



Biden's approval, record inflation, economic recovery, COVID-19 mortality, and vaccination rate among Americans—A longitudinal study of state-level data from April 2021 to January 2022

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ABSTRACT

The COVID-19 pandemic has brought an unprecedented impact on Americans for over three years. One effective strategy to mitigate the pandemic's damage lies in the vaccine. This study aims to investigate the effects of state-level predictors that vary month-by-month on changes in vaccination rates. Panel data of state-level indicators are built for all 50 states from April 2021 to January 2022. The dependent variable is the monthly increase in vaccination rate, and the independent variables include measures of Biden's approval, inflation, economic recovery, and COVID-19 mortality for each month of this study period. Fixed-effects regression is adopted for longitudinal statistical estimation. Findings show that over time Biden's approval and COVID-19 death are positively associated with the growth in the vaccination rate, while inflation and economic recovery are negatively associated with the vaccination rate. Significant interactions are identified among these predictors. The findings from analyzing panel indicators at the state level complement the current literature dominated by examining cross-sectional data and provide public health officials with fresh insights to promote the vaccine rollout.

1. Introduction

The pandemic caused by SARS-CoV-2 (COVID-19) has disrupted the lives of Americans for close to four years. The cases and deaths grow exponentially, with more than 100 million people being infected and over one million losing their lives. To fight against COVID-19, the vaccine is critical to mitigating the damages (CDC, 2021). Substantial evidence has shown the vaccine's effectiveness in fostering immunity and reducing transmission. However, the vaccination rate remains low, and 70 % of the population was fully vaccinated by September 2023 (CDC, 2023). Vaccine hesitancy remains widespread, and the most given reasons to refuse the COVID-19 vaccine include safety concerns, doubt about the development, and misinformation that compromised acceptance (Machingaidze and Wiysonge, 2021; Troiano and Nardi, 2021). A review article systematically summarized the current literature on this subject and analyzed vaccine hesitancy's potential causes, consequences, and impacts (Dubé et al., 2021). More importantly, the low vaccination rate should be attributed to social factors in addition to individual skepticism. For example, the politicization of the pandemic made the Republican constituency have infrastructures with insufficient availability of vaccines, low incentives, and weaker mandates

(Gadarian, Goodman, and Pepinsky, 2022). Similarly, the various economic conditions (e.g., inflation) and the public health landscapes (e.g., infection and mortality) also drive some states to have a larger proportion of residents remain unvaccinated. The unvaccinated population poses a major threat to controlling the pandemic and delaying the track of attaining herd immunity. Against this backdrop, there is an urgent need to understand predictors that promote or inhibit vaccine rollout.

Most existing studies of Americans analyzed survey data and identified that the public intention to be vaccinated could be attributed to different individual-level factors, including political orientation (Larsen et al., 2022), trust (Szilagy et al., 2021), social network (Hao, 2022), risk perception (Wong and Yang, 2022), and sociodemographic characteristics (Latkin et al., 2021). These findings help design behavioral nudges to overcome vaccine hesitancy (Dai et al., 2021; Lama et al., 2022). Meanwhile, a few cross-sectional studies using county-level data find that the vaccination rate is associated with the local context, and a lower proportion of residents receive the vaccine in counties with higher Republican voters and rurality (Albrecht, 2022; Sun and Monnat, 2022; Yang, Matthews, and Sun, 2022; Zhang et al., 2022).

Despite the contribution of previous research, there has not been a study on this topic that examines collective-level factors from a

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longitudinal perspective. Compared to information collected at one point that cannot account for temporal variabilities, panel data that reflects the differences between multiple time points can better and more accurately reveal causal associations between the change in predictors and the change in the outcome. For example, the state’s political, economic, and public health conditions that vary over time could influence the trajectory of vaccination rates.

In response to the evolving pandemic, this study aims to fill the gaps by analyzing state-level monthly indicators from April 2021 to January 2022. The primary argument is the constantly changing political conditions and the pandemic’s shifting impact on the economy and mortality are expected to affect the vaccination rate. First, the pandemic has been politicized from the outset, with Democratic and Republican leaders framing COVID-19 differently by sending contrasting messages about its severity (Gadarian, Goodman, and Pepinsky, 2022). For example, President Biden highlighted the risk, recommended mitigation measures, and promoted the vaccine, while former President Trump downplayed the threat, rejected strategies to control the pandemic, and disseminated misinformation about the vaccine. The politically driven rhetoric and elite cues led to the polarization of public discourse and made COVID-19 vaccines a contentious issue (Graham et al., 2020; Hao and Shao, 2023; Mayer et al., 2022; Pink et al., 2021; Shao and Hao, 2020). According to the background, this study tests whether the change in Biden’s approval rate over time is associated with the change in vaccination rate.

In addition, the inflation and economic recovery from the pandemic might inhibit the public’s vaccine uptake. The U.S. witnessed the skyrocketing cost of living since mid-2021, and recorded inflation continued throughout 2022. Higher inflation might make people prioritize concerns for basic needs such as food and shelter but have less concern about the pandemic, which leads to a low vaccination rate. There has not been a study to examine inflation’s effect on public response to the pandemic, and this study will fill the gap. Meanwhile, the recovering economy would send a misleading message that the return to normalcy is on track and the COVID-19 outbreak is under control. Previous studies using cross-sectional data find that people from states whose economies recovered closer to the pre-pandemic level became less likely to take precautionary measures such as wearing a mask than those from states whose economies were far from full recovery (Hao and Shao, 2021; 2022). Building on those arguments, this study examines that, from a longitudinal perspective, the ongoing economic recovery is associated with a decline in the vaccination rate.

Furthermore, if people residing in states exposed to growing COVID-19 deaths, their risk perceptions could be heightened, leading to risk reduction behaviors such as taking the vaccine. In comparison, when people live in states with declining COVID-19 deaths, their willingness to be inoculated might be diminished. However, it is necessary to note that the direct connection is likely mediated by other factors. For example, COVID-19 skeptics in states with high death rates are likely to share discourses that misinterpret the statistics of mortality and discount personal experiences. The argument for the direct connection is supported by the construal level theory that describes how psychological distance influences one’s perceptions and behaviors (Liberman and Trope, 2008; Trope and Liberman, 2010). The perceived distance to COVID-19 risk could become a barrier to vaccination if the distance is perceived as far away. Conversely, risk mitigation actions such as vaccine uptake can be more easily motivated if the distance is perceived as close enough. For example, an analysis of a cross-national survey of 15 countries, including the U.S., showed that people from countries with higher case rates are more likely to take the vaccine (Hao, 2023). Expanding from existing research that analyzed data from a single time-point, this study will examine the relationship between vaccination rates and mortality using panel data.

2. Methods

2.1. Panel data

The data used in this study are from multiple sources and organized in panels that contain monthly observations from all 50 states. Summary statistics of variables, including mean, standard deviation, minimum, and maximum, are shown in Table 1.

2.2. Dependent variable

The vaccination rate (fully vaccinated/total population) data from April 2021 to January 2022 is obtained from the CDC. The time frame is set because the data began to be available for a full month in April. Also, as presented in Fig. 1, the national average increased from 24 % to 63 % during this period. The rate grew slowly since then, reaching only 70 % until September 2023, 20 months after January 2022. To investigate the temporal changes in the vaccination rate, this study uses data when there is evident variability.

Meanwhile, the vaccination rate varies across states, as displayed in Fig. 2. By January 31st, 2022, the states in the northeastern generally achieved over 70 % vaccination rates with Vermont (80 %), Rhode Island (79 %), and Maine (78 %) leading the list. In comparison, states in the South and Midwest have rates below 60 % with Alabama and Wyoming ranked at the bottom with less than half of their population being fully vaccinated. The monthly increase in the vaccination rate is computed (subtract the indicator at the end of the month such as May 31st by the beginning of the month such as May 1st) and used as the dependent variable for regression analysis.

2.3. Independent variables

The study includes four predictors. First, Biden’s approval data is extracted from the COVID States project, a multi-institutional collaborative endeavor that collected large U.S. samples over time. Starting in April 2020, the project surveyed approximately 20,000 people nationwide in 20-plus waves. The survey was conducted by PureSpectrum via an online platform, which aggregates and duplicates paid panelists from multiple sources. The data are quota-sampled to approximate the population of each U.S. state with respect to age, race/ethnicity, and gender. One question asked people whether they approved or disapproved of the way the president is handling the COVID-19 outbreak, and the percentage of respondents who approve is adopted to measure the level of Biden’s approval.

Second, the level of inflation is measured by the state inflation tracker released by the Joint Economic Committee of the U.S. Congress. The data reflects the monthly percentage of increase in prices since January 2021.

Third, economic recovery is gauged using a back-to-normal index constructed by Moody’s Analytics and CNN Business. The index represents the percentage of the economy returning to its pre-pandemic level and captures a wide range of indicators including the labor market, housing value, investments, consumer behavior, and travel and leisure

Table 1
Descriptive Statistics for All Variables Included in the Analyses.

	Mean	S.D.	Min	Max
<i>Dependent Variable</i>				
Vaccination Rate ¹	3.332	2.867	0.300	18.600
<i>Independent Variables</i>				
Biden’s Approval	48.116	10.088	23.900	71.900
Inflation	4.741	1.607	1.723	8.228
Back-to-Normal Index	94.413	4.895	77.830	111.987
COVID-19 Death ²	580	941	1	10,438

¹ Vaccination rate refers to the monthly increase.

² COVID-19 death is the monthly increase in mortality.

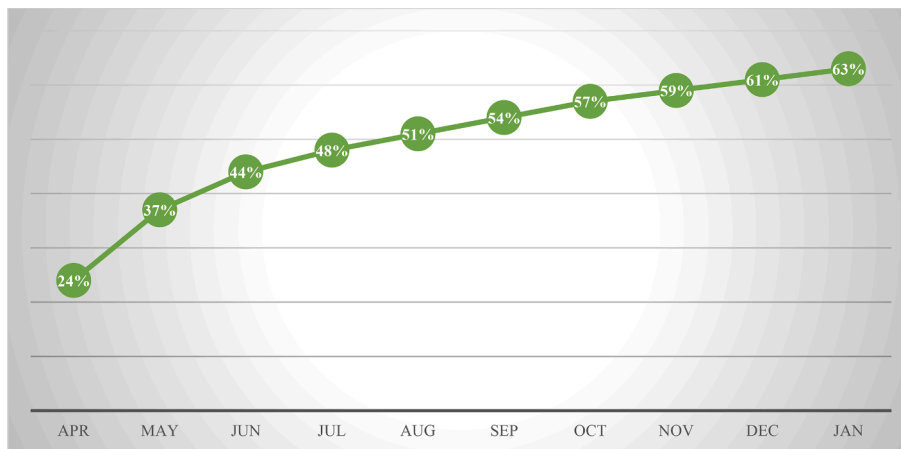


Fig. 1. Vaccination Rate of Americans, April 2021-January 2022.

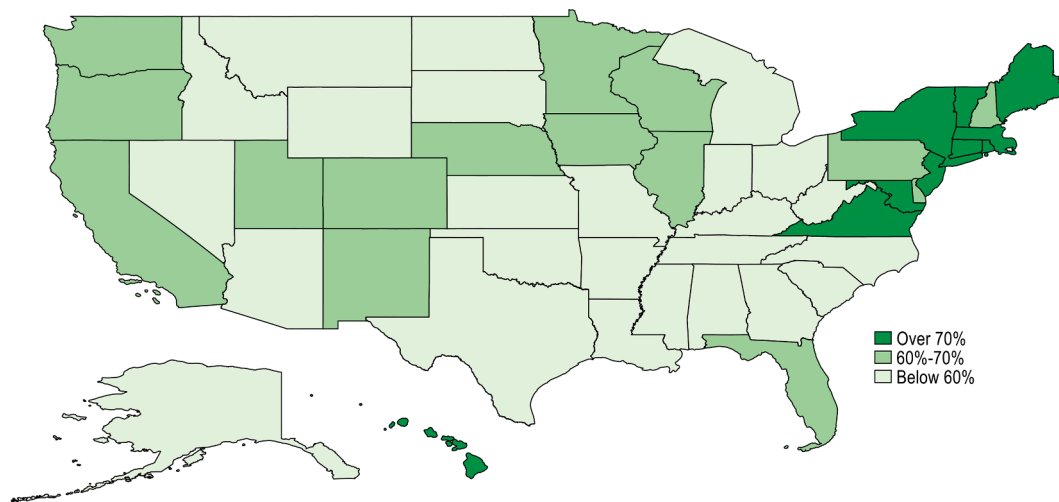


Fig. 2. Vaccination Rate of Americans across States, January 31st, 2022.

activity. The index has daily indicators and the monthly average was computed.

Finally, the COVID-19 death measures the severity of the pandemic’s impact, and the information is extracted from the CDC. The monthly increase in COVID-19 deaths is computed by subtracting the indicator at the end of the month from the indicator at the beginning of the month.

2.4. Statistical estimation

This study aims to test the effects of multiple predictors. Because the effects usually take time to evolve and do not occur spontaneously with the outcome, the vaccination variable is lagged by one month. Thus, the panel contains measures of vaccination rate from May 2021 to January 2022 that are matched with measures of the predictors from April to December 2021. In other words, this study uses measures for the independent variables one month earlier than those for the dependent variable. In addition, Biden’s approval measure is only available in April, June, September, November, and December 2021. The other months with missing data are filled with data from a previous or a later month. As discussed in the results section, additional models were estimated to address the limitation.

Fixed and random effects regression are two commonly used econometric methods to analyze panel data. The former is the pooled ordinary least squares estimation of time-demeaned data, while the latter estimates quasi-demeaned data (Allison, 2009; Wooldridge,

2009). Both models allow the incorporation of multiple independent variables at different time points and reduce the likelihood of false inferences due to reciprocal causality (Bollen and Brand, 2010). The chi-square statistics of the Hausman test were statistically significant for all analyses, indicating that fixed effects models should be used in this case.

All measures have been transformed into a logarithmic form to correct skewness. The coefficients with standard errors in parentheses are presented in Table 2. Because Biden’s approval and inflation are highly correlated, these two variables are included in separate models (Models 1 and 2) to avoid the multicollinearity issue, plus the back-to-normal index and COVID-19 death. Model 3 adds an interaction between Biden’s approval and COVID-19 death, while Model 4 includes another interaction between inflation and the back-to-normal index.

3. Results

The analyses yield several findings. First, Biden’s approval is positively and significantly associated with the growth in the vaccination rate. States are likely to increase vaccination rates more when approval rates are high. According to Model 1, a one-unit increase in Biden’s approval is associated with a 1.8-unit increase in the vaccination rate after controlling for other variables in the model. Second, inflation is negatively related to the change in the vaccination rate, as shown in Model 2. A one-unit growth in the inflation measure is accompanied by a

Table 2
Regression Results on Lagged Vaccination Rate from State-level Predictors Over Time.

	Model 1	Model 2	Model 3	Model 4
Biden's Approval (ln)	1.840*** (0.188)	-	0.049 (0.667)	-
Inflation (ln)	-	-1.201*** (0.074)	-	-14.088** (4.930)
Back-to-Normal Index (ln)	-10.910*** (0.921)	-4.881*** (0.926)	-10.690*** (0.916)	-8.282*** (1.593)
COVID-19 Death (ln)	0.065 [†] (0.036)	0.089** (0.029)	-1.121** (0.425)	0.082** (0.029)
Biden's Approval (ln) × COVID-19 Death (ln)	-	-	0.304** (0.109)	-
Inflation (ln) × Back-to-Normal Index (ln)	-	-	-	2.844** (1.088)
Constant	43.143	24.468	49.121	39.891
R-square	0.220	0.479	0.232	0.504

The dependent variable lagged for a month in longitudinal analyses.

[†] p < 0.10; *p < 0.05; **p < 0.01; ***p < 0.001.

1.2-unit reduction in the vaccination rate, holding other variables constant. Third, over time, the back-to-normal index is negatively associated with the vaccination rate, and COVID-19 death has a positive impact, and the findings remain in Models 1 and 2. Thus, states have higher vaccination rates if they experience slow economic recovery or greater mortality.

The effects of these predictors are visualized in Figs. 3 and 4 after computing adjusted means of vaccination rate given different values of the independent variables. The solid line provides estimated scores for the dependent variable with 95 % confidence intervals. Accordingly, the estimated lagged vaccination rate increases concomitantly with the growth in Biden's approval and COVID-19 deaths and decreases concomitantly with higher inflation and back-to-normal index.

In addition, the interaction between Biden's approval and COVID-19 death is positive and significant ($\beta = 0.304$, $p < 0.01$), as presented in Model 3. The interaction effect is displayed in Fig. 5. COVID-19 death has a more substantial impact on elevating the vaccination rate among states with stronger Biden's approval because the slope for the high

Biden's approval scenario is in a positive direction while the slopes for the scenarios of moderate and low approval are flat or in a negative direction.

Furthermore, the interaction between inflation and the back-to-normal index is positive and significant ($\beta = 2.844$, $p < 0.01$), as revealed in Model 4. The interaction effect is plotted in Fig. 6. The inhibiting effect of the back-to-normal index on vaccination rate is stronger for states with low inflation because the declining slope is steeper than the slope for alternative scenarios of moderate and high inflation.

(Fig. 6).

4. Discussion

The unprecedented COVID-19 pandemic has had a devastating impact on Americans. The contagious variants plus relaxed precautions against transmission could fuel another spike in coronavirus infections. While the vaccine can reshape the course of the pandemic and has been made widely available to a growing eligible population, the percentage of the fully vaccinated population was lower in the U.S. compared to other developed countries and the growth has been almost stagnant since 2022. Thus, it is important to identify factors that might help increase the vaccine rollout.

One primary finding of this study is that the increase in Biden's approval over time promotes the growth in the vaccination rate. The approval implies public trust in President Biden, and we might expect people who approve of his performance to be more motivated to receive the vaccine as it is a way to endorse the recommendations that the Biden administration has been promoting. Trust can reduce vaccine hesitancy and a study analyzing national survey data shows that the odds of taking the vaccine increase when the respondent's trust in President Biden increases (Hao and Shao, 2022). Another study finds that residents of states with more votes for Biden in the 2020 presidential election are more likely to take the monovalent booster (Hao and Shao, 2023). An alternative way to perceive the political divide is to compare the average vaccination rate between states Biden won and lost in the 2020 presidential election. A bar chart in Fig. 7 shows that the numbers were close (18 % vs. 17 %) on April 1st, 2021. However, the gap amplified by the end of January 2022, with 69 % of residents from Biden states becoming

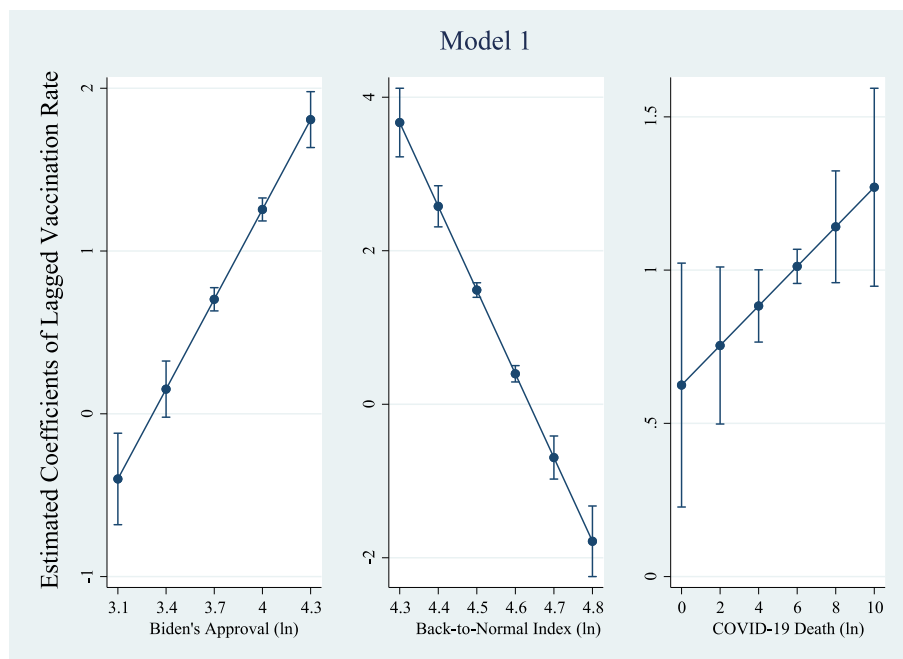


Fig. 3. Estimated Lagged Vaccination Rate of Americans Predicted by Biden's Approval, Back-to-Normal Index, and COVID-19 Death in the Regression Analyses.

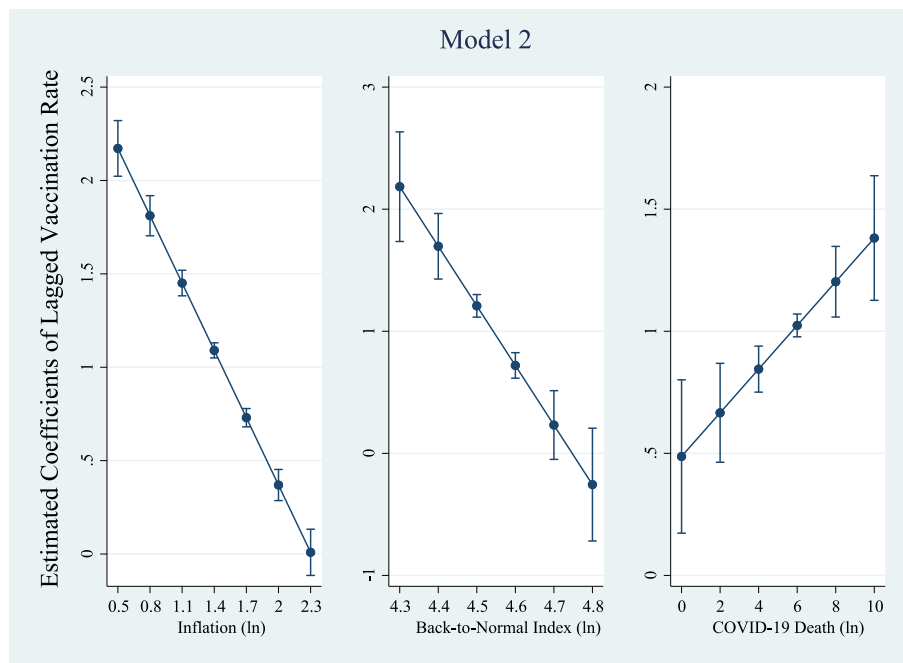


Fig. 4. Estimated Lagged Vaccination Rate of Americans Predicted by the Consumer Price Index, Back-to-Normal Index, and COVID-19 Death in the Regression Analyses.

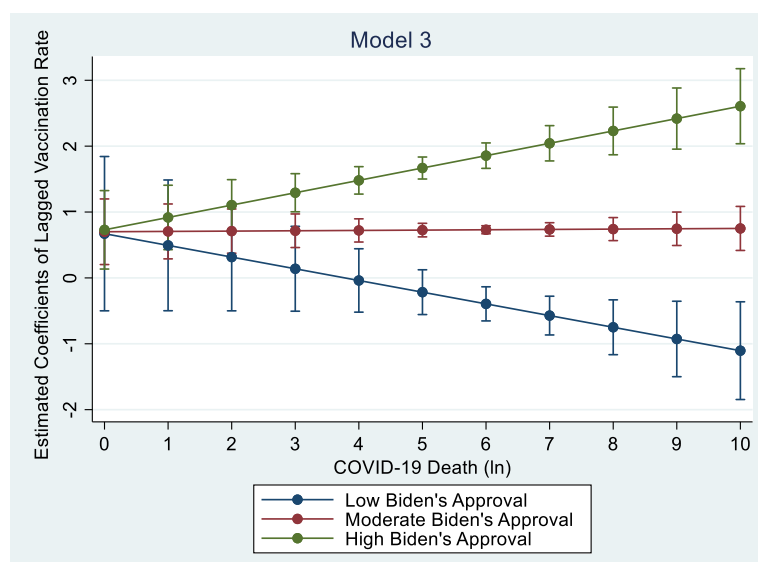


Fig. 5. Estimated Lagged Vaccination Rate of Americans Predicted by COVID-19 Death Depending on Biden's Approval in the Regression Analyses.

fully vaccinated compared to 56 % for Trump states. Previous studies using survey data found that Republicans and conservatives have greater skepticism and hesitancy about the vaccine than their counterparts (Fridman et al., 2021; Stroope et al., 2021). The broad political climate plays a more critical role in shaping one's decision on vaccine uptake, with the vaccination rates being significantly low in Republican counties where the vaccination sites receive less support from policymakers and a social norm of vaccination is far from established (Albrecht, 2022; Yang, Matthews, and Sun, 2022). The finding of this longitudinal analysis reinforces the results of those studies analyzing cross-sectional data and demonstrates that the changing political climate influences public mindsets on vaccination decisions.

In addition, both inflation and economic recovery are negatively associated with the change in vaccination rate. The higher inflation

could drive people to focus more on cost-of-living issues while neglecting the growing cases/deaths, thus becoming less active in receiving the vaccine. At the same time, better economic recovery and the transition toward normalcy create a false image that the pandemic is almost over, which makes people disregard the risk and perceive it as unnecessary to continue receiving the vaccine. This study is the first to analyze inflation's effect on COVID-19 vaccination. The longitudinal analyses of the back-to-normal index complement previous cross-sectional studies that showed the side effect of economic recovery on public response to the pandemic (Hao and Shao, 2021; 2022).

Furthermore, COVID-19 death is positively associated with the vaccination rate. As suggested by the construal level theory (Liberman and Trope, 2008), living in states with growing COVID-19 deaths helps bring the psychological distance to this pandemic closer. As a result,

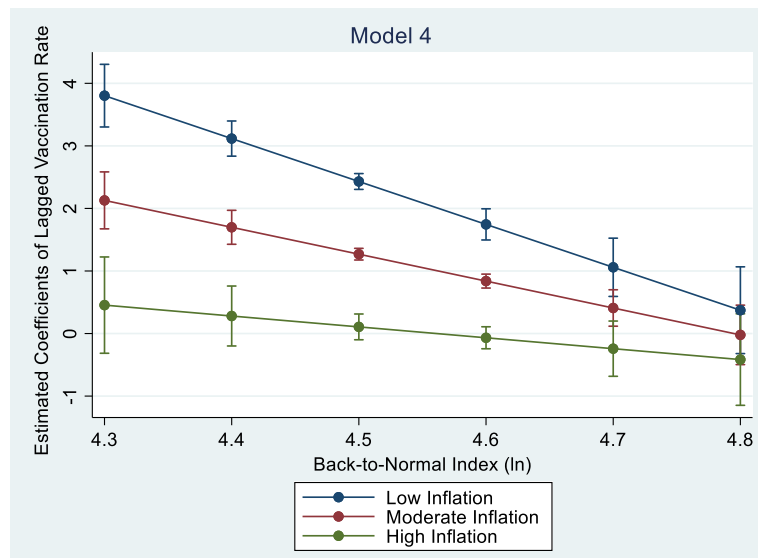


Fig. 6. Estimated Lagged Vaccination Rate of Americans Predicted by Back-to-Normal Index Depending on Inflation in the Regression Analyses.

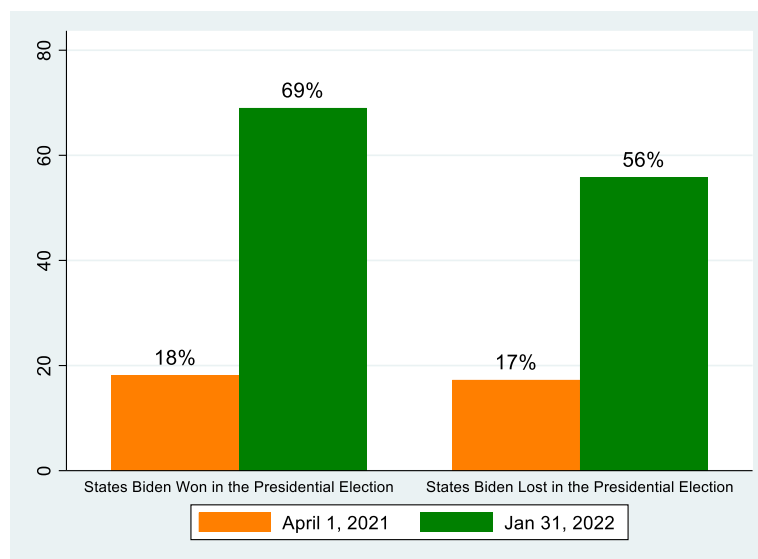


Fig. 7. Differences in Vaccination Rate of Americans between States that Biden Won and Lost in the 2020 Presidential Election.

people in these states sense a more severe and urgent threat and are thus more motivated to become fully vaccinated to reduce the chance of getting infected. The connection between risk gravity and vaccination uptake is also mediated by other factors, as discussed below. The finding aligns with previous survey studies of Americans and found people from states with higher deaths/cases are more likely to keep social distance and wear a face mask in response to the pandemic (Hao and Shao, 2021; Hao, Shao, and Huang, 2021).

Finally, this study reveals two significant interactions. First, Biden’s approval not only has a direct effect on elevating the vaccination rate but also mediates the effect of COVID-19 death. In other words, these two factors have a combined impact on promoting vaccination, with residents from states of growing COVID-19 mortality becoming even more likely to receive the vaccine if residents also increasingly approve of Biden’s performance. In other words, the direct connection between COVID-19 mortality and vaccination rate is mediated by the state’s political climate. Second, while inflation is negatively associated with the change in vaccination rate, higher inflation could reduce the inhibiting effect of the back-to-normal index. One underlying reason is

that people might not sense the benefits of economic recovery when inflation remains high, and thus do not sense the return to normalcy, stay alert for the pandemic’s disruption, and still believe in the necessity of vaccination.

Most previous studies have investigated factors shaping Americans’ attitudes toward the vaccine using public opinion surveys. The findings reveal individual characteristics such as being Democrat, more educated, and older are related to greater chances of vaccine uptake (Dai et al., 2021; Latkin et al., 2021; Szilagyi et al., 2021). The individual decisions to take the vaccine are also rooted in their home state’s context, as revealed by some cross-sectional analyses of county-level data (Albrecht, 2022; Sun and Monnat, 2022). This study complements the literature by explicitly analyzing panel data of state-level indicators longitudinally. Compared to cross-sectional data that is static in time, one advantage of panel data is the capability to reveal the dynamics of scenarios and monitor the trajectory of vaccination progress influenced by the constantly changing political, economic, and public health conditions over time. Including inflation into consideration is another unique aspect of this study because this factor’s effect on

COVID-19 received less attention despite its widespread influence on people's lives. Results show variations in vaccination rates over time are associated with changes in Biden's approval, inflation, economic recovery, and COVID-19 death independently and interactively.

According to the findings, some intervention strategies might be leveraged to persuade a sufficient proportion of the U.S. population to take the vaccine promptly. The politicization of the COVID-19 pandemic has driven the polarized discourses (science-trusting vs. science-distrusting) that inhibit public reception of scientifically reasonable recommendations (Rughiniş and Flaherty, 2022). The continued presence of a partisan gap speaks to the need to de-politicize the arguments surrounding the vaccine and reduce the polarization regarding this issue. Public health experts need to highlight a common identity that all Americans share when facing the same virus, and the vaccine recommendation is based on scientific evidence instead of political bias. Meanwhile, it is necessary to highlight that political bias is not the only obstacle to promoting vaccine uptake, and another important factor is public trust in these experts. The public has various attitudes towards vaccination, as found in a cross-national study among Europeans (Rughiniş et al., 2022). To reduce vaccine hesitancy, promoting confidence in professional organizations such as the WHO and trust in domestic healthcare professionals is an effective approach (Rozek et al., 2021). Thus, we must convince vaccine skeptics about the legitimacy of science-based recommendations and ensure the information is successfully delivered instead of being dismissed.

This study has limitations, and research on this topic calls for more inquiries. First, only four time-variant predictors are included for investigations due to data availability. Subsequent research might consider incorporating additional predictors. Second, the findings of longitudinal analyses are interpreted by referring to the existing paradigms used to account for cross-sectional studies. Thus, additional panel data studies are needed to refine the interpretation. Finally, the FDA approved the vaccine for infants in June 2022, a booster for all adults in September 2022, and an annual booster in 2023 Fall. Thus, scholars might consider outcome measures such as the booster rate or children's vaccination rate and explore predictors when information is available.

CRediT authorship contribution statement

Feng Hao: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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