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Multilevel determinants on COVID-19 booster intention among Americans

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ABSTRACT

The pandemic has disrupted public health and social well-being for more than two years. With the vaccine efficacy waning over time and the spread of new variants, a booster becomes increasingly imperative. This study investigates predictors of the American public's COVID-19 booster intention. A national survey was conducted from September 23rd to October 31st, 2021, on a representative sample. The survey data is merged with state-level indicators of vaccination rate, case rate, political context, and economic recovery. Multilevel regression modeling is adopted for statistical estimation. Results show that a higher proportion of vaccinated people in the network is positively related to one's chance of getting the booster ($\beta = 0.593, p = 0.000$). In comparison, a higher proportion of infected people in the network is negatively related to one's intention to become boosted ($\beta = -0.240, p = 0.039$). Additionally, the higher educated ($\beta = 0.080, p = 0.001$) and older ($\beta = 0.004, p = 0.013$) were more likely to say they would get the booster than their counterparts. Meanwhile, the odds of people taking the COVID-19 booster decrease by 3.541 points ($p = 0.002$) for each unit increase in the case rate at the state level. This study articulates that individual intention to take the booster is a function of their personal characteristics and is also rooted in social networks. These findings contribute to the literature and have policy implications. Knowledge of the profiles among people who intend to take/refuse the booster provides essential information to leverage certain factors and maximize booster uptake to mitigate the pandemic's devastating impact.

1. Introduction

The pandemic caused by SARS-CoV-2 (COVID-19) has disrupted the lives of Americans for more than two years. The latest data shows >96 million people have been infected and over one million lost their lives by September 2022. To fight against COVID-19, the vaccine is critical to mitigating the impacts on public health and social well-being (CDC, 2021). Currently, 80% of the U.S. population has received at least one dose of the vaccine, and 68% of the population are fully vaccinated, >20 months after the first vaccine was administered in December 2020 (CDC, 2022). However, with the vaccine efficacy waning over time and the spread of the Omicron variant, especially the BA.5 subvariant, a booster becomes increasingly imperative (del Rio et al., 2022; Gupta and Topol, 2021). Studies found that the booster can increase the protection against symptomatic infection and prevent severe disease or death (Muik et al., 2022; Patel, 2021). Despite the proven effectiveness and widespread availability, hesitancy remains (Larson and Broniatowski, 2021; Machingaidze and Wiysonge, 2021). The most given reasons to refuse the COVID-19 vaccine include safety concerns, a lack of trust in the efficacy, doubt about the development, and negative intentions from peer

groups (Schneider et al., 2021; Troiano and Nardi, 2021). Misinformation has further increased public anxieties and compromised acceptance (Bonnievie et al., 2021). The data shows low distribution rates with only 33% of Americans receiving the booster (CDC, 2022). Against this backdrop, there is an urgent need to understand the public attitudes toward the COVID-19 booster and identify factors leading to booster intention.

Studies about public opinion about the COVID-19 vaccine have been conducted around the world on populations such as in the United Kingdom (Becchetti et al., 2021), Germany (Seddig et al., 2022), Italy (Capasso et al., 2021), Sweden (Campos-Mercade et al., 2021), Turkey (Dal and Tokdemir, 2022), and Japan (Sasaki et al., 2022). Existing studies of Americans have documented stark variation in public intentions to be vaccinated against COVID-19, which is attributed to sociodemographic characteristics including income, education, gender, age, and race (Cao et al., 2022; Daly and Robinson, 2021; Latkin et al., 2021; Niño et al., 2021). The lower-income, less-educated, younger, male, and African Americans tend to have a lower risk perception of the pandemic and thus be more hesitant to take the vaccine. Political orientation shapes one's mind with Republicans and conservatives less

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likely to take the vaccine than Democrats and liberals (Dolman et al., 2022; Fridman et al., 2021; Larsen et al., 2022; Stroope et al., 2021). Other studies reveal determinants such as trust (Szilagyi et al., 2021), risk perception (Wong and Yang, 2022), message framing (Diamant et al., 2022), information channel (Piltch-Loeb et al., 2021), belief in misinformation (Stoler et al., 2022), and attitude toward the vaccine (Harris et al., 2022). Vaccine availability (Chu and Liu, 2021) and attributes (Kreps et al., 2021) also affect one's willingness to inoculate.

Although previous research has improved the understanding of public opinion on the vaccine, few studies investigated one's attitude regarding the booster (Hahn et al., 2022; Lennon et al., 2022). One primary reason is the booster became available to all adults by late 2021 and the relevant questions were not included in previous surveys. In addition, there has not been a study focusing on the effects of one's social network. The features of a network can decide the contents of (mis)information and affect one's intention of booster uptake. Finally, while individual-level predictors have been explored in the current research, there is a lack of examination of predictors at the collective level.

In response to the evolving pandemic, this study fills the gaps by analyzing a national survey conducted in the Fall of 2021 plus corresponding state-level indicators. Multilevel regression is estimated to understand how personal characteristics (social network and sociodemographic background) and state health, political, and economic conditions shape the public intention to take the booster. The findings shed light on why some people are inclined to get boosted while others are hesitant and provide public health officials with insights to promote the booster to the general population.

2. Methods

2.1. Data source

The data of this study are obtained from several sources. All individual-level data, including measures of one's intention to take the COVID-19 booster, social network, and sociodemographic background, are drawn from Understanding America Study (UAS). The UAS is a longitudinal study of nationally representative samples for roughly 7400 American households managed by the University of Southern California's Center for Economic and Social Research. The panel members (≥ 18 years) are randomly recruited through address-based sampling from the U.S. Postal Service Computerized Delivery Sequence File (Alattar et al., 2018). The survey was tested before the first wave was administered from March 10th to 31st, 2020. Since then, the UAS panelists were invited to participate in a total of 30 waves of surveys related to the COVID-19 pandemic (Kapteyn et al., 2020). Participants complete surveys online in English or Spanish, and those without Internet access are provided with a tablet and broadband Internet. Households who log into the UAS website are asked to agree to an online informed consent before they take the first survey. Those who need the tablet are required to return a signed informed consent form. The UAS only collects anonymized data, does not have direct access to personally identifiable information, and keeps records for this study confidential as far as permitted by law. The participants can continue to the next question of the survey if they fail to respond to a previous item. Respondents were compensated with about \$20 for each half-hour of their survey time.

On average, there are approximately 6200 respondents for each of the 30 survey waves. The UAS produces sample sizes that are statistically sufficient to support studies covering the target populations. For this study, 7060 respondents from all 50 states and Washington D.C. completed the survey administered from September 23rd to October 31st, 2021. The analyses are performed only for respondents who have already received their first dose of the vaccine ($n = 5449$). The observation for each state varies with some populous states such as Florida ($n = 247$) and Texas ($n = 209$) having more respondents while less populous states such as Idaho ($n = 14$) and North Dakota ($n = 13$) having fewer respondents. This wave is the UAS Covid Survey where the booster

intention questions were added. During this period, the booster was made available to individuals 65 years and older and younger adults at risk of severe COVID-19 or whose jobs frequently expose them to the virus. In addition, four state-level variables about vaccination rate, case rate, political context, and economic recovery are included and merged with individual-level data.

2.2. Variable measurement

The dependent variable is a question that asked respondents how likely they would receive a booster shot for COVID-19 when available. Responses and coding include very unlikely (1), somewhat unlikely (2), unsure (3), somewhat likely (4), and very likely (5).

Regarding the individual-level predictors, two ratio variables measure one's social network. The denominator about network size is represented by a question asking how many family or close friends each respondent has. One indicator used the number of respondents' family or close friends that received the COVID-19 vaccine as the numerator and computed the proportion. The other indicator used the number of their family or close friends infected by COVID-19 as the numerator and calculated the proportion.

The dependent variable and the key independent variables of social networks generally measure what they are intended to measure. The focus of this study is one's booster status which is reflected in the likelihood of receiving a booster ranging from unlikely to likely. In addition, the social network regarding COVID-19 is measured in two dimensions. One is the percent of family and friends vaccinated, and the other gauges the percent of family and friends who contracted the virus. The ratios vary among respondents and the variation is hypothesized to affect the individual intention to become boosted.

Next, eight variables are used that cover one's infection status (being infected by the virus = 1), household income (measured in five categories: below \$25,000, \$25,000–\$49,999, \$50,000–74,999, \$75,000–99,999, and \$100,000 and above), education (measured in five categories: high school and less, some college, associate degree, Bachelor's degree, and graduate degree), gender (male = 1), age, and race (measured in three dummy variables of white, black, and other). Measures of political background are not included because they are unavailable in this survey wave.

There are four state-level predictors. First, the vaccination rate was computed by taking the proportion of fully vaccinated people out of the total population. The data is from the CDC. The rates varied during the period when the survey was conducted and the mean of these daily rates is used for analyses. Second, each state's cumulative cases for the survey period were extracted from a dataset compiled by the New York Times and shared on the GitHub website. The average number was divided by the 2021 population from the Census to compute the case rate. Third, the political context is measured by the proportion of Biden votes in the 2020 presidential election and the data is from MIT's Election Lab. Fourth, 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 a mean of these daily indicators is computed. The summary statistics of these variables are reported in [Appendix 1](#).

2.3. Statistical estimation

To examine one's booster intention, the dependent variable of the analysis is one's attitude ranging from opposed to acceptive. The vaccination and infection ratios among one's family and friends are used to gauge social networks. The other individual-level independent variables control personal health and sociodemographic background, including whether being infected, income, education, genera, age, and race. The state-level independent variables reflect the public health, political, and economic conditions regarding vaccination rate, case rate, Biden votes, and the back-to-normal index. The data is hierarchical with

two levels: the individual units of analysis at a lower level are nested within the state units at a higher level. Thus, a multilevel regression model with random intercepts is used to assess the influence of individual-level and state-level variables on one's intention to take the booster (Robson and Pevalin, 2016). Previous studies on Americans' risk perception and mask-wearing related to COVID-19 have used the approach to estimate multilevel data (Hao and Shao, 2021; Hao et al., 2021).

Multiple models are estimated as displayed in Table 1. Model 1 includes individual-level variables. The four state-level measures are added in Model 2. The unstandardized coefficients are presented with standard errors shown in parentheses. The two-sided *p*-values are reported in text and displayed in asterisks to indicate the level of statistical significance.

The models are estimated on 4408 respondents out of 5449 survey participants who have received the first vaccine dose. The missing values appear mostly in the dependent variable (801 observations missing) and the self-infected measure (194 observations missing). The missing values for the other variables are relatively few with <100 observations. To address the issue, A multiple imputation approach is used to generate 20 datasets that have complete data (Royston, 2004). Regression analyses on these datasets after imputing missing values found similar results as reported in the following section.

3. Results

The frequency distribution of the dependent variable displays that 18% of respondents were less likely to say they would take the booster, 6% were unsure, and 76% were likely to take the booster. The UAS has a response rate of 15–20% based on the calculation of the American Association for Public Opinion Research's standard, which is similar to those of the GfK KnowledgePanel and the American Life Panel (Alattar et al., 2018). The data are weighted when performing regression analysis using the wave-specific weight variable (final_weight). The relative final post-stratification weight corrects for differential survey nonresponse rates and aligns the survey sample with the reference population in terms of a predefined set of demographic and economic variables (gender, race/ethnicity, age, education, household size, household income, census region, and urban/rural characteristics). The UAS uses estimates from the most recent available version of the Census Bureau's

Table 1
Multilevel regression results on booster intention.

	Model 1	Model 2
<i>Individual-level independent variables</i>		
Proportion of family or close friends vaccinated	0.593*** (0.138)	0.595*** (0.143)
Proportion of family or close friends infected	-0.240* (0.117)	-0.227 (0.119)
Self-infected	-0.306 (0.297)	-0.309 (0.298)
Household income	0.028 (0.021)	0.027 (0.021)
Highest level of education	0.080** (0.025)	0.079** (0.025)
Male	-0.008 (0.045)	-0.011 (0.045)
Age	0.004* (0.002)	0.005* (0.002)
White	0.112 (0.525)	0.091 (0.514)
Black	-0.186 (0.522)	-0.210 (0.512)
Other race	0.101 (0.510)	0.090 (0.499)
<i>State-level independent variables</i>		
Vaccination rate	-	-0.011 (0.006)
Case rate	-	-3.541** (1.123)
Biden votes	-	0.161 (0.426)
Back-to-Normal index	-	0.004 (0.010)
<i>Model statistics</i>		
Constant	2.974	3.622

p* < 0.05; *p* < 0.01; ****p* < 0.001, two-sided.

Current Population Survey Annual Social and Economic Supplement as the benchmark for population distributions of these variables. The weight ensures the representativeness of the survey sample with respect to the U.S. population 18 years of age or older.

Model 1 shows that one's social network significantly affects their booster intention but in different ways. Notably, a higher proportion of vaccinated people in the network are positively related to one's chance of getting the booster ($\beta = 0.593, p = 0.000$). In comparison, a higher proportion of infected people in the network are negatively related to one's intention to become boosted ($\beta = -0.240, p = 0.039$). For the other variables, the higher educated ($\beta = 0.080, p = 0.001$) and older ($\beta = 0.004, p = 0.013$) were more likely to say they would get the booster than their counterparts. The statistical significance of these individual-level variables largely remains in subsequent models after adding state-level variables. The effects of infection status ($p = 0.302$), income ($p = 0.175$), gender ($p = 0.860$), being white ($p = 0.832$), being black ($p = 0.722$), and being other race ($p = 0.844$) are insignificant. The effects of these variables are displayed in Fig. 1.

Next, Model 2 tests the effects of state-level vaccination rate ($p = 0.056$), case rate ($p = 0.002$), Biden votes ($p = 0.706$), and back-to-normal index ($p = 0.696$). The only variable that has a significant coefficient is the case rate. The odds of people taking the COVID-19 booster decrease by 3.541 points for each unit increase in the case rate. The effect of this variable with 95% confidence intervals is visualized in Fig. 2. The adjusted means of booster intention are computed given different values of state case rates after controlling for other variables in the model. Accordingly, the estimated likelihood of taking the COVID-19 booster decreases concomitantly with the increase in the case rate. In addition to these variables, the influence of alternative state-level measures, including booster rates ($p = 0.680$), death rates ($p = 0.015$), and income ($p = 0.629$), are also tested and findings are presented in Appendix 2. Similar to the case rate, the death rate is also significantly and negatively associated with one's booster intention.

In sum, the analyses that control for a series of individual-level and state-level variables reveal the influence of different factors on one's intention to take the COVID-19 booster. From a social network perspective, more vaccinated people can promote one's booster intention. However, respondents who have more links with others who are diagnosed with COVID-19 or reside in states with more confirmed cases were less likely to say they would take the booster. A cross-level interaction between this social network indicator and state case rate is estimated and the finding is statistically insignificant. The underlying reasons are explored in the discussion section. The intention to take the booster is also influenced by one's education and age. Multiple diagnostics are performed to test the model fit, and the results show that the models are specified reasonably well. The Snijders/Bosker R-square values suggest that the state-level case rates account for around 9% of the variance in personal intention to take the booster and individual-level variables explain 4% of the variance in the dependent variable. The tests for multicollinearity find no substantial problem.

4. Discussion

The COVID-19 pandemic has brought substantial impact and the Omicron variant intensified the situation with early January witnessing more than one million cases daily. The subvariant of Omicron known as BA.5, which is more contagious than the original strain BA.1, has become the dominant coronavirus strain in the U.S. The new variants plus relaxed precautions against viral transmission might fuel another spike in coronavirus infections. Meanwhile, the booster has been proven effective in combating the variant and providing greater protection than being fully vaccinated. However, less than one-third of Americans have taken the booster and the monthly growth rate has reduced to <1 % since February. It is important to know how to persuade more people who are qualified to get boosted. This study aims to address the concern and identify factors that lead to the heterogeneity of one's booster

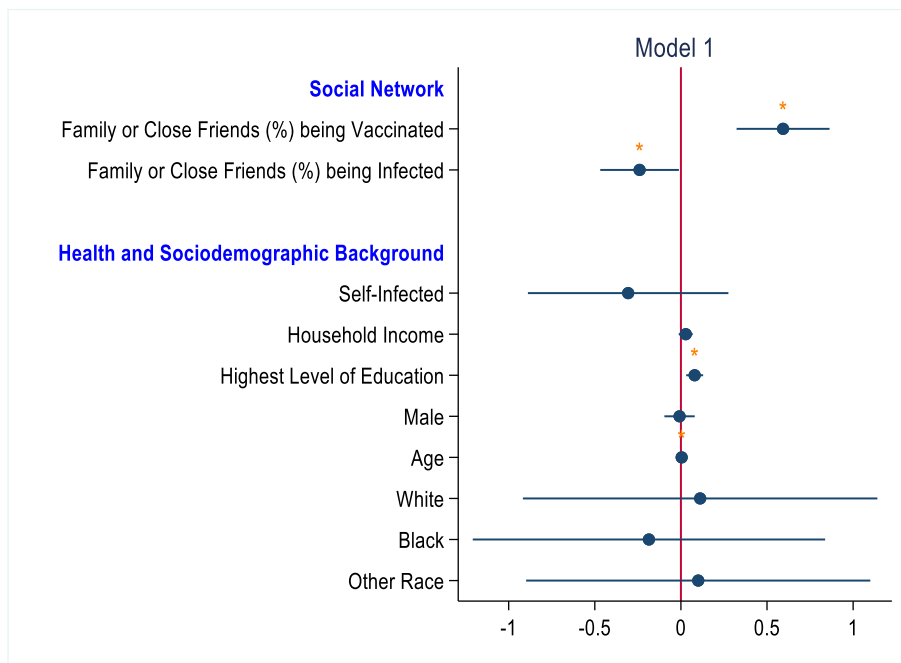


Fig. 1. Effects of individual-level predictors on public booster intention. *Refers to statistically significant coefficients.

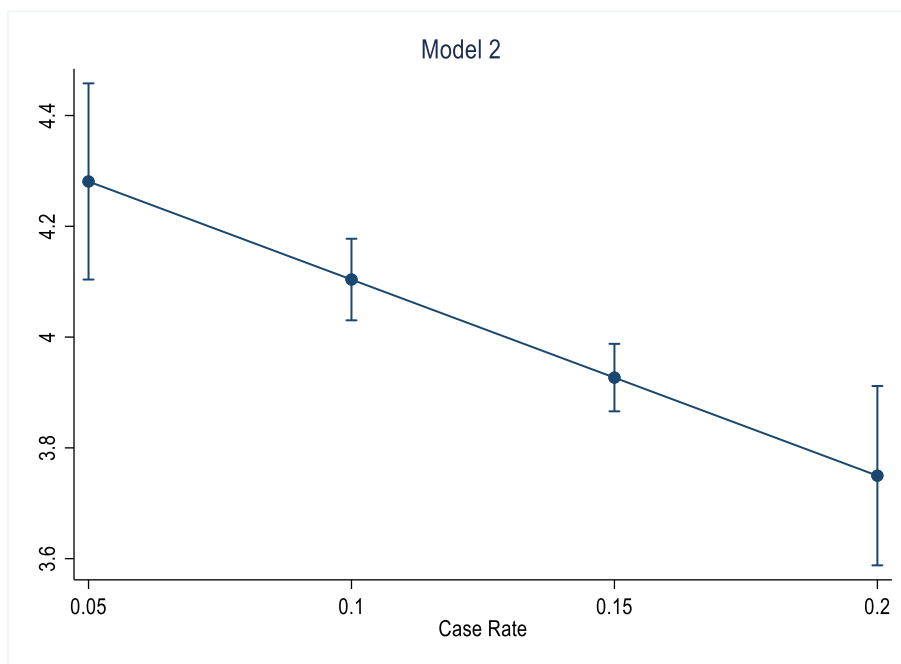


Fig. 2. Booster intention predicted by state-level case rate.

intention.

The primary finding is the social network's effect. On the one side, the extensive connections people possess with vaccine takers can increase their chances of getting boosted. One reason is that a distinct social identity is established among the pro-vaccine population and individuals tend to align their attitudes and behaviors with others in the group (Motta et al., 2021). Meanwhile, they are likely being exposed to timely information on the efficacy of the vaccine and influenced by the group's receptive view on vaccination, which together leads to booster uptake. Previous studies highlight that networking with others who are acceptive of the COVID-19 vaccine is a robust predictor of one's

intention to get the vaccine (Graupensperger et al., 2021) or the behavior of vaccine uptake (Hao and Shao, 2022) while networking with family and friends who are discouraging vaccination leads to lower vaccine uptake (Latkin et al., 2022). On the other side, this study reveals that people with more family and friends in their networks who are infected or from states with high case rates less likely to say they would take the COVID-19 booster. One possible explanation is that the connections with the infected population might make people perceive the vaccine as ineffective and it is not necessary to take the booster. A study of the post-positive reluctance of Italians shows that having already contracted COVID-19 leads people to underestimate, not overestimate,

the importance of vaccination (Caserotti et al., 2022). Another explanation might reside in the misinformation shared by the infected that drives skepticism and hinder the behavioral responses. A study about vaccine confidence among American primary care physicians reveals that a troubling proportion of the group lacks confidence in the safety, effectiveness, and importance of the vaccine, which could influence the mindsets of patients, especially those who contracted COVID-19 (Callaghan et al., 2022).

There has been research on public opinion about the COVID-19 vaccines in other countries (Becchetti et al., 2021; Campos-Mercade et al., 2021; Sasaki et al., 2022). Regarding the booster, one study of people who had completed a primary vaccination series in Naples, Italy, revealed that females, older, and those who receive information regarding the benefit of the booster are more likely to become boosted (Folcarelli et al., 2022). Another study of Japanese in Fukushima found that the younger cohort with a higher antibody level is more hesitant over the booster. The concerns about the adverse reactions also shape one's decision on booster uptake (Yoshida et al., 2022).

For Americans, most previous studies have surveyed factors shaping public attitudes toward the vaccine (Diament et al., 2022; Fridman et al., 2021; Latkin et al., 2021; Szilagyi et al., 2021). One study of healthcare workers at the beginning of 2021 found that the vaccine-hesitant respondents also have a low acceptance of a hypothetical booster (Pal et al., 2021). This study complements the literature by investigating determinants that promote or inhibit booster intention. Results show that individual intention to take the booster is a function of their personal characteristics and features of social networks. The design of behavioral nudges and incentive programs can help overcome vaccine and booster hesitancy (Dai et al., 2021; National Academies of Sciences, Engineering, and Medicine, 2022). According to the findings, some intervention strategies might be leveraged to increase the booster intention. First, encouraging vaccine takers to recommend boosters to others is an effective approach. A social network highlighting the vaccine's efficacy can help spread scientifically accurate information and counter misinformation. Second, public health experts need to establish a mechanism to emphasize the necessity of the booster for people who contracted the virus to avoid losing confidence in the vaccine and diffusing biased judgment. These efforts to promote booster intention might target the populations who are hesitant such as the less-educated and younger. In addition, studies of people from other countries revealed the pivotal role of healthcare workers, doctors, and scientific journals as sources of information that help to address vaccine hesitancy (Di Giuseppe et al., 2021; Wang et al., 2021). These tools can also be leveraged to raise awareness regarding the safety and benefits of the

booster and to improve booster uptake for Americans.

This study has limitations and research on this topic call for more inquiries. First, even though a weight variable is applied when estimating regression models, the sampling strategy and the representativeness of the sample could still be a concern. The social desirability bias might affect one's response to questions such as booster status and the proportion of network members being infected or vaccinated. The lack of questions asking respondents to rate the validity of the survey might affect the face validity of the measures. Second, this study analyzes a wave of the UAS survey conducted in the Fall of 2021. The public's attitudes and behavior regarding the booster might be different due to the changes in the pandemic's trajectory, the growing availability of boosters, and more information about the variants. The FDA approved the first COVID-19 booster for all adults in November 2021 and authorized the updated booster targeting the BA.4 and BA.5 Omicron sub-lineages on August 31st, 2022. Subsequent research should continue monitoring public opinion using more latest or panel data. Third, while the effects of social networks have been identified, more information is needed to explain why different networks have contrasting influences. This study offers potential explanations based on statistical estimations and follow-up in-depth interviews with people who have an extended network of either vaccine takers or infected cases are helpful to figure out the roots that trigger the network's influence. Finally, since public opinion about the pandemic has been politicized (Shao and Hao, 2020, 2021), scholars might consider other predictors at both the individual level (political orientation and experience with long COVID symptoms) or collective level (vaccine mandate and monetary incentives) that might also shape one's decision to take the booster when data are available.

Statement on funding and conflicts of interest

The author received no funding for this study and there is no conflict of interest.

Credit author statement

Feng Hao: Conceptualization, Formal Analysis, Visualization, Writing – original draft, Writing - review & editing.

Data availability

Data will be made available on request.

Appendix A. Appendix

Appendix 1
Descriptive statistics.

Variable	Mean	S.D.	Min	Max
<i>Dependent variable</i>				
Covid-19 booster intention	4.062	1.375	1	5
<i>Individual-level independent variables</i>				
Proportion of family or close friends vaccinated	0.767	0.256	0	1
Proportion of family or close friends infected	0.193	0.217	0	1
Self-infected	0.015	0.123	0	1
Household income	3.254	1.467	1	5
Highest level of education	3.151	1.416	1	5
Gender (male = 1)	0.419	0.493	0	1
Age	53	16	18	111
White	0.779	0.415	0	1
Black	0.078	0.268	0	1
Other race	0.135	0.342	0	1

(continued on next page)

Appendix 1 (continued)

Variable	Mean	S.D.	Min	Max
<i>State-level independent variables</i>				
Vaccination rate (fully vaccinated/population)	0.551	0.080	0.407	0.702
Case rate (cases/population)	0.133	0.030	0.055	0.179
Proportion of Biden votes in 2020 presidential election	0.486	0.120	0.264	0.921
Back-to-Normal index	95.355	4.060	82.810	103.960

Appendix 2

Multilevel regression results on booster intention with other state-level variables

	Model S1
<i>Individual-level independent variables</i>	
Proportion of family or close friends vaccinated	0.599*** (0.142)
Proportion of family or close friends infected	-0.235* (0.116)
Self-infected	-0.305 (0.295)
Household income	0.027 (0.021)
Highest level of education	0.080** (0.025)
Male	-0.013 (0.044)
Age	0.004* (0.002)
White	0.091 (0.511)
Black	-0.197 (0.510)
Other race	0.091 (0.495)
<i>State-level independent variables</i>	
Booster rate	-2.975 (7.224)
Death rate	-92.132* (37.953)
Personal income	0.000 (0.000)
<i>Model statistics</i>	
Constant	3.315

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$, two-sided.

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