COVID-19 cases and deaths. The result shows that there is no negative correlation and no statistical significance. However, Hypothesis 3 can be justified using this dataset as they show a positive correlation that is statistically significant.

## Discussion/Implications

All the findings above appear to be surprising. However, the most surprising result was Hypothesis 3 whereby vaccination rate is positively correlated to unemployment in Macomb County. This contradicts the original idea I had after reading articles [2],[3],[4] about how vaccination could reduce the number of COVID-19 cases and deaths, reviving the economy and bring down unemployment rate.

Upon further search to explain this phenomenon, I found this a study by the National Library of Medicine researching the association between county-level income per capita, unemployment rate and COVID-19 vaccination rate in the United States. The paper claims that the unemployment rate was positively associated with COVID-19 vaccination rates. For every 1% increase in unemployment rate, county-level COVID-19 vaccination rates increased by 0.41%[5]. This finding is consistent with a prior study stating that during the first 100 days of COVID-19 vaccination in the U.S. This shows that the result from this project is consistent with a peer-reviewed and established research paper.

However, the paper later concluded that for county that has higher percentage of Non-Hispanic white, the unemployment is negatively correlated with vaccination rate. At the same time, I was aware that this claim was made in the research discussion section: *“Interestingly, since Black and Indigenous People of Color individuals (BIPOC) have faced higher risks of unemployment during the COVID-19 pandemic, they may be more motivated to vaccinate against COVID-19 in order to return to the workforce”*. I then try to draw association between the aforementioned study and Macomb County, Michigan. In contradiction to the generalization of the previous conclusion, Macomb County consists of 79% white residents [8] and BIPOC consists of 11% of the population.

I then continued to investigate whether the economic status might potentially lead to the positive correlation between vaccination and unemployment rate in Macomb County after being inspired by [7]. Consequently, it is found that the largest economic sector in Macomb County is manufacturing. During the pandemic, the manufacturing sector was one of the most impacted sectors due to lockdown mandates and supply chain disruption. It is likely that majority of the job loss in this county came from manufacturing sector. And because the nature of manufacturing, many organizations have implemented vaccine mandate to protect employees in the factory. Many of these factory workers who lost their jobs during the pandemic might decide to get vaccinated in order to return to similar working environments in the factories.

As a result, I believe that the strong positive correlation between unemployment rate and vaccination are not related to the distribution of ethnicity. This is where I understood the effect of the human-centered data science concept marginalization and discrimination. As an established institution, any published statements will be likely taken as a policy guidance for organizations. The publisher of the article, National Library of Medicine, should have provided a percentile that this claim is true and not generalize to all of the counties in the United States. As shown from my project, there are outliers, such as Macomb County, whereby the correlation is due to other factors rather than race.

A potential extension from this project is to study the relationship between sector specific unemployment rate and vaccination rate. The findings from this relationship combining with studies on vaccination mandate in various local manufacturing organization will provide a more holistic view in explaining the strong positive correlation between unemployment and vaccination rate.

## Limitations

- Missing details on whether the number of COVID-19 cases and deaths include patients who have been vaccinated. This piece of information would allow a better correlation analysis between the impact of COVID-19 infection.
- Missing details on sector breakdown for unemployment rate. There is limited information about the sector origin of the unemployment numbers.
- Missing details on how many percentages of the unemployed have been vaccinated. This data will allow this research to better pinpoint the causality of vaccination towards unemployment rate.
- It is assumed that vaccination time series is not seasonal. However, based on the number of COVID-19 cases, it might seasonal due to the rise of COVID-19 cases during winter.

## Conclusion

The statistical analysis has shown that in Macomb County, Michigan between December 2020 and October 2022, the number of COVID-19 cases and deaths have no correlation with unemployment rate. Similarly, there is no correlation between vaccination rate and number of COVID-19 cases and deaths as well. However, there is a strong positive correlation (coefficient = 0.49, p-value = 0.0017) between unemployment rate and vaccination rate. This result is consistent with other peer reviewed studies about vaccination and unemployment rate when COVID-19 vaccine rolled out for the first 100 days. This contradicts with the general belief that unemployment rate is negatively correlated to vaccination rate. Further investigation suggests that the impact of vaccination on unemployment rate is more long term, and the dataset has limited time range to see this effect. During the process of investigating for potential explanation for the positive correlation, I stumbled upon an example of potential discrimination against certain race because of overgeneralization. [2] points out that vaccination and unemployment rate are positively correlated in areas where the majority residents are BIPOC. On the contrary, Macomb County is majority white. This contradiction led me to understand the risk in generalizing ethnicity factor in causality. At the same time, this potentially suggests future research to focus on other potential factor such as the type of sector in Macomb County, Michigan.



## References

- [1] Centers for Disease Control and Prevention. (2021, June 7). *CDC COVID-19 study shows mRNA vaccines reduce risk of infection by 91 percent for fully vaccinated people*. Centers for Disease Control and Prevention. Retrieved December 9, 2022, from <https://www.cdc.gov/media/releases/2021/p0607-mrna-reduce-risks.html>
- [2] Guo, Y., Kaniuka, A. R., Gao, J., & Sims, O. T. (2022, February 3). *An epidemiologic analysis of associations between county-level per capita income, unemployment rate, and covid-19 vaccination rates in the United States*. International journal of environmental research and public health. Retrieved December 11, 2022, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8835135/>
- [3] Macomb County, MI. Data USA. (n.d.). Retrieved December 11, 2022, from <https://datausa.io/profile/geo/macomb-county-mi#economy>
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- [8] U.S. Census Bureau quickfacts: Macomb County, Michigan. United States Census Bureau. (n.d.). Retrieved December 12, 2022, from <https://www.census.gov/quickfacts/macombcountymichigan>

## Data Sources

1. Monthly unemployment rate in Macomb County: [The US Bureau of Labor Statistics](#)
2. COVID-19 number of cases and deaths: [COVID-19 Data from John Hopkins University](#)
3. Daily vaccination count in Macomb County: [COVID-19 Vaccine Dashboard](#)