Explaining vaccine hesitancy: A COVID-19 study of the United States

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Abstract
Using recent data on the unvaccinated population across US states, this paper focuses on the determinants of vaccine hesitancy related to the COVID-19 pandemic. Findings show that more prosperous states and states with more elderly residents and more physicians have lower vaccine hesitancy. There was some evidence of the significance of race, but internet access and history of other contagious diseases failed to make a difference. States with centralized health systems and those with mask mandates generally had a lower percentage of unvaccinated populations. Finally, the presence of Democrats in state legislatures tended to lower vaccination hesitancies, ceteris paribus.

INTRODUCTION

A growing body of academic research has emerged over the past 2 years focusing on different aspects of the causes and effects of the current pandemic (for reviews, see Brodeur et al., 2021; Padhan & Prabheesh, 2021; also see Jawad et al., 2021). With respect to the causes or determinants, nearly all of the economic investigations have focused on the socio-economic-political causes of the various containment measures, most notably trying to explain the vaccination disparities across various jurisdictions (Baldwin and Weder di Mauro, 2020; Motie and Biolsi, 2021).

With the availability of the different COVID-19-fighting vaccines around the world (https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-(covid-19)-vaccines; also see Kaur & Gupta, 2020) and in order to address the varying vaccination rates around different jurisdictions, the focus of policymakers has shifted to increasing vaccination delivery so that herd immunity is achieved and economic and social activities can return to “normal.” Increasing the vaccination rates, however, has been a challenge that has turned out to be somewhat beyond the purely economic aspects. In many instances, abundant vaccine supplies and even zero vaccine prices have failed to increase vaccination rates up to saturation levels. Thus, vaccine hesitancy has become a significant policy and debate issue (https://brownstone.org/articles/who-is-to-blame-for-vaccine-hesitancy/).

There is a small body of research that has emerged on vaccine hesitancy (Dror et al., 2020; Jones et al., 2022; Khubchandani et al., 2021; Norhayati et al., 2022; Sallam, 2021; Tan et al., 2022), focusing on different aspects. Relatedly, Goel and Jones (2022) consider the risks associated with vaccine passports. Yet, given the varying rates of vaccination success across jurisdictions, policymakers seem to lack formal guidance regarding how to effectively overcome vaccine hesitancy. This present research, focusing on vaccine hesitancy across US states, attempts to provide some insights. In particular, we uniquely present a formal empirical analysis of the determinants of vaccine hesitancy using data from states in the United States.

During the current pandemic, the United States has experienced a total of over 89 million cases of COVID-19 and over 1 million deaths from COVID-19, with approximately 125,000 new cases being reported and over 500 deaths reported on August 10, 2022—https://usafacts.org/visualizations/coronavirus-covid-19-spread-map. These data detail the importance of looking at the progress in vaccinations against COVID-19. According to usafacts.org, approximately 79% of the population have received at least one dose of the vaccine, 67% are fully vaccinated, and 32% of the population have received a booster dose.

Many influences, including economic, social, health, and political might come to bear upon the decisions to vaccinate and, conversely,
to not vaccinate. For instance, Persad et al. (2020) consider the role of race, Sylvester (2021) considers the influence of education, Goel and Nelson (2021a) consider the role of the internet, Jones et al. (2022) considers the role of cultural tightness, and Tan et al. (2022) focus on the age issues. In addition, vaccination efforts around the world have become a politically-charged issue and the United States is no different (see da Fonseca et al., 2021; Nayak et al., 2021). We consider a number of these aspects, and details are outlined in the following section and in Table 1.

Interestingly, while healthcare workers, in general, empower states/nations to better administer vaccines, some healthcare workers themselves have shown vaccine hesitancy (Biswas et al., 2021; https://www.theatlantic.com/health/archive/2022/02/home-healthcare-covid-vaccination/622029/). We formally evaluate the strength of the influence of health care workers by studying the impact of the number of physicians per capita in a state on vaccine hesitancy. Physicians might themselves have aversion to vaccinations, or they might be active advocates of COVID-19 prevention measures (also see Li et al., 2021).

In the spectrum of the various mitigation and prevention measures against the coronavirus pandemic, some measures like masking and distancing requirements have been implemented from time to time across different US states, while others like lockdowns have not found much public or political support in the United States (see Alfano & Ercolano, 2020; for a cross-national study of the efficacy of lockdowns against the spread of COVID-19). In order to explain the correlations behind differing vaccination rates, this paper formally analyzes the determinants of the unvaccinated populations. For this purpose, we use recent cross-state data from the United States, considering economic, health, social, and political aspects. There are substantial socio-economic-political differences across individual states in the United States, given the federalist nature of the government structure. Thus, the findings should also be of value to other jurisdictions/nations.

Our findings show more prosperous states and states with more elderly and more physicians tended to have lower vaccine hesitancy. There was some evidence of the significance of race factors, but internet access and state history of other contagious diseases failed to make a difference. States with centralized health systems and those with mask mandates generally tended to have a lower vaccine hesitancy. Thus, the structure of public health spending mattered more than its mere size. Finally, the increasing presence of Democrats in state legislatures tended to be associated with lower vaccination hesitancies, ceteris paribus.

The structure of the rest of the paper includes the model, data, and estimation in the next section, followed by results, and conclusions.

2 | MODEL, DATA, AND ESTIMATION

2.1 | Model

With i denoting a state, the general form of our estimated relation, with no vaccination rate in a given state (NOvaccine) as the dependent variable, is:

\[ \text{NOvaccine}_{it} = f\left(Z_i, \text{Economic factors}_{it}, \text{Health sector}_{it}, \right) \]

\[ \quad \quad \text{Political factors}_{ij}, \text{MEXICO}_{bor}, \text{CANADA}_{bor} \ldots \]

where

\[ Z = \text{INCOME}, \text{RACE}, \text{ELDERLY}, \text{RELIGION}, \text{PHYSICIANS}, \text{MASKS} \]

\[ b = \text{UNEM}, \text{EDUC}, \text{INTERNET} \]

\[ m = \text{CONTAGIOUSdisease}, \text{CentralizedHEALTH}, \text{HEALTHspending} \]

\[ j = \text{governorDEM}, \text{senateDEM}, \text{houseDEM}, \text{CORRUPTION} \]

Among the set of explanatory variables that we consider, the vector Z includes determinants that we include in all the models estimated to explain vaccine hesitancy across states in the United States. The underlying theoretical rationale is that attitudes toward vaccinations or vaccination hesitancy are driven by the public’s risk attitudes (see Caserotti et al., 2021; Goel & Jones, 2022; Li et al., 2021; Pogue et al., 2020), the institutional setup, and economic prosperity (capturing affordability). Risk attitudes in turn are shaped by the information people have (proxied by INTERNET, EDUC, INCOME, UMEM), while RACE, ELDERLY, and RELIGION capture personal attributes. Further, PHYSICIANS, MASKS, CentralizedHEALTH, HEALTHspending, governorDEM, senateDEM, houseDEM, CORRUPTION relate to institutional setups in place across states. As a robustness check and a more direct accounting for the effect of riskiness on vaccinations (Section 3.6), we consider the role of uncertainty in driving vaccination hesitancy. Alternately viewed, beyond risk attitudes, the institutional and economic aspects can be seen as related to transaction costs of vaccinations. Higher transaction costs, ceteris paribus, would lead the public to forgo vaccinations. Further, more risk-averse individuals, especially those without accurate information on the costs and benefits of vaccinations, are likely to be vaccine-hesitant.

The choice of the set of Z variables is based on the extant literature (e.g., Baldwin & Weder di Mauro, 2020; Troiano & Nardi, 2021), plus the plausibility of their expected influence on vaccine hesitancy. These include INCOME, RACE, ELDERLY, RELIGION, PHYSICIANS, and MASKS. INCOME, measured as state median household income, captures the better ability to bear possible adverse consequences of non-vaccination, and income is generally positively correlated with education. Further, more prosperous states would generally have a better institutional capacity to vaccinate their populations and to disseminate related information. Income is an indicator of socioeconomic privilege that may be linked to vaccination rates (Agarwal et al., 2021).

The role of social factors has been noted by several scholars with regard to their impact of COVID-19 vaccination rates and vaccine hesitancy (e.g., Latkin et al., 2021; Savoia et al., 2021; Siegel et al., 2021). The underlying rationales relate to equality (inequality) of access to public services, information, and the means to obtain them, as well as practices and norms that might differ across races due to cultural differences—“structural racism” in the usage of Siegel et al. (2021). Accordingly, in our study, the variables RACE, ELDERLY, and RELIGION capture social aspects that are likely relevant in someone’s decision to seek or not seek vaccinations, whereas PHYSICIANS is a measure of health capacity, although there has been some hesitancy among healthcare workers to vaccinate (Biswas et al., 2021;
| Variable          | Definition                                                                                                                                                                                                 | Source   |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| NOvaccine         | The fraction of the selected state's population who are not fully vaccinated. Calculated as one minus the fraction of the population who are fully vaccinated. To be considered fully vaccinated you need to have one dose of the Janssen/Johnson & Johnson vaccine or two doses of the Pfizer-BioNTech or the Moderna vaccines. Date collected: Feb. 3, 2022 | [1]      |
| NOvaccine2        | NOvaccine data collected on date: Feb. 18, 2022                                                                                                                                                    | [1]      |
| VaccineATTITUDE1  | COVID-19 vaccine hesitancy rate measured as a percent of the population at the state-level, which is based on the US Census Bureau's Household Pulse Survey question: “Once a vaccine to prevent COVID-19 is available to you, would you ... get a vaccine?,” which provides the following options: (1) “definitely get a vaccine”; (2) “probably get a vaccine”; (3) “unsure”; (4) “probably not get a vaccine”; (5) “definitely not get a vaccine.” We use three definitions to capture the strength of hesitancy to receive a vaccine. VaccineATTITUDE1, capturing weak attitudes or hesitancy, is defined as survey responses indicating they would “probably not” or “unsure” or “definitely not” receive a COVID-19 vaccine when available. | [12]     |
| VaccineATTITUDE2  | COVID-19 vaccine (strongly) hesitancy rate measured as a percent of the population at the state-level, which is based on the US Census Bureau's Household Pulse Survey question: “Once a vaccine to prevent COVID-19 is available to you, would you ... get a vaccine?,” which provides the following options: (1) “definitely get a vaccine”; (2) “probably get a vaccine”; (3) “unsure”; (4) “probably not get a vaccine”; (5) “definitely not get a vaccine.” We use three definitions to capture the strength of hesitancy to receive a vaccine. VaccineATTITUDE2, addressing strong attitudes or hesitancy, is defined as survey responses indicating they would “definitely not” receive a COVID-19 vaccine when available. | [12]     |
| INCOME            | Median household income, measured in thousands of dollars in the year 2019.                                                                                                                                 | [2]      |
| ELDERLY           | Fraction of the population that is 65 years and over in the year 2019.                                                                                                                                 | [2]      |
| RACE              | Fraction of the population that is Black in the year 2019.                                                                                                                                              | [3]      |
| RELIGION          | The percent of the population that is Christian in the year 2010.                                                                                                                                      | [4]      |
| PHYSICIANS        | The number of active physicians per 10,000 state resident population in the year 2018.                                                                                                               | [11]     |
| MASKS             | Dummy variable equal to 1 for the eight states that have mask mandates, and zero otherwise. These states require most people to wear a face mask in indoor public places regardless of vaccination status. The eight states include California, Hawaii, Illinois, Nevada, New Mexico, New York, Oregon, and Washington. Date: December 20, 2021. | [5]      |
| UNEM              | Unemployment rate (fraction) in the year 2019.                                                                                                                                                           | [2]      |
| EDUC              | Fraction of the population 25 years and over with a bachelor’s degree or higher in the year 2019.                                                                                                        | [2]      |
| INTERNET          | Fraction of total households with a broadband Internet subscription in the year 2019.                                                                                                                  | [2]      |
| CONTAGIOUSdisease | The number of reported cases for HIV diagnoses, Chlamydia, and Lyme Disease as a fraction of the total population in the year 2009.                                                                           | [6]      |
| CentralizedHEALTH | Dummy variable equal to one if the state's public health is centralized, and zero otherwise (year = 2009). A state is considered centralized if all the public health services are administered through a central office. | [7]      |
| HEALTHspending    | Direct state and local expenditures for health and hospitals measured in thousands of dollars divided by total population for the year 2019.                                                              | [8]      |
| governorDEM       | Dummy variable equal to one if the political affiliation of the governor is Democrat and zero otherwise for year 2019.                                                                                     | [9]      |
| senateDEM         | Fraction of the state senate that is Democrat for the year 2019.                                                                                                                                  | [9]      |
| houseDEM          | Fraction of the state house that is Democrat for the year 2019.                                                                                                                                   | [9]      |
| CORRUPTION        | The number of Federal public corruption convictions per 100,000 population. These data were averaged over the years 2017–2019.                                                                              | [10]     |
| UNEMsd            | The standard deviation of the unemployment rate from 2019 to 2021.                                                                                                                                  | [13]     |
| ECONuncertain     | Economic Policy Uncertainty Index for year 2021. This index measures the uncertainty within a state that is due to state and local policy issues. The index is constructed based on the fraction of news articles that contain terms regarding the economy, uncertainty, and policy. Higher numbers denote more uncertainty. | [14]     |
| CANADabor         | Dummy variable equal to 1 if the state borders Canada and zero otherwise.                                                                                                                                |          |
| MEXICObor         | Dummy variable equal to 1 if the state borders Mexico and zero otherwise.                                                                                                                                |          |

Note: Data sources: [1] https://www.mayoclinic.org/coronavirus-covid-19/vaccine-tracker, [2] US Census Bureau, 2019 American Community Survey 1-Year Estimates, [3] http://wonder.cdc.gov/wonder/help/bridged-race.html, [4] Clifford Grammich, Kirk Hadaway, Richard Houseal, Dale E. Jones, Alexei Krindatch, Richie Stanley, and Richard H. Taylor, 2010. US Religion Census: Religious Congregations & Membership Study, 2012, (copyright), Association of Statisticians of American Religious Bodies, see also <www.asarb.org>. [5] https://leadingage.org/regulation/state-state-face-mask-mandates, [6]
used survey data from Israel, completed by healthcare workers and members of the general population, regarding the acceptance of a potential COVID-19 vaccine. Their results indicated that healthcare staff involved in the care of COVID-19-positive patients, and individuals considering themselves at risk of disease, were more likely to self-report acquiescence to COVID-19 vaccination (if and when the vaccine became available). Furthermore, Momplaisir et al. (2021) find racial and ethnic influences in vaccine hesitancy among health care workers.

The political inclinations of the executive branch of the state government might impact the willingness and the speed of the government’s response to vaccinations (see da Fonseca et al., 2021; Nayak et al., 2021; Potrafke, 2018, for a broader related survey; also, see https://theconversation.com/politicizing-covid-19-vaccination-efforts-has-fuelled-vaccine-hesitancy-175416); Agarwal et al. (2021) note the association of political ideology with racial disparities in COVID-19 vaccination rates. Accordingly, we include three measures: (a) governorDEM is a dummy variable identifying states with a Democrat as a governor; (b) senateDEM is the fraction of a state’s senate that is Democrat; and (c) houseDEM is the fraction of the state house that is Democrat. The correlation between senateDEM and houseDEM is .967 (Table A1).

As an alternative measure of the (weakness of) institutional capacity, we include state corruption (CORRUPTION), measured by convictions for corrupt acts in a state. Vaccination holdouts in states with strict vaccination requirements for entry/travel/employment might view corruption as a means to bypass regulations and/or mitigate any related penalties (Goel and Nelson, 2021b).

Finally, we also account for the geographic location of different states by including variables identifying states bordering Canada and Mexico (CANADAbor and MEXICObor, respectively). Even with international borders largely closed during the pandemic, the casual flow of information and the relatively greater presence of transient populations from neighboring nations (maybe some stuck during the pandemic) might significantly frame vaccination or vaccine-hesitancy attitudes (also see, Mallapaty, 2022). The data section is next.

2.2 Data

The data used for the analysis consists of a cross-section of the 50 US states, plus the District of Columbia. The data are gathered from various reputable sources—see Table 1 for variable names, definitions, and sources, and Table 2 for corresponding summary statistics.
The main variable of interest is the percentage of the (state) population that has not been fully vaccinated against COVID-19. The Mayo Clinic provides estimates for the fraction of the state’s population that has been fully vaccinated. Thus, we compute the fraction of the population not fully vaccinated (NOvaccine) by taking one minus this value. To be considered fully vaccinated individuals must have at least one dose of the Janssen/Johnson & Johnson vaccine or two doses of the Pfizer-BioNTech or the Moderna vaccines.

On average, approximately 37% of the states’ population in the United States is unvaccinated at the time of writing. However, this average masks the considerable variation in the percentage of the population unvaccinated across states. For instance, Vermont has the smallest percentage of the population unvaccinated (20.5%), while Alabama has the largest share of the population unvaccinated (50.5%).

We also consider two alternate measures of vaccination attitudes based on survey responses to the following question from the US Census Bureau’s Household Pulse Survey: “Once a vaccine to prevent COVID-19 is available to you, would you … get a vaccine?” The vaccine broader attitude measure (VaccineATTITUDE1) includes those that answered this question with “probably not” or “unsure” or “definitely not” receive a COVID-19 vaccine when available, while VaccineATTITUDE2 includes those that answered with “definitely not.” These two variables are positively correlated with NOvaccine, our main dependent variable (with correlation coefficients being .82 and .78, respectively).

### 2.3 Estimation

Turning to a discussion of our estimation strategy, Equation 1 is linearized and then estimated using the Ordinary Least Squares (OLS) regression.

To ensure that OLS is valid, we report several diagnostic tests. First, we report the Cameron and Trivedi’s (1990) information matrix (IM) test of the OLS regression model. This test is decomposed into tests for heteroskedasticity, skewness, and kurtosis under the null hypothesis that error is free from heteroskedasticity, skewness, and kurtosis. The test results, reported at the bottom of Table 3, show that we fail to reject the null in all cases, except in Model 3.1 there is some evidence that the errors are heteroskedastic and skewed. As a result, we report heteroskedasticity-robust standard errors for all models.14

To check for multicollinearity, we also report the variance inflation factors (VIF). The VIFs reported at the bottom of Table 3 are all well below the benchmark 10, suggesting that multicollinearity is not a major concern. The results section follows.

| Table 2 Summary statistics |
|-----------------------------|
| N  | Mean | St. dev. | Max | Min |
| NOvaccine | 51 | 0.374 | 0.0863 | 0.505 | 0.205 |
| NOvaccine2 | 51 | 0.366 | 0.0873 | 0.500 | 0.198 |
| VaccineATTITUDE1 | 51 | 0.122 | 0.0521 | 0.251 | 0.040 |
| VaccineATTITUDE2 | 51 | 0.080 | 0.0386 | 0.171 | 0.022 |
| INCOME | 51 | 65.511 | 11.171 | 92.266 | 45.792 |
| ELDERLY | 51 | 0.169 | 0.0202 | 0.213 | 0.114 |
| RACE | 51 | 0.127 | 0.108 | 0.475 | 0.00994 |
| RELIGION | 51 | 43.35 | 11.90 | 66 | 9 |
| PHYSICIANS | 51 | 29.73 | 8.816 | 74.50 | 19.60 |
| MASKS | 51 | 0.157 | 0.367 | 1 | 0 |
| UNEM | 51 | 0.0439 | 0.00878 | 0.0660 | 0.0260 |
| EDUC | 51 | 0.327 | 0.0654 | 0.597 | 0.211 |
| INTERNET | 51 | 0.858 | 0.0314 | 0.912 | 0.768 |
| CONTAGIOUSdisease | 50 | 0.00403 | 0.00151 | 0.0102 | 0.00195 |
| CentralizedHEALTH | 50 | 0.160 | 0.370 | 1 | 0 |
| HEALTHspending | 51 | 0.890 | 0.498 | 2.978 | 0.174 |
| governorDEM | 50 | 0.460 | 0.503 | 1 | 0 |
| senateDEM | 50 | 0.462 | 0.218 | 1 | 0.100 |
| houseDEM | 49 | 0.476 | 0.192 | 0.900 | 0.150 |
| CORRUPTION | 51 | 0.298 | 0.399 | 2.366 | 0 |
| UNEMsd | 51 | 2.226 | 0.946 | 5.427 | 0.751 |
| ECONuncertain | 51 | 178.64 | 106.27 | 608.67 | 16.60 |
| CANADAbor | 51 | 0.255 | 0.440 | 1 | 0 |
| MEXICObor | 51 | 0.0784 | 0.272 | 1 | 0 |

Note: See Table 1 for variable definitions.
TABLE 3 Explaining vaccine hesitancy: Baseline models. Dependent variable: NOvaccine

|          | (3.1)         | (3.2)         | (3.3)         | (3.4)         | (3.5)         |
|----------|---------------|---------------|---------------|---------------|---------------|
| INCOME   | \(-0.005^{***}(0.001)\) | \(-0.004^{***}(0.001)\) | \(-0.004^{***}(0.001)\) | \(-0.006^{***}(0.001)\) | \(-0.005^{***}(0.000)\) |
| ELDERLY  | \(-1.643^{***}(0.380)\) | \(-1.629^{***}(0.383)\) | \(-1.668^{***}(0.388)\) | \(-1.651^{***}(0.397)\) | \(-1.751^{***}(0.380)\) |
| RACE     | 0.131*(0.065) | 0.118*(0.074) | 0.132*(0.066) | 0.149**(0.066) | 0.122*(0.067) |
| RELIGION | \(-0.000(0.001)\) | \(-0.000(0.001)\) | \(-0.000(0.001)\) | 0.000(0.001) | \(-0.000(0.001)\) |
| PHYSICIANS| \(-0.003^{**}(0.002)\) | \(-0.004^{**}(0.002)\) | \(-0.003(0.002)\) | \(-0.003^{*}(0.002)\) | \(-0.004^{**}(0.002)\) |
| MASKS    | \(-0.035^{*}(0.018)\) | \(-0.037^{*}(0.018)\) | \(-0.038^{**}(0.018)\) | \(-0.030^{*}(0.016)\) | \(-0.028(0.017)\) |
| UNEM     | 0.275(0.970)  | 0.221(0.300)  | 0.451(0.478)  | 0.004(0.015)  | \(-0.033(0.027)\) |
| EDUC     |               | 0.000(0.000)  |               |               |               |
| INTERNET |               |               |               |               |               |
| CANADAbor|               |               |               |               |               |
| MEXICObor|               |               |               |               |               |

**Diagnostic tests**

|                          | (0.070) | (0.277) | (0.222) | (0.179) | (0.213) |
|--------------------------|---------|---------|---------|---------|---------|
| Skewness test            | (0.089) | (0.138) | (0.125) | (0.479) | (0.187) |
| Kurtosis test            | (0.983) | (0.965) | (0.719) | (0.995) | (0.907) |
| Total                    | (0.042) | (0.201) | (0.151) | (0.237) | (0.175) |
| Mean VIF                 | 1.71    | 2.01    | 3.15    | 2.97    | 1.66    |
| Observations             | 51      | 51      | 51      | 51      | 51      |
| R-squared                | 0.771   | 0.772   | 0.775   | 0.776   | 0.781   |

Note: See Tables 1 and 2 for variable details. Each model is estimated using Ordinary Least Squares (OLS) with robust standard errors in parentheses and probability values in brackets. Constant is included in each model but not reported. Asterisks denote the following significance levels.

***p < .01. **p < .05. *p < .1.

3 | RESULTS

3.1 | Baseline models

The baseline results in Table 3 show that states with higher median household incomes (INCOME), states with a greater percentage of the elderly (ELDERLY), states with more physicians per capita (PHYSICIANS), and states with mask mandates in indoor spaces (MASKS) all tended to have lower vaccine hesitancy.\(^{15}\) Whereas INCOME and PHYSICIANS relate to the ability to obtain vaccinations, ELDERLY and MASKS relate more to attitudes toward vaccinations. Quantitatively, the elasticity of NOvaccine with respect to income (Model 3.1), is \(-.88\) (evaluated at respective means).

We further find that race (RACE—the percent of the state population that is black) tended to have a positive and significant effect on vaccine hesitancy, consistent with the findings of Fisher et al. (2020) and Willis et al. (2021). Beyond differing attitudes toward vaccinations, the positive effect might be partly due to differential access to vaccinations and related information in states with greater concentrations of certain races (see Persad et al., 2020).

The impact of religion, measured by the share of the population that is of the Christian faith in a state (RELIGION), did not have a significant effect on vaccine hesitancy. Further, the three economic variables, UNEM, EDUC, and INTERNET, failed to have a statistically significant impact.\(^{16}\) This was also the case for the two geographic variables, CANADAbor and MEXICObor, identifying states bordering Canada and Mexico, respectively (Model 3.5). Next, we consider several extensions to the baseline models.

3.2 | Considering aspects of the healthcare sector

In this section, we report results with the consideration of different dimensions of the healthcare sector. While greater healthcare capacity would in general increase vaccination rates, the organization and attitudes of the health sector/employees might contribute to vaccine hesitancy.\(^{17}\)

Of the healthcare sector variables reported in Table 4, states with centralized public health systems had a lower vaccine hesitancy, ceteris paribus (Model 4.2). Goel and Nelson (2021b) found that the structure of state public health systems in the United States impacts vaccination efficiency.

On the other hand, past history of contagious diseases (CONTAGIOUSdisease) and the size of public health spending in a state (HEALTHspending) failed to have a statistically significant impact on vaccine hesitancy. In other words, states with greater public spending on healthcare and those with a greater past prevalence of other contagious diseases were no different from others. The findings for the other controls are in general agreement with what was reported in Table 3.
3.3 | Considering political influences

The political ideologies of the parties in state legislatures (as well as those of the public) can impact the government’s attitudes to the containment of the pandemic (Bilewicz and Soral, 2021; also, see Holt, 2022).

When we consider the political influences on vaccination hesitancy in Table 5, the results with the Democratic variables (senateDEM and houseDEM) show a negative and significant association with vaccine hesitancy, implying that states with a greater bent toward the Democratic party tended to have a lower percentage of their populations that were not vaccinated. Further, states with a Democrat as a governor (governorDEM) tended to have a lower vaccine hesitancy, with the resulting coefficient statistically significant in two of the four models.

Quantitatively, the elasticities of senateDEM and houseDEM (from Models 5.5 and 5.6, respectively) were quite similar at around −.18, respectively (both evaluated at their respective means). Although the composition of state legislatures usually changes only gradually (especially in non-election years), these results imply that a 10% increase in the state house or state senate Democratic membership would lower vaccine hesitancy by about 2%.

Conversely, the presence of corruption in a state did not significantly affect vaccination hesitancy (Model 5.4). Goel and Nelson (2021b) found corruption to be positively correlated with vaccination rates (with the resulting variable(s) being significant at the 10% level).

3.4 | Robustness check: Considering no vaccination rates at a different time

Since vaccination rates change over time, and a random date picked for our NOvaccine dependent variable might be correlated with some event (day of the week, holiday, weather, etc.), we redid the analysis in Table 3 with the dependent variable measured at an alternative date. This provides a useful robustness check of our findings and we call the alternative dependent variable NOvaccine2. The correlation between NOvaccine and NOvaccine2 is .997 (Table A1), and the corresponding estimation results are reported in Table A2.

The results again support the baseline findings—INCOME, ELDERLY, PHYSICIANS, and MASKS have negative and statistically significant coefficients, while the coefficients on RACE are positive and (mostly) significant. On the other hand, states with greater literacy, higher unemployment rates, more adherents to the Christian faith, and states with international land borders were no different from others in terms of vaccine hesitancy. Thus, the robustness test with the dependent variable at an alternative date instills confidence in our findings.

3.5 | Robustness check: Using dependent variables capturing vaccination attitudes

One shortcoming of our dependent variable, NOvaccine, is that some of the non-vaccinated might be due to other reasons, rather than hesitancy. These could be associated with supply-side issues, transaction costs, travel, or job-related limitations. To address this aspect and consider another robustness check, we added two survey questions regarding survey respondents’ attitudes toward vaccinations: VaccineATTITUDE1 is broader measure of vaccine hesitancy, while VaccineATTITUDE2 is a narrower (stronger) measure (see Table 1 for details), as alternative measures of dependent variables.

The results, in Tables A3 and A4, respectively, quite closely support what was reported in the baseline models presented in Table 3. Specifically, INCOME, ELDERLY, and MASKS turn out to be the robust determinants of vaccine hesitancy.
|                          | (5.1)                  | (5.2)                  | (5.3)                  | (5.4)                  | (5.5)                  | (5.6)                  |
|--------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| **INCOME**               | -0.003*** (0.001)      | -0.003*** (0.001)      | -0.003*** (0.001)      | -0.003*** (0.001)      | -0.002** (0.001)       | -0.003*** (0.001)      |
| **ELDERLY**              | -0.596 (0.388)         | -0.856** (0.364)       | -0.859** (0.331)       | -0.967*** (0.324)      | -0.477 (0.350)         | -0.599 (0.385)         |
| **RACE**                 | 0.125** (0.052)        | 0.068 (0.065)          | 0.079 (0.059)          | 0.100* (0.056)         | 0.138** (0.053)        | 0.138** (0.052)        |
| **RELIGION**             | 0.000 (0.001)          | 0.000 (0.001)          | 0.000 (0.001)          | 0.000 (0.001)          | 0.000 (0.001)          | 0.000 (0.001)          |
| **PHYSICIANS**           | -0.007*** (0.001)      | -0.007*** (0.002)      | -0.007*** (0.002)      | -0.007*** (0.002)      | -0.005*** (0.001)      | -0.005*** (0.001)      |
| **MASKS**                | -0.012 (0.014)         | -0.022 (0.019)         | -0.023 (0.019)         | -0.018 (0.017)         | 0.002 (0.020)          | -0.001 (0.016)         |
| **governorDEM**          | -0.026** (0.013)       | -0.024 (0.014)         | -0.023 (0.014)         | -0.024* (0.013)        |                       |                        |
| **CentralizedHEALTH**    | -0.045*** (0.013)      |                       | -0.019 (0.017)         | -0.027* (0.015)        |                       |                        |
| **CONTAGIOUSdisease**    |                       | 2.555 (4.837)          |                       |                        |                       |                        |
| **HEALTHspending**       |                       |                       | 0.010 (0.013)          |                       |                       |                        |
| **CORRUPTION**           |                       |                       |                       | 0.032 (0.023)          |                       |                        |
| **senateDEM**            |                       |                       |                       |                       | -0.153** (0.062)      |                       |
| **houseDEM**             |                       |                       |                       |                       | -0.139** (0.052)      |                       |
| **Observations**         | 50                    | 49                    | 50                    | 50                    | 49                    | 49                     |
| **R-squared**            | 0.866                 | 0.826                 | 0.837                 | 0.843                 | 0.872                 | 0.872                  |

Note: See Tables 1 and 2 for variable details. Each model is estimated using Ordinary Least Squares (OLS) with robust standard errors are in parentheses. Constant is included in each model but not reported. Asterisks denote the following significance levels. ***p < .01, **p < .05, *p < .1.
3.6 | Robustness check: Addressing vaccine supply-side aspects

A lack of vaccinations could be partly due to supply-side issues related to the pandemic (see, e.g., Goel et al., 2021). We address this aspect by including two alternative proxies of uncertainty, UNEMsd and ECONOMICUncertain. Greater uncertainty would jeopardize suppliers’ decision-making, including reductions in investments that would limit supply (Goel & Ram, 1999). Relatively more risk-averse individuals would have a greater response to increased uncertainty. Consequently, some of the unvaccinated folks would then not be vaccinated due to a lack of vaccines (or due to increasing waiting/costs).

These results are in Table A5. The earlier results are largely supported, but the coefficients on UNEMsd and ECONOMICUncertain are statistically insignificant.

Interestingly, the coefficient on MASKS (and ELDERLY in most cases), loses statistical significance when unemployment variation, UNEMsd, is used as a control to proxy for uncertainty. In the presence of greater uncertainty, as measured by unemployment variation, states with masking requirements and those with more elderly populations were no different from others in terms of vaccine hesitancy.

3.7 | Robustness check: Dropping RELIGION as a regressor

Since the variable RELIGION is statistically insignificant in Tables 3, A3, and A4, as a final robustness check, we dropped RELIGION as a regressor. The corresponding results are in Table A6. The original results are supported. In particular, INCOME, ELDERLY, and MASKS are consistently negative and statistically significant in all cases. The concluding section follows.

4 | CONCLUDING REMARKS

Nesting the empirical analysis in the theory that the public’s personal attributes and institutional setups shape attitudes toward vaccine hesitancy, this paper uses data across US states and contributes to the body of research concerned with the COVID-19 pandemic, by focusing on the determinants of vaccine hesitancy. Besides the social externals from the unvaccinated, many businesses/organizations are facing challenges to fairly treat their vaccinated and unvaccinated employees. Whereas the issue of vaccine hesitancy has drawn the attention of some scholars (Khubchandani et al., 2021; Tan et al., 2022), this appears to be the first study that considers a rather large set of determinants of vaccine hesitancy, encompassing economic, social, health, and political aspects.

Our findings show that more prosperous states, states with more elderly, and states with more physicians tended to have lower vaccine hesitancy. From a policy perspective, poorer states, those with fewer physicians, and states with younger populations, should consider special measures to increase vaccination rates. A broader policy implication is that one overarching set of policies is unlikely to work in all cases. Conversely, policies for US states bordering foreign nations (Canada and Mexico) need not be different from other states. Furthermore, policies to mitigate uncertainties (such as variations in unemployment (UNEMsd) and policy uncertainty that we consider in Table A5) would not directly impact vaccination (hesitancy) rates.

In terms of magnitude, a 10% increase in the number of physicians in a state (per 10,000 state residents) would decrease vaccine hesitancy about 2.7% (Model 3.1, with the elasticity of NOvaccine with respect to PHYSICIANS, evaluated at respective means; see Table 2). Thus, we did not find evidence of significant vaccine hesitancy across health care workers, at least when captured by the number of physicians (see Biswas et al., 2021; Lucia et al., 2021). There was some evidence of the significance of race factors, but internet access and history of other contagious diseases failed to make a difference. The main results also hold when alternate dependent variables, based on surveys about vaccination attitudes, are considered (Section 3.5).

With regard to the direct role of the government, states with centralized health systems (i.e., the structure of the public health system setup in a state) and those with mask mandates generally tended to have a lower percentage of unvaccinated populations. Thus, the structure of public health spending mattered more than its mere size (measured via public health spending). The role of masks in increasing vaccinations can be informative for policymakers facing push-backs against such regulations.

Finally, with regard to political influences, the increasing presence of Democrats in the executives of state legislatures tended to be associated with lower vaccination hesitancies, ceteris paribus.

The main policy lesson from the analysis is that, whereas a number of economic-health-political influences impact vaccine hesitancy, most of these factors tend to change rather gradually over time. This flies in the face of the relative urgency to vaccinate the masses to achieve herd immunity.

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CONFLICT OF INTEREST
The authors declare that they have no relevant or material financial interests that relate to the research described in this paper.

DATA AVAILABILITY STATEMENT
Data are available on request from the authors.

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ENDNOTES

1 As a practical matter, barring surveying every unvaccinated person, it seems impossible to determine what fraction of the unvaccinated are hesitant as opposed to the fraction of the unvaccinated that are unable to be vaccinated (due to medical or access reasons). We take the share of the population that is unvaccinated to denote vaccine hesitancy.

2 Alfano (2022) showed that school closings in Europe were effective at curbing new COVID-19 infections.

3 In Section 3.5, we consider alternative dependent variables capturing data about surveys regarding vaccination attitudes.

4 Measurement of individuals’ risk aversion requires assumptions on their utility functions (also see Szpiro, 1986). Such an exercise is beyond the scope of this paper.

5 For instance, an earlier review of studies in the literature by Trolino and Nardi (2021) identified the role of ethnicity, working status, religiosity, politics, gender, age, education, income, and so on, as factors affecting vaccine hesitancy.

6 See, for example, https://www.vindy.com/news/local-news/2022/02/vaccine-hesitancy-dips-among-blacks/.

7 Physicians are part of health care workers and racial differences across health care workers have been shown to be associated with vaccine hesitancy (Momplaisir et al., 2021).

8 https://www.pewresearch.org/religion/2015/05/12/americas-changing-religious-landscape/

9 Using theoretical models, Goel and Haruna (2021) evaluate the relative social welfare under mask requirements versus mask recommendations.

10 Goel and Nelson (2021a) examine the effect of the qualitative nature of internet information (via internet search results) on COVID-19 vaccine delivery.

11 Internet penetration varies across US regions—see https://www.pewresearch.org/internet/2003/08/27/internet-use-by-region-in-the-u-s/.

12 Appropriate caution should be used in interpreting the findings due to the cross-sectional nature of our data, which is limited to the states in the United States.

13 The availability of some of the variables used in the analysis varies by year (Table 1). This is due to the discontinuity in the availability of related information driven by gathering and reporting lags (e.g., the population survey is conducted every 10 years). This data availability limitation is somewhat mitigated by the fact that some of the variables do not change, or change very slowly, over time (e.g., religious composition of states (RELIGION in Table 1), the structure of state health systems (CentralizedHEALTH), etc.). Finally, the date for CONTAGIOUSdisease makes sense since it is used for the years when the related diseases were relatively more rampant.

14 Using unadjusted standard errors in place of robust standard errors does not change the statistical significance of the estimated coefficients in any meaningful way.

15 As a note of caution, without a well-developed formal theory, many of our findings can be seen as capturing correlations, rather than definitive causality.

16 A part of the reason for the insignificant sign on INTERNET is likely the high correlation (0.82 in Table A1) it shares with INCOME.

17 See https://blogs.bmj.com/bmj/2021/09/10/the-uss-broken-healthcare-system-is-at-the-root-of-vaccine-hesitancy/

18 One reason for the lack of significance on the corruption variable might be that corruption convictions are lumpy, with convictions in a given state/year being abnormally low/high—for instance, when one large corruption scandal convicts many individuals.

19 We are grateful to the referee for bringing the underlying supply-side issues to our attention.

20 Another, more direct, measure of supply challenges would be pandemic-induced supply bottlenecks. However, at the time of writing information on such measures is not readily available across US states.

21 https://www.nytimes.com/2021/12/16/us/politics/military-vaccine-mandate.html; https://www.bloomberg.com/news/articles/2022-01-07/citigroup-confronts-vaccine-holdouts-in-no-jab-no-job-mandate

22 Note that COVID-19 vaccinations are underway by the US government for those without health insurance. Thus, that aspect, although another form of direct government involvement to counter the pandemic, is the same across states and, therefore, not formally included in the analysis.

23 One limitation of our study is that the available data is mostly at the state level (except for the variables VaccineATTITUDE1 and VaccineATTITUDE2 that are based on survey responses) and the vaccine hesitancy decisions are ultimately individual decisions.

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TABLE A1  Correlation matrix of key variables

|       | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 16  |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| NOvaccine | 1.000 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| NOvaccine2 | .997 | 1.000 |     |     |     |     |     |     |     |     |     |     |     |     |     |
| INCOME | –.692 | –.708 | 1.000 |     |     |     |     |     |     |     |     |     |     |     |     |
| ELDERLY | –.197 | –.167 | –.350 | 1.000 |     |     |     |     |     |     |     |     |     |     |     |
| RACE | .153 | .156 | .007 | –.240 | 1.000 |     |     |     |     |     |     |     |     |     |     |
| RELIGION | .219 | .233 | –.249 | –.046 | .422 | 1.000 |     |     |     |     |     |     |     |     |     |
| PHYSICIANS | –.641 | –.638 | .614 | –.058 | .319 | .062 | 1.000 |     |     |     |     |     |     |     |     |
| MASKS | –.289 | –.310 | .203 | –.001 | –.171 | –.242 | .000 | 1.000 |     |     |     |     |     |     |     |
| INTERNET | –.508 | –.525 | .817 | –.255 | –.271 | –.492 | .301 | .135 | 1.000 |     |     |     |     |     |     |
| DISEASES | .098 | .089 | .071 | –.291 | .770 | .344 | .394 | –.025 | –.270 | 1.000 |     |     |     |     |     |
| centralizedHEALTH | –.178 | –.170 | –.153 | .297 | .164 | .084 | .044 | .107 | –.358 | .371 | 1.000 |     |     |     |     |
| HEALTHspending | .256 | .261 | –.059 | –.203 | .183 | –.053 | –.117 | .129 | –.058 | .262 | .023 | 1.000 |     |     |     |
| governorDEM | –.479 | –.485 | .303 | .137 | –.035 | –.092 | .309 | .473 | .253 | .054 | .035 | –.005 | 1.000 |     |     |
| senateDEM | –.828 | –.832 | .644 | .108 | .133 | –.132 | .719 | .439 | .350 | .219 | .340 | –.189 | .518 | 1.000 |     |
| houseDEM | –.822 | –.824 | .590 | .194 | –.026 | –.178 | .697 | .504 | .365 | .012 | .277 | –.241 | .544 | .967 | 1.000 |
| CORRUPTION | .068 | .074 | .107 | –.129 | .336 | .211 | .480 | –.171 | –.096 | .391 | –.154 | –.101 | –.087 | .123 | –.258 |

Note: \( N = 51; \) see Tables 1 and 2 for variable definitions.
### TABLE A2
Explaining vaccine hesitancy: Baseline models with the no vaccinations variable captured at a different date. Dependent variable: NOvaccine2

|          | (A2.1)     | (A2.2)     | (A2.3)     | (A2.4)     | (A2.5)     |
|----------|------------|------------|------------|------------|------------|
| INCOME   | -0.005**   | -0.005**   | -0.004**   | -0.006***  | -0.005**   |
|          | (.001)     | (.001)     | (.001)     | (.001)     | (.001)     |
| ELDERLY  | -1.535***  | -1.523***  | -1.558***  | -1.542***  | -1.629***  |
|          | (.395)     | (.400)     | (.405)     | (.410)     | (.399)     |
| RACE     | 0.134**    | 0.123(.074)| 0.135*(.067)| 0.152**    | 0.127*(.067)|
|          | (.066)     | (.067)     | (.067)     | (.067)     | (.067)     |
| RELIGION | -0.000(.001)| -0.000(.001)| -0.000(.001)| 0.000(.001)| 0.000(.001)|
| PHYSICIANS| -0.003**    | -0.003**   | -0.003**   | -0.003**   | -0.003**   |
|          | (.002)     | (.002)     | (.002)     | (.002)     | (.002)     |
| MASKS    | -0.040**   | -0.041**   | -0.042**   | -0.035**   | -0.033**   |
|          | (.017)     | (.016)     | (.017)     | (.015)     | (.016)     |
| UNEM     | 0.0216(.982)|          |            |            |            |
| EDUC     |            |            |            | -0.218(.302)|
| INTERNET |            |            |            | 0.450(.479) |
| CANADAbor|            |            |            | 0.004(.016) |
| MEXICObor|            |            |            | -0.029(.027) |
| Observations | 51 51 51 51 51 | 51 51 51 51 51 | 51 51 51 51 51 | 51 51 51 51 51 | 51 51 51 51 51 |
| R-squared| 0.773      | 0.773      | 0.776      | 0.778      | 0.781      |

Note: See Tables 1 and 2 for variable details. Each model is estimated using Ordinary Least Squares (OLS) with robust standard errors in parentheses and probability values in brackets. Constant is included in each model but not reported. Asterisks denote the following significance levels.

***p < .01. **p < .05. *p < .1.

### TABLE A3
Explaining vaccine hesitancy: Baseline models with an alternate dependent variable. Dependent variable: VaccineATTITUDE1

|          | (A3.1)     | (A3.2)     | (A3.3)     | (A3.4)     | (A3.5)     |
|----------|------------|------------|------------|------------|------------|
| INCOME   | -0.003**   | -0.002***  | -0.002(0.001)| -0.003***  | -0.003***  |
|          | (.001)     | (.001)     | (.001)     | (.001)     | (.001)     |
| ELDERLY  | -0.744*    | -0.708*    | -0.761**   | -0.746*    | -0.821**   |
|          | (.381)     | (.362)     | (.390)     | (.389)     | (.373)     |
| RACE     | 0.021(.051)| -0.012(.077)| 0.021(.050)| 0.026(.059)| 0.029(.051)|
|          | (.001)     | (.001)     | (.001)     | (.001)     | (.001)     |
| RELIGION | -0.001(.001)| -0.001(.001)| -0.001(.001)| -0.001(.001)| -0.001(.001)|
| PHYSICIANS| -0.001(.001)| -0.002(.001)| -0.001(.001)| -0.001(.001)| -0.002(.001)|
| MASKS    | -0.029**   | -0.035**   | -0.031**   | -0.028**   | -0.024**   |
|          | (.013)     | (.016)     | (.013)     | (.013)     | (.011)     |
| UNEM     | 0.671(1.034)|          |            |            |            |
| EDUC     |            |            |            | -0.151(.338)|
| INTERNET |            |            |            | 0.122(.417) |
| CANADAbor|            |            |            | 0.013(.014) |
| MEXICObor|            |            |            | -0.021(.020) |

**Diagnostic tests**

|                      | (A3.1) | (A3.2) | (A3.3) | (A3.4) | (A3.5) |
|----------------------|--------|--------|--------|--------|--------|
| Heteroskedasticity   | [0.505]| [0.715]| [0.200]| [0.686]| [0.289]|  
| Skewness test        | [0.513]| [0.666]| [0.184]| [0.554]| [0.501]|  
| Kurtosis test        | [0.389]| [0.453]| [0.349]| [0.375]| [0.475]|  
| Total                | [0.555]| [0.790]| [0.147]| [0.723]| [0.350]|  
| Mean VIF             | 1.71   | 2.01   | 3.15   | 2.97   | 1.66   |
| Observations | 51 51 51 51 51 | 51 51 51 51 51 | 51 51 51 51 51 | 51 51 51 51 51 | 51 51 51 51 51 |
| R-squared | 0.572 | 0.578 | 0.576 | 0.573 | 0.595 |

Note: See Tables 1 and 2 for variable details. Each model is estimated using Ordinary Least Squares (OLS) with robust standard errors in parentheses and probability values in brackets. Constant is included in each model but not reported. Asterisks denote the following significance levels.

***p < .01. **p < .05. *p < .1.
### TABLE A4 Explaining vaccine hesitancy: Baseline models with an alternate dependent variable. Dependent variable: VaccineATTITUDE2

|                  | (A4.1)      | (A4.2)      | (A4.3)      | (A4.4)      | (A4.5)      |
|------------------|-------------|-------------|-------------|-------------|-------------|
| INCOME           | -0.002***   | -0.002***   | -0.002***   | -0.002***   | -0.002***   |
|                  | (0.001)     | (0.001)     | (0.001)     | (0.001)     | (0.001)     |
| ELDERLY          | -0.473(.289)| -0.433(.261)| -0.484(.296)| -0.475(.296)| -0.522**    |
|                  | (0.008)     | (0.008)     | (0.008)     | (0.008)     | (0.008)     |
| RACE             | 0.004(.038) | -0.034(.058)| 0.004(.038) | 0.009(.046) | 0.011(.038) |
| RELIGION         | -0.001(.000)| -0.000(.000)| -0.001(.000)| -0.001(.001)| -0.001(.000)|
| PHYSICIANS       | -0.001(.001)| -0.001(.001)| -0.000(.001)| -0.001(.001)| -0.001(.001)|
| MASKS            | -0.024**    | -0.030**    | -0.025**    | -0.022**    | -0.020**    |
|                  | (0.011)     | (0.013)     | (0.011)     | (0.011)     | (0.010)     |
| UNEM             |             |             |             |             | 0.758(.778) |
| EDUC             |             | -0.104(.239)|             |             |             |
| INTERNET         |             |             |             |             | 0.141(.318) |
| CANADAbor        |             |             |             |             | 0.009(.010) |
| MEXICObor        |             |             |             |             | -0.013(.017)|

Diagnostic tests

|                      | (0.507) | (0.736) | (0.242) | (0.581) | (0.294) |
|----------------------|---------|---------|---------|---------|---------|
| Heteroskedasticity test |         |         |         |         |         |
| Skewness test       | (0.199) | (0.325) | (0.261) | (0.190) | (0.232) |
| Kurtosis test       | (0.301) | (0.590) | (0.344) | (0.251) | (0.363) |
| Total               | (0.380) | (0.697) | (0.209) | (0.428) | (0.237) |
| Mean VIF            | 1.71    | 2.01    | 3.15    | 2.97    | 1.66    |

Observations 51 51 51 51 51

R-squared 0.534 0.550 0.539 0.537 0.555

Note: See Tables 1 and 2 for variable details. Each model is estimated using Ordinary Least Squares (OLS) with robust standard errors in parentheses and probability values in brackets. Constant is included in each model but not reported. Asterisks denote the following significance levels.

***p < .01. **p < .05. *p < .1.

### TABLE A5 Explaining vaccine hesitancy: Baseline models with supply side control variables

|                  | (A5.1)      | (A5.2)      | (A5.3)      | (A5.4)      | (A5.5)      | (A5.6)      |
|------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| INCOME           | -0.004***   | -0.004***   | -0.002***   | -0.002***   | -0.002***   | -0.002***   |
|                  | (0.001)     | (0.001)     | (0.001)     | (0.001)     | (0.001)     | (0.001)     |
| ELDERLY          | -1.609***   | -1.517***   | -0.645(.400)| -0.701**    | -0.373(.300)| -0.445(.280)|
|                  | (0.408)     | (0.376)     | (0.400)     | (0.391)     | (0.439)     | (0.280)     |
| RACE             | 0.135*(.070)| 0.069(.068) | 0.032(.051) | -0.015(.089)| 0.015(.039) | -0.028(.063)|
| RELIGION         | -0.000(.001)| -0.000(.001)| -0.001(.001)| -0.001(.001)| -0.001(.000)| -0.000(.000)|
| PHYSICIANS       | -0.003**    | -0.004**    | -0.002**    | -0.002**    | -0.001(.001)| -0.000(.001)|
| MASKS            | -0.032(.023)| -0.030**    | -0.020(.016)| -0.035**    | -0.015(.013)| -0.030**    |
|                  | (0.017)     | (0.017)     | (0.016)     | (0.016)     | (0.016)     | (0.017)     |
| UNEM             | 1.154(.103)| 0.726(.124)| 0.762(.124)| 0.660(.852) |             |             |
| UNEMsd           | -0.002(.009)| -0.007(.007)| -0.007(.005)|             |             |             |

Diagnostic tests

|                      | (0.124) | (0.285) | (0.434) | (0.303) | (0.298) | (0.291) |
|----------------------|---------|---------|---------|---------|---------|---------|
| Heteroskedasticity test |       |         |         |         |         |         |
| Skewness test       | (0.045) | (0.758) | (0.572) | (0.596) | (0.235) | (0.213) |
| Kurtosis test       | (0.873) | (0.969) | (0.418) | (0.459) | (0.295) | (0.509) |
| Total               | (0.051) | (0.444) | (0.511) | (0.388) | (0.236) | (0.239) |
| Mean VIF            | 1.92    | 2.08    | 2.08    | 2.08    | 2.08    | 2.08    |

Observations 51 51 51 51 51 51

R-squared 0.772 0.786 0.579 0.578 0.549 0.551

Note: See Tables 1 and 2 for variable details. Each model is estimated using Ordinary Least Squares (OLS) with robust standard errors in parentheses and probability values in brackets. Constant is included in each model but not reported. Asterisks denote the following significance levels.

***p < .01. **p < .05. *p < .1.
### TABLE A6  Explaining vaccine hesitancy: Baseline models without RELIGION as a control

| Dependent variable: | NoVaccine (A6.1) | VaccineATTITUDE1 (A6.2) | VaccineATTITUDE2 (A6.3) |
|---------------------|------------------|-------------------------|-------------------------|
| INCOME              | -0.004*** (0.001) | -0.002*** (0.001)       | -0.002*** (0.000)       |
| ELDERLY             | -1.633*** (0.375) | -0.706* (0.366)         | -0.443 (0.274)          |
| RACE                | 0.123* (0.064)    | -0.006 (0.054)          | -0.018 (0.041)          |
| RELIGION            | —                | —                       | —                       |
| PHYSICIANS          | -0.004** (0.002)  | -0.002 (0.001)          | -0.001 (0.001)          |
| MASKS               | -0.034* (0.017)   | -0.026** (0.013)        | -0.022** (0.011)        |

**Diagnostic tests**

|                           | (A6.1)       | (A6.2)       | (A6.3)       |
|---------------------------|--------------|--------------|--------------|
| Heteroskedasticity test   | 0.101        | 0.532        | 0.537        |
| Skewness test             | 0.111        | 0.316        | 0.076        |
| Kurtosis test             | 0.981        | 0.313        | 0.161        |
| Total                     | 0.070        | 0.475        | 0.235        |
| Mean VIF                  | 1.69         | 1.69         | 1.69         |

| Observations | 51 | 51 | 51 |
|--------------|----|----|----|
| R-squared    | 0.771 | 0.551 | 0.508 |

**Note:** See Tables 1 and 2 for variable details. Each model is estimated using Ordinary Least Squares (OLS) with robust standard errors in parentheses and probability values in brackets. Constant is included in each model but not reported. Asterisks denote the following significance levels:

- ***$p < .01$,
- **$p < .05$,
- *$p < .1$.

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