State-level Religiosity and the Initial Adoption of mRNA COVID-19 Vaccines

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Received: 09/01/2022
Accepted: 09/25/2023

Abstract

How does religiosity affect a state's adoption of novel, COVID-19 vaccines? We hypothesize that religiosity (the degree to which people in a society are highly religious) will have a deterring effect on the adoption of mRNA COVID-19 vaccines. We examine this idea using U.S. state-level data from the Centers for Disease Control in February - March 2021 on the initial adoption of mRNA COVID-19 vaccines (i.e., Pfizer-BioNTech and Moderna vaccines) during the COVID-19 crisis. Post hoc analysis reveals that this negative effect is broadly consistent across different Protestant groups (i.e., Evangelical Protestants, Historically Black Protestants and Mainline Protestants) while Catholics show mostly no significant effect on adoption, except for a marginal effect in February 2021. The findings demonstrate the importance of religious institutions in the determination of a state's rate of adoption of mRNA COVID-19 vaccines.

1 Introduction

Religion is a persistent component of cultural institutions around the world. In highly religious societies, religious institutions serve as a hierarchical mechanism for reinforcing moral order and constraining behavior of people within a geographic area (Chircop et al., 2020; Harrington and Gelfand, 2014). Despite a long-standing recognition of the importance of religiosity in economic and innovation processes (see Drivas et al., 2020; Di Pietro and Masciarelli, 2021; Iannaccone, 1998; Kumar et al., 2022; Smith et al., 2021), empirical inquiries into the link between religiosity and innovation adoption are rather recent. By innovation, we mean an idea, practice, or object that is perceived to be new by the target audience (Dewar and Dutton, 1986; Gotvassli, 2008).

In this article, we examine how state-level religiosity affects the rate of adoption of novel, messenger RNA (also, mRNA) vaccines in the United States during the COVID-19 pandemic. Our arguments suggest that highly religious states will tend to restrain the initial adoption of novel mRNA COVID-19 vaccines. While conventional vaccines can take several months to develop through growing weakened forms of a virus, mRNA vaccines are relatively faster to construct by using the pathogen's genetic code (Pfizer, 2022). During the COVID-19 pandemic, mRNA vaccines were brought to market at a significantly faster pace than conventional vaccines. Such significant departure from existing norms of new product development can produce uncertainty and concerns in the upstream end of the market (e.g. Chua et al., 2015; Uzuegbunam and Geringer, 2021). Moreover, these concerns can also extend downstream, which can ultimately affect the acceptance of a novel vaccine in the marketplace (Jackson et al., 2020).

We draw on U.S. state-level data that include variables that capture the rate of mRNA COVID-19 vaccines adoption, as well as variables that indicate the level of religiosity of different US states. (Information on the specific variables can be found in Data and Methods section.) The findings highlight the importance of religious institutions in determining initial adoption of mRNA COVID-19 vaccines. The evidence is consistent with the view that Protestant religious groups have the lowest levels of mRNA vaccine adoptions relative to Catholics (Andrade, 2021). Theoretically, we advance existing literature that shows that vaccine innovation adoption is a highly socialized process, in addition to being an economic issue (Chen, 2005). While our empirical findings align with recent papers that demonstrate the overall adverse effect of religiosity on COVID-19 vaccine adoption (Andrade, 2021; Hassen et al., 2022; Olagoke et al., 2021; Orlandi et al., 2022), our state-level approach, capturing the initial introduction of mRNA vaccines, allows us to offer more intricate and concrete findings that elucidate the complex relationship between religiosity and COVID-19 vaccine adoption (Volet et al., 2022).

Furthermore, our post hoc findings contribute to understanding of racial dimensions of this vaccine adoption phenomenon. Racial disparities in vaccine adoption have traditionally been explained by distrust in government and media institutions (Corcoran et al., 2021). Prior work shows that Black people tend to have comparatively lower rates of vaccine adoption. Our findings add to this evidence by indicating that states with higher levels of religiosity have wider disparities between White and Black American mRNA vaccine adoptions. However, this finding should be interpreted with caution pending the gathering of further statistical evidence.

The practical implication of this study is that healthcare leaders and policy makers should adopt a nuanced approach in their engagements with religious leaders and organizations throughout the vaccine development process, to build trust for the vaccines (Olagoke et al., 2021). Such an approach should be sensitive to the specific drivers of vaccine hesitancy among different religious subpopulations within a geographic area, explaining clearly how the vaccine development process addresses these concerns. Importantly, the communication strategy used to convey vaccine information to people in highly religious states needs to prioritize transparency. As pointed out by Volet et al. (2022), communication strategies that emphasize transparency are more likely to engender trust among the targeted communities. Such transparency is likely to increase adoption rates of novel vaccines during a crisis (and improve public health outcomes) in these communities that are characterized by strong religious norms.

2 Religiosity Impact on mRNA Vaccines Adoption

There is growing evidence in the literature, at different levels of analysis, that religiosity affects the likelihood or rate of vaccine adoption. While being fairly consistent in terms of the broad effects of religiosity on vaccine adoption, the literature has also produced some mixed results. We review some of the evidence below.

Some recent studies have found no significant effect of religious faith traditions on vaccine hesitancy (conventional immunizations) for families with young children (Williams et al., 2021). In contrast, in a survey of African countries, researchers observe higher rates of vaccinations (conventional vaccines, non-COVID-19 vaccines) among children from highly religious families compared to children from families without religion (Volet et al., 2022).

However, the mRNA COVID-19 vaccine, with its rapid development and emergency use authorization (supported by formal institutions such as the Food and Drug Administration, FDA) deviates from the typical trajectories of vaccine development. The mRNA technology allowed firms Pfizer-BioNTech and Moderna to achieve greater efficacy in record time. In reference to the COVID-19 mRNA vaccine, Natalie Dean, a biostatistician at the University of Florida argues that *"the speed of advance challenges our whole paradigm of what is possible in vaccine development"*(Ball, 2021). In a similar vein, Dan Barouch, director of the Center for Virology and Vaccine Research at Harvard Medical School contends that *"It shows how fast vaccine development can proceed when there is a true global emergency and sufficient resources, . . . It has shown that the development process can be accelerated substantially without compromising on safety"* (Ball, 2020). We expect that such rapid advance in commercialization of this vaccine will be a source of concern for highly religious societies.

COVID-19 vaccine hesitancy has been shown in various studies to be correlated to religiosity. For instance, at the individual level, a study of 501 United States based participants showed that an individual's level of religiosity is negatively associated with COVID-19 vaccination intentions (Olagoke et al., 2021). This empirical finding is supported by Corcoran et al. (2021) who, in their study of Christian nationalism in the United States, show that survey respondents that have high agreement with the question of *"To what extent do you agree or disagree that the federal government should declare the United States a Christian nation?"* had comparatively lower adoption rates of COVID-19 vaccines. Similar evidence is available from other individual level studies outside of the United States. For example, Andrade (2021) found in a study of 230 Venezuelan students that Protestants are the least likely to adopt COVID-19 vaccines, followed by Catholics and then non-religious. Consistent with the above evidence, O'Brien and Noy (2021) previously found that highly religious people generally exhibited a higher opposition to science.

However, these religiosity effects may be tempered or nullified by other factors. At the country level, a recent study of 22 European countries demonstrates that religiosity effects are not universal across all religions. Orlandi et al. (2022) show that though religiosity generally has a negative effect on COVID-19 vaccine adoption, countries with Roman Catholics as the dominant religious group exhibited a positive effect between religiosity and COVID-19 vaccine adoption (Orlandi et al., 2022). Hence, religious affiliation may be a tempering mechanism on attitudes towards vaccine adoption.

In addition, highly religious communities are marked by tight norms and networks between their members, which can act as conduits of information transfer (Di Pietro and Masciarelli, 2021) and restraints for deviant behaviors (Gelfand et al., 2006; Harrington and Gelfand, 2014; Jackson et al., 2020). Religious institutions through hierarchical order establish strong controls to help structure a set of shared beliefs, ideas, and moral attitudes (Durkheim, 1984; Uz, 2015). This hierarchical structure in highly religious communities serves as a stable and reliable constraint on everyday situations of the people in the community (Gelfand et al., 2011). Such tightness in religious communities has a bearing on how individuals in these communities perceive (or act on) new technology.

First, tight networks in religious societies tend to buffer members from outside influence such that new ideas might encounter resistance at the outset. That is, people in highly religious communities are generally more likely to choose to receive information from trusted sources discussed in their communities. This tendency implies that information regarding the availability and benefits of new vaccines might be constrained in highly religious communities as individual action is guided by beliefs or norms of the associated religions and the hierarchies within. For instance, prior work indicates that 80% of Islamic religious leaders in Guinea believe that vaccines should not be allowed during Ramadan (Volet et al., 2022). Similar evidence from the U.S. Conference of Catholic Bishops (USCCB) about initial concerns regarding the use of fetal cells in the development of COVID-19 vaccines also illustrates the role of religious beliefs espoused by group hierarchies on the adoption of the COVID-19 vaccines. USCCB noted that: *"It is critically important that Americans have access to a vaccine that is produced ethically: no American should be forced to choose between being vaccinated against this potentially deadly virus and violating his or her conscience"* (Wadman, 2020). Paradoxically, Pope Francis' subsequent endorsement of COVID-19 vaccines seemed to have spurred Catholics to adopt these vaccines across the world (Orlandi et al., 2022).

Second, due to their well-established norms and methods that enable coordinating for survival from historical threats (Gelfand et al., 2011, 2021), highly religious communities would choose to address contemporary threats by using existing approaches (e.g., prayers) for coordinating action rather than using newer, seemingly unproven technologies. Indeed, previous research suggests that highly religious people might be predisposed towards perceiving technology as being inconsistent with ethical and moral beliefs (O'Brien and Noy, 2021). That is, higher levels of religiosity in a state are likely to engender beliefs in divine protection and healing as a more viable alternative to addressing threats such as COVID-19 (Volet et al., 2022). In sum, religious institutions can fully enact the strength of beliefs, norms, and sanctioning mechanisms in deterring the adoption of mRNA vaccines at the state level.

HYPOTHESIS 1. At the state level, the effect of religiosity on the initial adoption rate of mRNA vaccines is negative.

3 Data and Methods

3.1 Empirical Context, Data Sources and Sample

We empirically tested the study hypothesis using cross-sectional, U.S. state-level data on the market introduction of COVID-19 mRNA vaccine innovation. The mRNA technology is considered a disruptive innovation because it draws on a new technology base to develop a product for an existing market (Rothaermel, 2017). This technology takes a different technological trajectory from existing technologies in this market, and in so doing creates a new technological paradigm Dosi (1982).

The U.S. Food and Drug Administration (FDA) issued Emergency Use Authorizations (EUAs) for the Pfizer-BioNTech mRNA COVID-19 vaccine on December 11, 2020, and Moderna mRNA COVID-19 vaccine on December 18, 2020 (FDA, 2021; Scott et al., 2021). Following these issuances, vaccines were distributed to U.S. states. Each state issued guidelines on the prioritization of vaccine recipients, varying in how quickly they were able to administer vaccines. The vaccination data used in the main analysis were collected between January 30 and February 23, 2021, during the initial stages of vaccine adoption in the United States. During this initial period of observing the dependent variable in this study, only mRNA vaccines were administered in the United States. Thus, this technology and this period provide a meaningful research context for understanding our hypothesis. Supplemental vaccination data were collected in March and used in robustness checks shown in Tables 4 and 5.

Our study leverages Centers for Disease Control (CDC) data on the COVID-19 pandemic that track the adoption of mRNA vaccines across the United States. The data also document key variables pertaining to the administration and distribution of vaccines at the state level. Further, the CDC reports COVID-19 caseloads and death rates, which provide a useful base of control variables that might also explain differences in adoption patterns across states. To complement this data, we collected data from several other sources. We collected religiosity data from both Pew research poll and Gallup poll conducted in 2006 and 2007, respectively (see Harrington and Gelfand, 2014, for a similar measure). Third, we leveraged the University of Kentucky Center for Poverty Research (UKCPR) National Welfare Data, which include recent (2018) state-level estimates of unemployment, poverty, food insecurity, and political structure. The UKCPR dataset was constructed from various sources including the Bureau of Labor Statistics (BLS), U.S. Census Bureau sources, and the Council of State Governments. Finally, we collected data on vaccine exemptions from the National Conference of State Legislatures, which draws its data from different state sources.

In sum, our initial data sources capture the entire population of 50 U.S. states and Washington D.C. (i.e., 51 observations). However, due to a few missing data our final sample used in the multivariate regression analysis represents 49 U.S. states.

3.2 Variables

3.2.1 Dependent Variables

Our main dependent variable captures overall mRNA vaccine adoption by February 23, 2021, at the state level. This represents the total number of vaccine doses administered for every 100,000 people in a state. The alternate dependent variable measures the total number of vaccine doses administered for every 100,000 of the population 18 years and older. Both variables are natural log transformed to reduce skewness, *Ln Vaccine Doses Administered per100k* and *Ln Vaccine Doses Administered per 100k (18+)*.

3.2.2 Independent Variables

One measure of *Religiosity* represents the average percentage measure of highly religious people across the Gallup and Pew Research surveys. See Appendix A for illustrations of both surveys.

3.2.3 Control Variables

We controlled for alternative explanations in our multivariate regression analysis. The control variables for this study are in three categories. The first category of control variables captures the availability of vaccines in states and includes measures of vaccine distributed to the state per 100,000 state population (i.e., *mRNA vaccine distributed per 100K*), and *state-level vaccine exemptions*, which captures the number of exemptions in the state (i.e., either religious or philosophical exemptions, 0 = no exemptions, 1 = one type of exemption, and 2= two types of exemption). We also included measures for COVID-19 case rates and death rates standardized by 100,000 state population in the state. We expect that these measures should also affect the demand for COVID-19 vaccines.

The second category of control variables includes measures of resource constraints in the state such as unemployment rate, poverty rate, and food insecurity rate. Finally, we control for the political structure in the state, which may affect supply factors related to vaccination. We use two proxies for political structure, including a dummy variable to capture the party affiliation of governor (i.e., *governor is a Democrat*) and *proportion of state legislature that is Democrat* (house and senate). Table 1 summarizes the study variables, their measurements, and sources.

4 Findings

Table 2 reports summary statistics and bivariate correlation for the key variables of this study. As shown in this Table, the bivariate correlations between religiosity and both measures of mRNA vaccine adoption are negative and statistically significant at the 1% and 5% level respectively. Thus, bivariate correlations between the independent and dependent variables in Table 2 provide initial support for our claims in Hypothesis 1.

Table 3 reports the results of the multivariate regression analysis using ordinary least squares (OLS) regression. Consistent with our prediction, the results show a negative statistically significant effect for religiosity in Model 2 ($\beta = -0.0092, p < 0.01$) and Model 4 ($\beta = -0.0080, p < 0.01$).Furthermore, we note that the negative effect of religiosity is economically meaningful. One unit increase in state-level religiosity (i.e., 1% increase) is associated with a 0.79% decrease in mRNA COVID-19 vaccine adoption rate. In sensitivity checks, we tried including additional control variables such as cultural variables. Furthermore, we implemented alternate modeling approaches that used either the Pew Research Center measure of religiosity or the Gallup Poll measure. All sensitivity checks produced results that are consistent with our main findings.

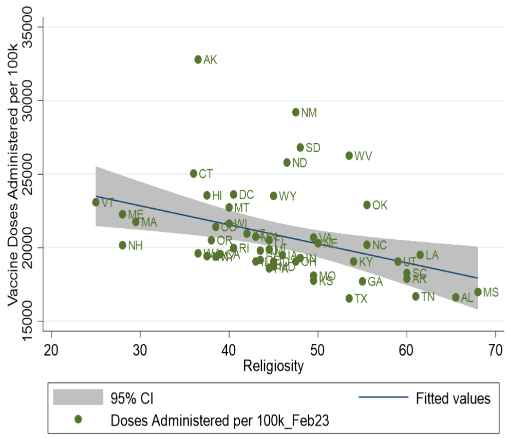
Furthermore, we conducted robustness checks using updated mRNA vaccine adoption data from the CDC on March 31, 2021. These checks used five alternative measures of mRNA vaccine adoption in regression analysis to re-examine our hypothesis: 1) total vaccine doses administered per 100,000 people in a state (Model 5); 2) Percent of people aged 65 years or more in a state that are fully vaccinated (Model 6); (3) Percent of state population that have received two doses (Model 7); (4) Percent of Moderna vaccines that have been administered (as a proportion of Moderna vaccines delivered to the state) (Model 8); and (5) Percent of Pfizer vaccines that have been administered (as a proportion of Pfizer vaccines delivered to the state) (Model 9). Together, the results reported in Models 5 through 9 in Table 4 show continued support for our hypothesis. Figure 1 shows an illustration of this result relative to alternate dependent variables.

Table 1: Variables, Measurement and Sources

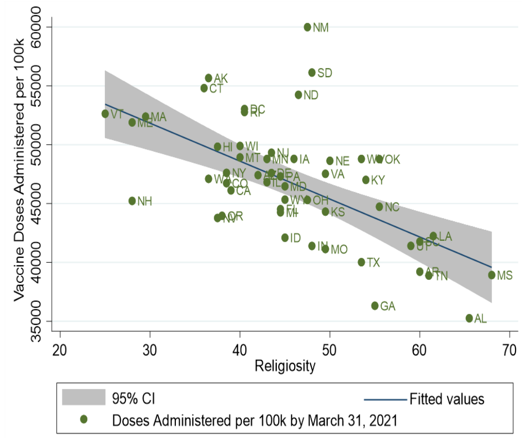
Variable	Measurement and Description	Data Source
ln. Vaccine Doses Administered per 100k by Feb 2021	Total number of mRNA COVID vaccines administered per 100,000 people in State by February 23, 2021, Log transformed	Centers for Disease Control
ln. Vaccine Doses Administered per 100k by March 2021	Total number of mRNA COVID vaccines administered per 100,000 people in State by March 31, 2021, Log transformed	Centers for Disease Control
Ln Vaccine Doses Administered per 100k (18+)	Total number of mRNA COVID vaccines administered per 100,000 of 18 years or older in State by Feb. 23, 2021, Log transformed	Centers for Disease Control
ln. % Of 65+ Pop Fully Vaccinated	Percent of 65 years+ state population that are fully vaccinated, Log transformed	Centers for Disease Control
ln. % Of State Pop with 2 Doses	Percent of state population that received 2 doses of COVID vaccine Log transformed	Centers for Disease Control
ln. % Of Moderna Vaccines Admin.	Percent of state population that received Moderna COVID vaccine, Log transformed	Centers for Disease Control
ln. % Of Pfizer Vaccines Admin.	Percent of state population that received Pfizer COVID vaccine, Log transformed	Centers for Disease Control
% Diff. btw White and Black population vaccination rates	Percent difference between White vaccination rates and Black vaccination rates in the state	Kaiser Family Foundation (KFF)
Religiosity	Averaged percentage measure of highly religious people across the Gallup and Pew Research surveys	Pew Research (2006) & Gallup Poll (2007)
Evangelical Protestants	Percent of Evangelical Protestants in State. When <1%, approximated to 0.1%	Pew Research (2014)
Historically Black Protestants	Percent of Historically Black Protestants in State. When <1%, approximated to 0.1%	Pew Research (2014)
Mainline Protestants	Percent of Mainline Protestants in State. When <1%, approximated to 0.1%	Pew Research (2014)
Catholics	Percent of people in state identified as Catholics. When <1%, approximated to 0.1%	Pew Research (2014)
Total vaccine distributed per 100k	The number of mRNA COVID 19 vaccine distributed to the state per 100,000 state population	Centers for Disease Control
Total state vaccine exemptions	The count of number of exemptions in the state (i.e., either or religious or philosophical exemptions, = 0, . . . , 2)	Centers for Disease Control
COVID case rate per 100k	The case rates from COVID 19 standardized by 100,000 people in the state	Centers for Disease Control
COVID death rate per 100k	The death rates from COVID 19 standardized by 100,000 people in the state	Centers for Disease Control
Unemployment rate	Percent of people in the state that are unemployed	Bureau of Labor Statistics*
Poverty rate	Percent of people in state that are poor	US Census Bureau*
Food insecurity rate	Percent of people in state that are food insecure	US Census Bureau*
Uninsured children percent	Percent of low-income uninsured children in the state	US Census Bureau*
Governor is Democrat (Y=1)	Dummy = 1 if Political Party Affiliation of Governor is Democrat.	Council for State Govt.*
State legislature that is Dem	Averaged measure of the fraction of state upper and lower house that is Democrat.	The Council for State Governments*

*Indicate data sourced through University of Kentucky Center for Poverty Research (UKCPR) National Welfare Data estimates for 2018

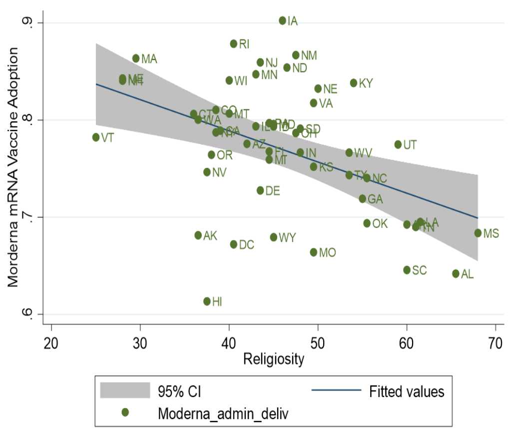
Figure 1: Religiosity and mRNA Vaccine Adoption (Using different measures of the dependent variable)



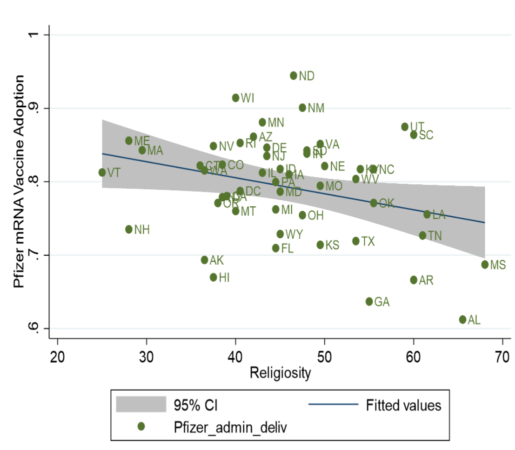
(a) Doses administered by Feb. 23 2021



(b) Doses administered by March 31, 2021



(c) Doses of Moderna administered



(d) Doses of Pfizer administered

Table 2: Summary statistics and bivariate correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Ln Vaccine Doses Administered per 100k	1.00												
2. Ln Vaccine Doses Administered per 100k (18+)	0.98	1.00											
3. Religiosity	-0.43	-0.33	1.00										
4. mRNA vaccine distributed per 100K	0.61	0.58	-0.31	1.00									
5. State total vaccine exemptions	-0.08	-0.02	0.12	-0.16	1.00								
6. COVID case rate per 100K	-0.12	-0.01	0.53	-0.29	0.21	1.00							
7. COVID death rate per 100K	-0.15	-0.15	0.23	-0.21	-0.06	0.52	1.00						
8. Unemployment rate	0.22	0.20	0.10	0.47	-0.17	-0.07	0.14	1.00					
9. Poverty rate	-0.05	-0.03	0.57	0.09	-0.13	0.13	0.2	0.54	1.00				
10. Food insecurity rate	0.07	0.10	0.47	0.02	-0.13	0.14	0.04	0.49	0.70	1.00			
11. Uninsured children percent	-0.13	-0.02	0.46	-0.18	0.22	0.44	-0.03	0.10	0.33	0.38	1.00		
12. Governor is Democrat (Yes=1)	0.02	-0.03	-0.22	0.02	-0.01	-0.31	0.04	0.06	-0.23	-0.26	-0.40	1.00	
13. State Legislature that is Dem	0.10	0.00	-0.56	0.14	-0.31	-0.53	0.02	0.05	-0.26	-0.37	-0.56	0.46	1.00
Mean	9.93	10.18	45.82	14,489	1.20	7,813	124	3.81	11.46	11.63	2.46	0.32	0.43
S.D.	0.14	0.14	9.58	2,245	0.60	2,350	52.57	0.85	3.05	2.98	1.17	0.47	0.19
Min	9.71	9.97	25.00	10,839	0.00	1,754	27.00	2.40	6.10	6.11	0.60	0.00	0.13
Max	10.40	10.68	68.00	26,294	2.00	12,789	239	6.6	19.6	18.47	6.20	1.00	0.95

Bivariate correlations greater than or equal to absolute value of 0.26, 0.29 and 0.39 are significant at the $p<0.1$, $p<0.05$, and $p<0.01$, respectively.

Table 3: Ordinary Least Squares Regression Results

	Model 1	Model 2	Model 3	Model 4
	Ln Vaccine Doses - per 100k		Ln Vaccine Doses - per 100k (18+)	
mRNA vaccine distributed per 100k	0.00004***	0.00004***	0.00004***	0.00004***
	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Total state vaccine exemptions	0.0074	0.0056	0.0129	0.0114
	[0.0300]	[0.0287]	[0.0291]	[0.0281]
COVID case rate per 100k	0.00001	0.00002**	0.00001*	0.00002**
	[0.0000]	[0.0000]	[0.0000]	[0.0000]
COVID death rate per 100k	-0.0001	-0.0003	-0.0003	-0.0004
	[0.0004]	[0.0004]	[0.0004]	[0.0004]
Unemployment rate	-0.0231	-0.0272	-0.02	-0.0236
	[0.0252]	[0.0263]	[0.0256]	[0.0277]
Poverty rate	-0.0092	0.0065	-0.0092	0.0045
	[0.0090]	[0.0083]	[0.0087]	[0.0087]
Food insecurity rate	0.0147**	0.0152**	0.0141*	0.0145**
	[0.0072]	[0.0071]	[0.0071]	[0.0070]
Uninsured children's percent	-0.0057	-0.007	0.0004	-0.0007
	[0.0181]	[0.0158]	[0.0173]	[0.0157]
Governor is Democrat (Y=1)	0.0052	0.0341	0.0086	0.0339
	[0.0325]	[0.0299]	[0.0312]	[0.0294]
State legislature that is Dem	0.1117	-0.0247	0.0969	-0.0222
	[0.1546]	[0.1545]	[0.1636]	[0.1679]
Religiosity		**-0.0092*** **		**-0.0080*** **
		[0.0026]		[0.0027]
Constant	9.1632***	9.5237***	9.3701***	9.6849***
	[0.1854]	[0.1849]	[0.1945]	[0.1992]
Observations	49	49	49	49
Adjusted R-squared	0.287	0.433	0.285	0.393

Robust standard errors in brackets; significance levels based on two-tailed tests.
*p <0.10, ** p <0.05, *** p <0.01.
Bold font indicates the coefficients of explanatory variable that are statistically significant.

Table 4: Robustness Checks (OLS Regressions)

	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
	ln. Vaccine Doses per 100k	ln.% Of 65+ Fully Vaccinated	ln.% Of State Pop. with 2 Doses	ln.% Of Moderna Vaccines	ln.% Of Pfizer Vaccines	%Diff. btw White & Black rates
Total vaccine distributed per 100k (By 03/31)	0.0000***	0.0000	0.0000***	-0.0000*	-0.0000*	-0.0001
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0002]
Total state vaccine exemptions	0.0133	-0.0105	0.0102	0.0033	0.0161	-0.3319
	[0.0150]	[0.0358]	[0.0232]	[0.0155]	[0.0193]	[1.2985]
COVID case rate per 100k	0.0000***	0.0000***	0.0000*	0.0000**	0.0000***	-0.0006
	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0006]
COVID death rate per 100k	0.0000	-0.0004	0.0002	0.0001	-0.0001	-0.0515**
	[0.0002]	[0.0005]	[0.0004]	[0.0002]	[0.0002]	[0.0250]
Unemployment rate	-0.0191	-0.0194	-0.0278*	0.0046	-0.0088	3.8355***
	[0.0127]	[0.0259]	[0.0160]	[0.0179]	[0.0170]	[1.3068]
Poverty rate	-0.0033	0.0039	0.0021	-0.0009	-0.0058	0.5929
	[0.0048]	[0.0092]	[0.0078]	[0.0051]	[0.0069]	[0.5848]
Food insecurity rate	0.0088*	0.0108	0.0138**	0.0031	0.0124**	-0.3563
	[0.0045]	[0.0078]	[0.0059]	[0.0054]	[0.0058]	[0.4062]
Uninsured children percent	-0.0133	-0.0257	-0.0323**	-0.0163	-0.0126	-0.386
	[0.0099]	[0.0183]	[0.0126]	[0.0117]	[0.0138]	[0.7648]
Governor is Democrat (Y=1)	0.0223	0.0577	0.0303	0.0094	0.0258	-1.7469
	[0.0187]	[0.0495]	[0.0304]	[0.0208]	[0.0277]	[1.9966]
State legislature that is Dem	0.1018	-0.2374	-0.0002	-0.0151	0.0655	-1.5138
	[0.0787]	[0.1533]	[0.0922]	[0.1201]	[0.1021]	[6.7373]
Religiosity	**-0.0055*** **	**-0.0098*** **	**-0.0080*** **	**-0.0075*** **	**-0.0058** **	**0.2781* **
	[0.0018]	[0.0031]	[0.0023]	[0.0023]	[0.0025]	[0.1433]
Constant	10.1059***	3.9646***	1.9797***	0.2575	0.0757	-24.0916
	[0.1787]	[0.2572]	[0.2041]	[0.2199]	[0.2221]	[15.0190]
Observations	49	49	49	49	49	43
Adjusted R-squared	0.69	0.257	0.668	0.34	0.203	0.473

Robust standard errors in brackets; significance levels based on two-tailed tests.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Bold font indicates the coefficients of explanatory variable that are statistically significant.

Table 5: Religious affiliation and mRNA Vaccine Adoption

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
	ln. Vaccine Doses per 100k by Feb 2021				ln. Vaccine Doses per 100k by March 2021				ln. % Of Moderna Vaccines				ln. % Of Pfizer Vaccines			
Total vaccine distributed per 100k (By 03/31)	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000	0.000	0.000	0.000	-0.000**	-0.000**	-0.000*	-0.000*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Total state vaccine exemptions	0.001	-0.002	0.007	0.000	0.007	0.004	0.010	0.008	0.007	0.005	0.007	0.01	0.015	0.012	0.017	0.016
	[0.029]	[0.030]	[0.029]	[0.031]	[0.021]	[0.020]	[0.021]	[0.022]	[0.020]	[0.020]	[0.019]	[0.020]	[0.021]	[0.021]	[0.022]	[0.023]
COVID case rate per 100k	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000*	0.000	0.000*	0.000*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
COVID death rate per 100k	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Unemployment rate	-0.019	-0.016	-0.016	-0.017	-0.019	-0.017	-0.020	-0.020	0.011	0.012	0.008	0.009	0.007	0.009	0.006	0.006
	[0.022]	[0.022]	[0.023]	[0.024]	[0.021]	[0.020]	[0.021]	[0.021]	[0.029]	[0.030]	[0.028]	[0.028]	[0.026]	[0.025]	[0.025]	[0.025]
Poverty rate	-0.003	-0.001	-0.008	-0.009	-0.013*	-0.011	-0.016**	-0.016**	-0.013**	-0.011*	-0.013**	-0.012**	-0.012	-0.011	-0.015*	-0.015**
	[0.009]	[0.010]	[0.009]	[0.009]	[0.007]	[0.007]	[0.007]	[0.007]	[0.006]	[0.006]	[0.006]	[0.006]	[0.008]	[0.007]	[0.007]	[0.007]
Food insecurity rate	0.011*	0.007	0.012*	0.013*	0.013*	0.010	0.014**	0.014**	0.000	-0.001	0.001	0.001	0.007	0.005	0.009	0.008
	[0.006]	[0.006]	[0.007]	[0.007]	[0.006]	[0.006]	[0.007]	[0.007]	[0.005]	[0.005]	[0.005]	[0.005]	[0.007]	[0.006]	[0.007]	[0.007]
Uninsured children percent	0.015	0.015	0.003	0.000	-0.004	-0.001	-0.013	-0.012	-0.017	-0.012	-0.019	-0.018	-0.005	-0.002	-0.013	-0.013
	[0.016]	[0.016]	[0.016]	[0.016]	[0.016]	[0.014]	[0.014]	[0.014]	[0.015]	[0.014]	[0.013]	[0.013]	[0.017]	[0.016]	[0.016]	[0.016]
Governor is Democrat (Y=1)	0.021	0.019	0.017	0.015	0.013	0.013	0.006	0.008	-0.016	-0.013	-0.021	-0.019	0.010	0.011	0.004	0.006
	[0.030]	[0.029]	[0.031]	[0.032]	[0.022]	[0.022]	[0.023]	[0.022]	[0.025]	[0.024]	[0.026]	[0.025]	[0.026]	[0.026]	[0.024]	[0.025]
State legislature that is Dem	0.127	0.079	0.098	0.131	0.249**	0.221**	0.240**	0.247**	0.067	0.064	0.076	0.06	0.131	0.107	0.124	0.128
	[0.138]	[0.131]	[0.147]	[0.155]	[0.106]	[0.095]	[0.106]	[0.109]	[0.139]	[0.137]	[0.132]	[0.139]	[0.120]	[0.112]	[0.115]	[0.118]
Evangelical Protestants	**-2.512*** **				**-1.231***				0.260				**-1.023***			
	[0.922]				[0.640]				[0.579]				[0.556]			
Historically Black Protestants		**-2.296*** **				**-1.459** **				-0.304				**-1.272** **		
		[0.811]				[0.663]				[0.581]				[0.604]		
Mainline Protestants			**-1.599** **				-0.195				**0.804***				-0.030	
			[0.672]				[0.423]				[0.460]				[0.487]	
Catholics				**-0.863***				-0.224				0.401				-0.138
				[0.503]				[0.276]				[0.301]				[0.283]
Constant	9.231***	9.291***	9.235***	9.187***	10.267***	10.315***	10.243***	10.240***	-0.189	-0.165	-0.218	-0.193	-0.172	-0.129	-0.199	-0.196
	[0.162]	[0.151]	[0.177]	[0.182]	[0.134]	[0.120]	[0.142]	[0.145]	[0.168]	[0.167]	[0.166]	[0.168]	[0.135]	[0.130]	[0.143]	[0.142]
Observations	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49
Adjusted R-squared	0.390	0.381	0.316	0.300	0.384	0.410	0.337	0.339	0.0775	0.0792	0.105	0.0915	0.128	0.161	0.0802	0.082
F-Stat	25.87***	30.60***	24.65***	25.08***	9.304***	14.69***	10.83***	10.70***	3.679***	3.389***	3.736***	3.780***	5.215***	5.625***	3.713***	3.961***

Robust standard errors in brackets; significance levels from two-tailed tests. * p <0.10, ** p <0.05, *** p <0.01.
Bold font indicates the coefficients of explanatory variable that are statistically significant.

Our analysis thus far has been on the rate of initial mRNA vaccine adoption. However, another concern in the literature is regarding potential inequality among different racial populations in the adoption of vaccines. It has been reported that Black/African Americans tend to have comparatively lower vaccine adoption rates than their white counterparts. This may be due to an inherent distrust of establishments stemming from prior unfavorable practices such as the Tuskegee Syphilis Study (Corcoran et al., 2021). Accordingly, Table 4 (Model 10) also shows data from the Kaiser Family Foundation (Kirzinger et al., 2020), which track racial disparities in the adoption of mRNA COVID-19 vaccines. The results reported in Model 10 indicate marginal support ($p < 0.1$) for the ex-post proposition that religiosity will tend to increase the gap between the rate of White population and Black population adoption of this new technology, in part due to the well documented differences between the public health role of Black and White churches in America (e.g., Blank et al., 2002).

Table 5 considers specific effects of certain religions on state-level adoption of COVID-19 vaccines. Different forms of the dependent variable are used to assess the relationship between these variables. The major religions in the sample include Evangelical Protestants, Black Protestants, Mainline Protestants and Catholics. The results indicate that Evangelical Protestants exhibit a negative effect on vaccine adoption at the initial stage in February 2021 (Model 1: β = -2.512, $p < 0.01$). The effect of Evangelical Protestants is weaker in March 2021 as shown in Model 5 of Table 5 (β = -1.231, $p < 0.1$). We observe qualitatively similar effects for Historically Black Protestants in Model 2 (β = -2.296, $p < 0.01$) and Model 6 (β =-1.459, $p < 0.05$).

Nevertheless, though Mainline Protestants seem to have a negative effect on vaccine adoption using February 2021 measurement in Model 3 of Table 5 (β = -1.599, $p < 0.05$), their effect is marginally positive in the specific adoption of Moderna vaccines as shown in Model 11 (β = 0.804, $p < 0.1$). Though the coefficient of Catholics is negative in all the models in Table 5, it is statistically insignificant in all models except in Model 4, where it is marginally significant (β = -0.863, $p < 0.1$). In sum, while we can conclude that Protestant groups broadly, exhibit a negative effect on mRNA vaccine adoption, we find very weak statistical evidence that Catholics have similar deterring effect at the initial introduction in February 2021 only.

5 Discussion and Conclusions

In this study, we examined how religiosity affects the initial adoption of novel, mRNA COVID-19 vaccines. As such, we first measured adoption in Feb. 2021, with supplemental data in March 2021 to better observe the initial pattern of adoption of these vaccines. Furthermore, we examined these relationships relative to specific mRNA COVID-19 vaccines (i.e., Moderna and Pfizer-BioNTech), and also accounted for the specific effects of different religions in our model.

The findings join prior work in demonstrating that religiosity is a strong predictor in COVID-19 vaccine adoption (Andrade, 2021; Olagoke et al., 2021; Orlandi et al., 2022). In doing so, our results show the importance of everyday reinforcing mechanisms of religious institutions in deterring adoption of a novel vaccine. In the case of mRNA vaccine adoption in the United States, the speed of development could have created uncertainty in highly religious communities. This trend can be seen in the increased negative correlation of vaccine doses adopted in states with high religiosity. Our findings lead us to recommend that state-level policy makers should consider how to leverage religious institutions in fostering vaccine adoption.

In addition, our findings also elucidate factors that appear to mitigate the negative effects of religiosity on vaccine adoption. For instance, states with higher proportions of Catholics may not have negative effects of high religiosity (Orlandi et al., 2022). In contrast, states with higher proportions of Historically Black or Evangelical Protestants show higher negative effects of religiosity. This difference in effects between Christian denominations, i.e., Catholic vs. Protestant, may in part be due to COVID-19 vaccine support from the central hierarchical structure of the Catholic Church vs the looser hierarchies of the Protestant religions, with each church having more autonomy in their decisions to support or not support COVID-19 vaccines.

Furthermore, in our robustness checks, we considered the possibility that religiosity might also have a bearing on race-based vaccination inequality. We suspect that the reason why religiosity might increase the gap between White and Black rates of vaccine adoption is because Black communities in highly religious states are exposed to dual deterring effects of religious beliefs (and norms); and prior abusive practices from institutional sources such as the Tuskegee Syphilis Study, which sowed distrust in Black communities for institutionally backed scientific developments (Corcoran et al., 2021). Yet, we acknowledge that the data in our study is preliminary and caution that the theoretical relationships are likely to be more complex. We encourage future research to investigate these race-based disparities further. Nevertheless, this preliminary finding regarding race suggests that policy makers in highly religious states should consider creative policies that will foster more productive engagements with Black church leaders in their communities.

In conclusion, this study points to the importance of harnessing creative but transparent networking approaches with religious leaders in highly religious states at the outset of the vaccine development process. The findings reveal some promising avenues for future economic studies into the role of religious environment in vaccine adoption.

Acknowledgements

The manuscript benefited from feedback on structure and grammar received from essay reviewer, Professor Thelma Obah, St. Paul, MN. Finally, the authors acknowledge the helpful feedback and developmental comments from Co-Editor, Professor Jamie Pavlik and two anonymous reviewers.

References

Andrade, G. (2021). Vaccine hesitancy and religiosity in a sample of university students in venezuela. *Human Vaccines & Immunotherapeutics*, 17(12):5162–5167.

Ball, P. (2021). What the lightning-fast quest for covid vaccines means for other diseases. *Nature*, 589:16–18.

Blank, M. B., Mahmood, M., Fox, J. C., and Guterbock, T. (2002). Alternative mental health services: The role of the black church in the south. *American Journal of Public Health*, 92(10):1668–1672.

Chen, T.-w. (2005). Vaccine innovations in an age of uncertainty: Bcg in france. *Technology in Society*, 27(1):39–53.

Chircop, J., Johan, S., and Tarsalewska, M. (2020). Does religiosity influence venture capital investment decisions? *Journal of Corporate Finance*, 62:101589.

Chua, R. Y., Roth, Y., and Lemoine, J.-F. (2015). The impact of culture on creativity: How cultural tightness and cultural distance affect global innovation crowdsourcing work. *Administrative Science Quarterly*, 60(2):189–227.

Corcoran, K. E., Scheitle, C. P., and DiGregorio, B. D. (2021). Christian nationalism and covid-19 vaccine hesitancy and uptake. *Vaccine*, 39(45):6614–6621.

Dewar, R. D. and Dutton, J. E. (1986). The adoption of radical and incremental innovations: An empirical analysis. *Management Science*, 32(11):1422–1433.

Di Pietro, F. and Masciarelli, F. (2021). The effect of local religiosity on financing cross-regional entrepreneurial projects via crowdfunding (local religiosity and crowdfinancing). *Journal of Business Ethics*, pages 1–15.

Dosi, G. (1982). Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11(3):147–162.

Drivas, K., Economidou, C., Karamanis, D., and Sanders, M. (2020). Mobility of highly skilled individuals and local innovation activity. *Technological Forecasting and Social Change*, 158:120144.

Durkheim, E. (1984). The division of labor in society (original publication in 1893).

FDA (2021). Covid-19 frequently asked questions. Accessed August 8, 2022.

Gelfand, M. J., Jackson, J. C., Pan, X., Nau, D., Pieper, D., Denison, E., Dagher, M., Van Lange, P. A., Chiu, C.-Y., and Wang, M. (2021). The relationship between cultural tightness–looseness and covid-19 cases and deaths: a global analysis. *The Lancet Planetary Health*, 5(3):e135–e144.

Gelfand, M. J., Nishii, L. H., and Raver, J. L. (2006). On the nature and importance of cultural tightness-looseness. *Journal of Applied Psychology*, 91(6):1225.

Gelfand, M. J., Raver, J. L., Nishii, L., Leslie, L. M., Lun, J., Lim, B. C., Duan, L., Almaliach, A., Ang, S., Arnadottir, J., et al. (2011). Differences between tight and loose cultures: A 33-nation study. *Science*, 332(6033):1100–1104.

Gotvassli, K.-A. (2008). Community knowledge-a catalyst for innovation. *Journal of Regional Analysis and Policy*, 38(1100-2016-90009).

Harrington, J. R. and Gelfand, M. J. (2014). Tightness–looseness across the 50 united states. *Proceedings of the National Academy of Sciences*, 111(22):7990–7995.

Hassen, H. D., Welde, M., and Menebo, M. M. (2022). Understanding determinants of covid-19 vaccine hesitancy; an emphasis on the role of religious affiliation and individual's reliance on traditional remedy. *BMC Public Health*, 22(1):1–11.

Iannaccone, L. R. (1998). Introduction to the economics of religion. *Journal of Economic Literature*, 36(3):1465–1495.

Jackson, J. C., Gelfand, M., and Ember, C. R. (2020). A global analysis of cultural tightness in non-industrial societies. *Proceedings of the Royal Society B*, 287(1930):20201036.

Kirzinger, A., Sparks, G., Hamel, L., Lopes, L., Kearney, A., Stokes, M., and Brodie, M. (2020). Kff covid-19 vaccine monitor: December 2020. *Kaiser Family Foundation*.

Kumar, S., Sahoo, S., Lim, W. M., and Dana, L.-P. (2022). Religion as a social shaping force in entrepreneurship and business: Insights from a technology-empowered systematic literature review. *Technological Forecasting and Social Change*, 175:121393.

O'Brien, T. L. and Noy, S. (2021). Threatening morality: Religious and political opposition to science in the united states. *Journal for the Scientific Study of Religion*, 60(3):628–644.

Olagoke, A. A., Olagoke, O. O., and Hughes, A. M. (2021). Intention to vaccinate against the novel 2019 coronavirus disease: The role of health locus of control and religiosity. *Journal of Religion and Health*, 60:65–80.

Orlandi, L. B., Febo, V., and Perdichizzi, S. (2022). The role of religiosity in product and technology acceptance: Evidence from covid-19 vaccines. *Technological Forecasting and Social Change*, 185:122032.

Pfizer (2022). What makes an rna vaccine different from a conventional vaccine? Accessed August 8, 2022.

Rothaermel, Frank, T. (2017). *Strategic Management*. McGraw-Hill Education, New York, NY, third ed. edition.

Scott, E. M., Stein, R., Brown, M. F., Hershberger, J., Scott, E. M., and Wenger, O. K. (2021). Vaccination patterns of the northeast ohio amish revisited. *Vaccine*, 39(7):1058–1063.

Smith, B. R., McMullen, J. S., and Cardon, M. S. (2021). Toward a theological turn in entrepreneurship: How religion could enable transformative research in our field. *Journal of Business Venturing*, 36(5):106139.

Uz, I. (2015). The index of cultural tightness and looseness among 68 countries. *Journal of Cross-Cultural Psychology*, 46(3):319–335.

Uzuegbunam, I. and Geringer, J. M. (2021). Culture, connectedness, and international adoption of disruptive innovation. *Journal of International Management*, 27(1):100807.

Volet, A. K., Scavone, C., Catalán-Matamoros, D., and Capuano, A. (2022). Vaccine hesitancy among religious groups: reasons underlying this phenomenon and communication strategies to rebuild trust. *Frontiers in Public Health*, 10:824560.

Wadman, M. (2020). Vaccines that use human fetal cells draw fire.

Williams, J. T., Rice, J. D., and O'Leary, S. T. (2021). Associations between religion, religiosity, and parental vaccine hesitancy. *Vaccine: X*, 9:100121.

A Appendix A

State level Religiosity as captured by Pew Research and Gallup Poll data. Average of both religiosity measures used in regressions.

Figure A1: Religiosity based on Pew Research

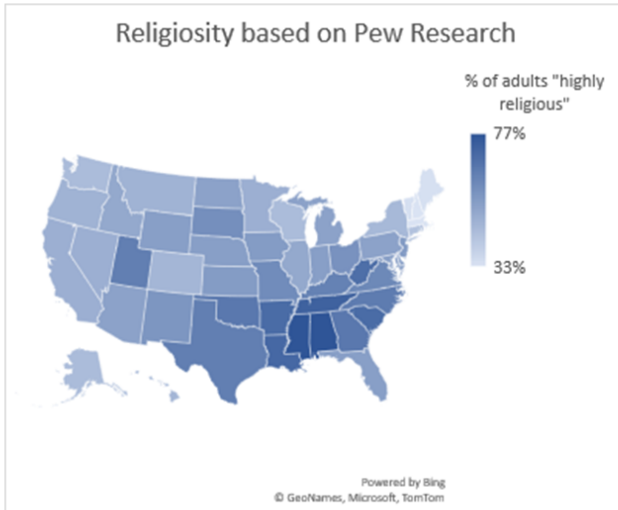


Figure A2: Religiosity based on Gallup Poll