# Religion, Prayer and Health Production

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**Abstract**

Economic models typically treat health production technologies as objective and commonly understood. In practice, people may act on subjective perceptions of these technologies shaped by cultural and religious beliefs. We study whether prayer responds to changes in objective disease risk in a manner consistent with economic optimization. During the COVID-19 pandemic, most US adults believed that prayer was effective against COVID-19 and prayed in order to keep themselves safe. We incorporate prayer into a simple health production framework and exploit staggered vaccine eligibility as a source of variation in the effective price of protection. Vaccine eligibility reduces prayer as well as avoidance (the use of masks and social distancing), indicating substitution across perceived health inputs. Consistent with inframarginality, strongly religious people show no response while weakly religious people reduce prayer by 27 percent. These findings suggest that religious practices respond to objective risk in ways that mirror standard economic substitution.

**JEL**: I12, Z12, I18

**Keywords**: Health, Religion, COVID-19

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## 1 Introduction

Economic models typically assume that people optimize using objective production technologies. However, in many domains, such as health, finance, and education, behavior depends upon subjective beliefs about how actions translate into outcomes. Cultural and religious institutions often shape these perceptions. An unanswered question is whether behaviors rooted in these belief systems respond to objective shocks in a manner consistent with standard economic optimization.

People commonly rely on "belief-based" inputs for health, including many examples from complementary and alternative medicine, folk medicine, and wellness fads. Prayer is an example of a belief-based health input. While people rely on prayer in different ways, it is common to ask God or another higher power for solutions to life challenges, including health problems, and to believe that these petitions are effective (Upenieks 2023, Wilkinson et al. 2008). In Figure 1, majorities in the US perceive that prayer is effective against a range of illnesses and say they have prayed for recovery, suggesting that many people perceive that prayer is a health input.[1] The economics of religion has modeled religious activity as responsive to incentives (Azzi and Ehrenberg 1975, Iannaccone 1990), however research has not yet examined whether religious practices behave like health inputs. This paper provides causal evidence that religious practices follow standard marginal substitution principles when embedded in a subjective production framework.

We study this question in the context of COVID-19 in the United States. As with other illnesses, large majorities of US adults saw prayer as effective against COVID-19 and say they prayed regularly to stay safe. Nine months into the pandemic, the government began to roll out vaccines that greatly reduced COVID-19 risk. The phased introduction of vaccines provides a credible source of identifying variation in the effective price of biomedical protection. We exploit variation in vaccine eligibility across individuals to estimate the impact of vaccine availability on vaccination, perceived mortality risk, prayer, and alternative protective behaviors.

[1] Across nine of ten listed illnesses, a majority believe prayer is effective and have prayed. The figure is based on a survey from December 2024 to February 2025 of 1563 participants in the Understanding America Study. Participants were drawn from a representative sample and had received the listed diagnoses within the past twelve months.

Our findings show that prayer declines in response to vaccine eligibility in a manner consistent with substitution across perceived health inputs. The response is strongest among individuals for whom prayer appears to be marginal, particularly those who do not identify with a specific religious denomination, while it is close to zero among strongly religious individuals for whom prayer is more routine and inframarginal. These patterns align with the comparative statics of the model.

We study these predictions using longitudinal data from the Understanding America Study, a nationally representative panel survey conducted throughout the COVID-19 pandemic (Alattar et al. 2018, Kapteyn et al. 2020). The phased rollout of vaccines between December 2020 and April 2021 generates plausibly exogenous variation in the effective price of biomedical protection. Vaccine eligibility sharply increases vaccination and reduces perceived mortality risk. Consistent with substitution across perceived health inputs, it also reduces the probability of weekly prayer by 1 percentage point (p.p.; 2 percent) and lowers avoidance by 0.05 standard deviations (s.d.). Scaling by the impact on vaccination yields Wald estimates of around -6.5 p.p. for prayer and -0.36 s.d. for avoidance among those induced to vaccinate.

We next examine heterogeneity predicted by the model. If prayer functions as a perceived health input, then its responsiveness to vaccine eligibility should depend on its centrality to a person's religious practice. The decline in prayer occurs primarily among weakly religious people, for whom vaccine eligibility reduces prayer by 1.6 percentage points (27 percent). By contrast, the effect is small and statistically insignificant for strongly religious people. This pattern is consistent with inframarginality: prayer is less responsive to price of other health inputs if it is embedded in routine practice and identity. Distinguishing between denominational categories further clarifies the mechanism. People with "no particular religion" drive the prayer response, while atheists and agnostics pray infrequently both before and after eligibility. This pattern suggests that for spiritual people with weak religious attachment, prayer may function as a marginal, situational health input that provides a sense of safety during periods of heightened uncertainty. To further probe this interpretation, we estimate the impact of vaccine eligibility on indices of coping and find that changes in prayer closely parallel changes in positive coping behaviors such as meditation, exercise, and relaxation.

By contrast, we find weaker differences by religiosity in the impact on science-based health behaviors. The effects of vaccine eligibility on vaccination and avoidance are similar across religiosity groups. For example, vaccination rises by 14 percentage points among strongly religious respondents and 15 percentage points among weakly religious respondents. This pattern aligns with similar perceptions of effectiveness of these inputs across religiosity subgroups.

This paper makes three contributions. First, it extends the economics of religion by embedding religious practice directly into a health production framework and testing comparative statics. While prior work models religious participation as an optimizing choice (Azzi and Ehrenberg 1975, Iannaccone 1990), it has not examined whether religious practices behave as substitutable inputs in response to exogenous changes in disease risk. We show that prayer responds in an expected way to a decline in the effective price of biomedical protection. This result provides causal evidence that a religious practice can conform to standard microeconomic principles as an input into a perceived production technology.

Secondly, the heterogeneity in our estimates clarifies the economic structure underlying this substitution. The response of prayer varies sharply across individuals, suggesting that religious practices differ in their economic role: for some, prayer appears to function as a situational and supplementary input, while for others it is a routine practice that is largely unresponsive to changes in objective risk. This pattern illustrates how to accommodate cultural practices within an optimizing framework. Practices that are central to identity may be inframarginal, while more peripheral practices respond to shocks in the economic environment.

Finally, the vaccine rollout provides a setting to examine substitution across protective behaviors in response to a large reduction in mortality risk. We find evidence of substitution between vaccination and prayer and between vaccination and avoidance. There are not significant differences by religiosity in the responses of science-based behaviors. These findings contribute to debates on behavioral responses to safety innovations and the interaction between cultural belief systems and public health interventions.

# 2 Context and Data

## 2.1 Pandemic Timing and Policies

In 2020, in response to the COVID-19 pandemic, the US implemented Operation Warp Speed to accelerate the development of COVID-19 vaccines (Burgos et al. 2021). The Food and Drug Administration granted an emergency use authorization (EUA) for the Pfizer vaccine on December 11, 2020. While the leading vaccines were somewhat effective at preventing infection, their largest impacts were in reducing the complications associated with severe COVID-19 infections (Mohammed et al. 2022). Contemporaneous news accounts show that the public quickly became aware of this feature of the vaccines (Medical News Today 2021).

Given the limited initial supply of vaccines, health authorities implemented a phased vaccination campaign that led to plausibly exogenous reductions in mortality risk. This effort loosely followed guidelines developed by the Food and Drug Administration Advisory Committee on Immunization Practices (ACIP) to offer the vaccine first to vulnerable people and essential workers (Dooling 2021). In general, the guidelines prioritized first responders (defined in various ways), the elderly, and people with existing health vulnerabilities. However, the FDA delegated distribution to state health departments, which adapted the guidelines to local priorities and circumstances. Eligibility dates also varied according to vaccine availability within each jurisdiction. Vaccinations began in earnest in January of 2021 and proceeded throughout the winter and spring of that year. By mid-April 2021, everyone aged 16 or older was eligible for vaccination. Although eligibility rules varied by state, age and health status explain most of the variation in the timing of vaccine eligibility.

Figure 2 illustrates the timing of the vaccine rollout and the importance of vaccine eligibility. We divide the sample by the median eligibility date and plot the percent of people who have been vaccinated by date for those with early and late eligibility. Red vertical bars in the figure indicate the beginning and end of the vaccination campaign. Those who were eligible early received the vaccine sooner. By February 1, 2021, those with early eligibility were 11 p.p. more likely to be vaccinated than those with late eligibility. By March 1, this difference rose to 23 p.p. and remained at 18 p.p. by April 1.[2]

[2] The persistent difference in vaccination into the summer of 2021 may reflect heterogeneity in other

## 2.2 Data and Variables

This analysis relies on data from the Understanding America Study (UAS). The UAS is an online panel survey administered by the University of Southern California (Alattar et al. 2018). Panel members are selected through address-based sampling and are compensated for participation. The survey uses post-stratification weights to make the sample nationally representative in terms of sex, race, age, marital status, and education. Weights also adjust for differences in the sampling probabilities of geographic units according to Census region, urbanicity, and population size. The number of respondents has expanded over time, to a total of 9114 by 2023.

During the pandemic, the UAS implemented a high-frequency panel survey related to COVID-19. Surveyors followed up with respondents 34 times from March 2020 through July 2023, with most surveys occurring every two weeks during 2020 and the first six months of 2021 (Kapteyn et al. 2020).[3] The COVID-19 panel survey included an extensive array of consistently-measured questions related to the health and economic impact of the pandemic.

To construct vaccine eligibility, our primary independent variable, we combine publicly available vaccine eligibility rules with individual respondent characteristics. We construct individual-specific eligibility dates based on state of residence, age, and occupation.[4] Because of variation in the details of the rollout by state, we identify 64 distinct eligibility dates between December 2020 and April 2021.

The primary outcomes for this analysis are vaccination, subjective COVID-19 mortality risk, prayer, and avoidance behavior. Vaccination is measured through a self-report of the date when the respondent received at least one dose of a COVID-19 vaccine. Subjective

individual characteristics, such as age, that were associated with eligibility. We discuss the implications of these patterns for our estimates in the empirical analysis below.

[3]Surveyors carried out an initial survey from March 10-31, 2020 and then resurveyed respondents every two weeks through February 2021. Respondents were resurveyed every four weeks from February-June 2021. Five additional follow-ups were conducted from September 2021 through July 2023. There are 8107 unique respondents during the survey waves prior to the vaccine rollout and 16,423 unique respondents afterward. A median of 6238 respondents answer the survey in each round.

[4]Multistate, a government relations firm, created and maintained a state-by-state list of vaccine eligibility dates and criteria. The UAS elicited the occupations of respondents using six digit O*NET occupation codes from February-May 2021. The timing of the occupation elicitation introduces the possibility that reported occupations could be endogenous to vaccine eligibility. Appendix A.6 investigates this issue and shows that vaccine eligibility is not associated with changes in employment status.

mortality risk is the respondent's subjective probability that he or she will die of COVID-19 within three months conditional on infection.[5] We measure prayer through an indicator of whether the respondent has prayed "to stay safe from COVID-19" in the past week.[6] We create an "avoidance index" to collapse the array of measures of social distancing and the use of masks that are available in the data by computing the first principal component. Combining mask and social distancing variables into a single index is sensible because social distancing reduces the need for someone to use a mask. We normalize this index to have a mean of zero and standard deviation of one across the data.

We carry out a heterogeneity analysis according to the respondent's level of religiosity. Religiosity is measured using an index established by the Pew Research Center (Smith et al. 2015). The index includes the importance of religion in the respondent's life, attendance at religious services, regular prayer, and a belief in God. Following the Pew approach, we divide the sample into "weakly religious", "moderately religious" and "strongly religious" subgroups. Appendix A.3 describes these variables in more detail. Most components of the religiosity index are measured prior to vaccine eligibility. For a subset of respondents, some index elements are based on responses collected in 2022. Appendix A.4 shows that all results are robust when religiosity is defined using only pre-rollout responses.

To further explore these results, we distinguish between two denominational subgroups who are the primary constituents of the "weakly religious" category. Atheists and agnostics make up 54 percent of this group, while people with "no particular religion" (NPR) make up 32 percent. NPR respondents actively chose this designation over atheism/agnosticism or a particular denomination. Ethnographic evidence suggests that people in this group tend to be spiritual, whereas atheists and agnostics are often anti-spiritual (Lee 2014, Karim and Saroglou 2023). In our data prior to the vaccine rollout (across all religiosity levels), 42

[5] The survey also measures subjective infection risk and subjective hospitalization risk. Respondents could either enter a response digitally or drag a slider from 0 to 100 percent to answer. We focus on mortality risk conditional on infection because the vaccines had the most salient impact on this margin. Estimates using other probabilities, or unconditional COVID-19 mortality risk (the product of subjective infection risk and subjective mortality risk conditional on infection) yield similar results.

[6] This measure does not include additional details about the prayer such as the duration or the frequency within the week. One concern is that highly religious people may be inframarginal for prayer over a week but could adjust prayer frequency over smaller intervals. In fact, additional data suggest that more highly religious people are marginal for weekly prayer, which minimizes this concern. We discuss this issue further in Section 5.2.

percent of NPR respondents reported praying about COVID-19, compared to 7 percent of atheists and agnostics.

Our analysis also examines heterogeneity according to the perceived effectiveness of vaccines. This variable is measured on a four-point Likert scale in November and December of 2020, immediately prior to the beginning of the vaccine rollout. To simplify the exposition, and because few people say that vaccines are highly ineffective, we collapse these categories and distinguish between people who perceive that vaccines are effective and ineffective.

### 2.3 Sample Characteristics

This subsection summarizes the relevant characteristics of the UAS sample. Panel A of Table 1 provides summary statistics for the sample over the period from March-December 2020, prior to authorization and distribution of COVID-19 vaccines. Column 1 shows results for the full sample. With weighting, the sample matches the distribution of age, gender, marital status, and geographic location of the US. Over half of respondents have a chronic health condition that was used to determine vaccine eligibility.[7]

Columns 2-6 of Table 1 show how demographic and religious characteristics vary according to levels of religiosity. Although many differences are statistically significant, most comparisons are small in magnitude. Religiosity is correlated with female gender, marital status, and residence in the South. The most strongly religious subgroup in Column 6 is disproportionately Protestant and evangelical according to Table A.4.

Figure 3 illustrates perceptions about the perceived effectiveness of avoidance (masks and social distancing), vaccination and prayer, distinguishing between Pew religiosity categories. People have high confidence in masks, social distancing, and vaccination as ways to prevent COVID-19, and these perceptions are very similar regardless of religiosity. By contrast, the perceived effectiveness of prayer varies sharply by religiosity. Among the least religious respondents, 29 percent believe that prayer is somewhat or very effective as a way to prevent COVID-19. By contrast, 81 percent of the most religious respondents believe that prayer

[7] Table A.4 summarizes the religious denominations within the sample. 17 percent of respondents are Protestant, 14 percent are Catholic, and 19 percent belong to other religious denominations. 9 percent of respondents self-identify as evangelical. 48 percent of respondents say that they are Atheist, agnostic, or have "no particular religion."

is somewhat or very effective, with the vast majority of these responses indicating very effective. For this group, prayer is slightly less effective than social distancing by as effective as wearing a mask.

Panel B of Figure 3 gauges perceptions of a complementarity between prayer and science-based health inputs. We elicit whether people perceive that prayer enhances the effectiveness of either vaccines or masks, as it would if these inputs were seen as complements. Most people do not perceive complementarities, regardless of their level of religiosity. Among the least-religious cohort, 5 percent perceive that prayer makes these behaviors more effective. Even among the most-religious respondents, only 20 percent of respondents perceive that prayer enhances the effectiveness of masks or vaccines. The lack of perceived complementarity informs our model below by suggesting a large elasticity of substitution across prayer and other health inputs.[8]

## 3 Model

This section develops a simple model to explore the implications of the belief that prayer is a health input. People maximize utility over *perceived* health, $h$, and other consumption, $c$. We interpret the production function as describing perceived health production rather than objective biomedical health. People produce perceived health by purchasing two health inputs, $v$ and $x$, representing vaccination and another input, which could be either prayer or avoidance. $p_v$ and $p_x$ are the input prices, and we normalize price of consumption to 1. People choose the cost-minimizing combination of vaccination and the alternative input needed to achieve their desired level of health. To proceed, we solve the cost minimization problem over $x$ and $v$ to derive the implicit price of health, $p_h$, and then maximize utility over consumption and health. We obtain theoretical predictions about the effect of vaccine eligibility by considering a discrete drop in $p_v$.

[8] Appendix A.2 describes a supplementary analysis of this issue. In January and February of 2025, we elicited the probability that hypothetical people would contract COVID-19. These people differ in terms of whether they pray regularly, get vaccinated, and engage in avoidance behavior. Prayer and avoidance only modestly reduced perceived infection risk conditional on vaccination, further suggesting that these inputs are not seen as complements.

### 3.1 Health Production

People produce health using a CES production function with two inputs, $v$ and $x$. $\alpha$ indicates the weight that the person places on $x$ and is related to religiosity and perceived vaccine effectiveness below. The elasticity of substitution, $\sigma$, ranges from 0, which represents perfect complements, to infinity, which represents perfect substitutes. For a given level of health, $\overline{h}$, people optimize over $x$ and $v$ by solving the following cost minimization problem.

$$\min_{x,v} \; p_v v + p_x x$$
$$\text{subject to}$$
$$[\alpha x^{\frac{\sigma-1}{\sigma}} + (1-\alpha) v^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \;\geq\; \overline{h}$$

This cost minimization problem yields the following conditional factor demands:

$$v \;=\; \frac{h}{\big[A(\alpha)\big]^{\frac{\sigma}{\sigma-1}}} \tag{1}$$

$$x \;=\; \frac{h\, s^{-\sigma}}{\big[A(\alpha)\big]^{\frac{\sigma}{\sigma-1}}} \tag{2}$$

where $A(\alpha) \equiv \alpha s^{1-\sigma} + (1-\alpha)$ and $s \equiv \frac{(1-\alpha)p_x}{\alpha p_v}$ is the relative cost-effectiveness of $x$ in terms of producing health. Computing the expenditure associated with these factor demands leads to an expression for the "price of health", $p_h$.

$$p_h \;=\; [\alpha^\sigma p_x^{1-\sigma} + (1-\alpha)^\sigma p_v^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{3}$$

The derivative of this expression equals the vaccine cost share, $s_v$. Since this share is positive, the price of health increases in the price of vaccination.

$$s_v \;\equiv\; \frac{\partial \ln p_h}{\partial \ln p_v} \;=\; \frac{(1-\alpha)^\sigma p_v^{1-\sigma}}{\alpha^\sigma p_x^{1-\sigma} \;+\; (1-\alpha)^\sigma p_v^{1-\sigma}} \in (0,1) \tag{4}$$

Next we maximize utility over $c$ and $h$ using the expression for $p_h$ from Equation (3).

$$\max_{h,c} \; [\beta h^{\frac{\gamma-1}{\gamma}} + (1-\beta)c^{\frac{\gamma-1}{\gamma}}]^{\frac{\gamma}{\gamma-1}}$$

$$\text{subject to}$$

$$p_h h + c \leq y$$

Solving this utility maximization problem leads to the optimal level of health, which can be substituted into Equations (1) and (2) to obtain closed-form solutions for the health inputs.

$$h^* \;=\; \frac{y\beta^\gamma}{(1-\beta)^\gamma p_h^\gamma \;+\; \beta^\gamma p_h} \tag{5}$$

### 3.2 The Impact of Vaccine Eligibility

To model the arrival of the COVID-19 vaccine, we compare $h^*$, $x^*$, and $v^*$ in the pre-vaccine period (Period 0), when $p_{v0} = \infty$, and the post-vaccine period (Period 1), when $p_{v1} > 0$ takes a small finite value. To simplify the discussion, we assume that $\sigma > 1$, so that $x$ and $v$ are sufficiently substitutable, consistent with evidence presented earlier.

We consider the impact of the introduction of vaccines on $v^*$, $h^*$ and $x^*$. For health and the alternative good, it is convenient to analyze the ratios between Period 1 and Period 0, $\frac{h_1}{h_0}$ and $\frac{x_1}{x_0}$. However since $v_0^* = 0$, the ratio $\frac{v_1}{v_0}$ is not defined. Instead, for vaccines, we can consider $\Delta v = v_1 > 0$.

$$\Delta v \;=\; \frac{h_1^*}{\big[A_1(\alpha)\big]^{\frac{\sigma}{\sigma-1}}} \;>\; 0. \tag{6}$$

Equation (3) shows that the introduction of vaccines, which reduces $p_v$, also necessarily reduces $p_h$. Substituting $p_{h0}$ and $p_{h1}$ into Equation (5) and taking the ratio, we obtain the expression:

$$\frac{h_1^*}{h_0^*} \;=\; \frac{p_{h0} + (\frac{1-\beta}{\beta})^\gamma p_{h0}^\gamma}{p_{h1} + (\frac{1-\beta}{\beta})^\gamma p_{h1}^\gamma} \;>\; 1 \tag{7}$$

This expression shows that the introduction of vaccines improves perceived health.

The effect on $x$ is most clearly seen by taking the ratio $\frac{x_1^*}{x_0^*}$. Equation (8) shows that the effect of vaccine availability on the other input $x$ is ambiguous because it reflects three opposing forces: perceived health improves (pushing $x$ up), vaccination becomes cheaper (pulling $x$ down through substitution), and the CES aggregator mechanically adjusts the input mix (again pushing $x$ up). Behavioral compensation (a reduction in $x$) occurs when the substitution effect dominates the two upward forces.

$$\frac{x_1^*}{x_0^*} = \underbrace{\frac{h_1}{h_0}}_{>1} \times \underbrace{\left(\frac{s_0}{s_1}\right)^{\sigma}}_{<1} \times \underbrace{\left(\frac{A_0(\alpha)}{A_1(\alpha)}\right)^{\frac{\sigma}{\sigma-1}}}_{>1} \gtrless 1. \tag{8}$$

Changes in perceived health reflect both vaccine uptake and substitution across inputs. Therefore input adjustments need not map one-to-one into changes in perceived health. Utility maximization may lead to a tradeoff between these inputs because changes in perceived health depend jointly on vaccine adoption and adjustments in other health inputs. Although vaccine eligibility lowers the price of vaccination, the net effect on perceived health reflects both increased vaccination and any substitution away from alternative inputs. As a result, input utilization may adjust even when perceived health changes only modestly.

### 3.3 Predictions by Perceived Vaccine Effectiveness and Religiosity

Next we consider how the effects of vaccine eligibility vary with $\alpha$, the weight on the alternative good in the health production function. The $\alpha$ parameter captures the perceived relative productivity of $x$ compared to $v$. Considering $x$ as prayer, a large value of $\alpha$ is associated with both high religiosity and low confidence in vaccines. This symmetry means that predictions for religiosity and perceived vaccine effectiveness are isomorphic but oppositely signed.

Figure 3 provides guidance about realistic magnitudes of $\alpha$. No group considers prayer to be much more effective than vaccination. At most, strongly religious people perceive prayer to be moderately more effective. All religiosity groups see avoidance as slightly more effective than vaccination. These patterns are consistent with moderate and low values of $\alpha$, rather than values near 1, which helps to sign our predictions for the comparative statics below.

To estimate the differential effect on vaccination, we log differentiate Equation (6) with respect to $\alpha$.

$$\frac{d \ln \Delta v}{d\alpha} = \underbrace{\frac{1}{h_1^*} \cdot \frac{dh_1^*}{d\alpha}}_{<\ 0} + \underbrace{\frac{\sigma}{1-\sigma} \cdot \frac{A_1'(\alpha)}{A_1(\alpha)}}_{\gtrless\ 0} \tag{9}$$

The sign of this expression depends upon the last component. The second term is negative as long as vaccines are relatively cheap and effective and $\alpha$ is moderate, so that $x$ is not overwhelmingly important in beliefs. The critical threshold depends upon the prices, as well as $\alpha$ and $\sigma$.

Next we consider the comparative static of health and log-differentiate with respect to $\alpha$.

$$\frac{d}{d\alpha} \ln\left(\frac{h_1^*}{h_0^*}\right) = \underbrace{\frac{1 + c\gamma p_{h0}^{\gamma-1}}{p_{h0} + c\, p_{h0}^{\gamma}} \cdot \frac{dp_{h0}}{d\alpha}}_{<\ 0} - \underbrace{\frac{1 + c\gamma p_{h1}^{\gamma-1}}{p_{h1} + c\, p_{h1}^{\gamma}}}_{>0} \cdot \underbrace{\frac{dp_{h1}}{d\alpha}}_{\geq 0} \tag{10}$$

This expression is strictly negative under the assumption that $p_{v1} \leq p_x$. The first term captures the differential effect of $\alpha$ on perceived health prior to the vaccine rollout. An increase in $\alpha$ lowers the price of health in the pre-vaccine period, $p_{h0}$. However a comparison of perceived COVID-19 mortality risk by religiosity in Table 1 shows that religiosity groups have similar perceived health prior to the vaccine rollout, so this term may be near zero. The second term reflects the effect of $\alpha$ on the price of health in the post-vaccine period, $p_{h1}$. Since $p_{v1} \leq p_x$, an increase in $\alpha$ weakly increases $p_{h1}$, making the second term non-positive. Therefore, we expect smaller improvements in perceived health for more religious people, as well as for people who do not believe in vaccines.

Next we consider the comparative static for the alternative health input, $x$. Because the direct effect of vaccine availability is ambiguously signed in Equation (8), the interaction with respect to $\alpha$ is ambiguously signed as well. This interaction consists of the health effect in Equation (10) and a CES reweighting term that is ambiguously signed. As discussed, the health effect is negative. In addition, the second term represents reweighting of health inputs within the CES production function once vaccines are introduced. This term may be negative (leading to a weaker effect on health for high-$\alpha$ people) if the $x$ input is inframarginal and therefore does not decline substantially once vaccines are introduced.

$$\frac{d}{d\alpha}\ln\left(\frac{x_1^*}{x_0^*}\right) = \underbrace{\frac{d}{d\alpha}\ln\left(\frac{h_1^*}{h_0^*}\right)}_{<0} + \underbrace{\frac{\sigma}{\sigma-1}\frac{d}{d\alpha}\ln\left(\frac{A_0(\alpha)}{A_1(\alpha)}\right)}_{\gtreqless 0}, \tag{11}$$

Because of both terms, we may expect a smaller change in $x$ for people with higher values of $\alpha$. These people adjust their health demand less and therefore also adjust $x$ less. If $x$ is more inframarginal for high-$\alpha$ people, utilization will respond less to changes in $p_v$. In the case of prayer, religious people may have smaller declines in prayer either because they perceive smaller health improvements from vaccination or because prayer is more inframarginal. Since the perceived effectiveness of avoidance does not vary with religiosity in Figure 3, we do not expect differences by religiosity in the impact of vaccination on avoidance. Alternatively, vaccine skepticism is also associated with high $\alpha$. Therefore we expect smaller prayer and avoidance responses for people who distrust vaccines.

Table 2 summarizes these theoretical predictions. The direct effect of the vaccine rollout should be to increase vaccination, reduce subjective mortality risk, and reduce prayer and avoidance. We expect a weaker effect on vaccination, subjective mortality risk and prayer for more religious people. However we do not predict a difference in the impact on avoidance by religiosity since all groups have similar beliefs about the effectiveness of avoidance and vaccines in Figure 3. By a similar theoretical logic, the vaccine rollout has a larger effect for people who believe in vaccines, and these people experience larger declines in subjective mortality risk, prayer, and avoidance. Since they derive from the common mechanism of $\alpha$, these sources of heterogeneity provide complementary tests of the model.

## 4 Analysis of the COVID-19 Vaccine Rollout

Next we test the model's predictions by evaluating the impact of the COVID-19 vaccine rollout on vaccination, perceived mortality risk, prayer and science-based avoidance behavior. By preventing severe infections, the arrival of vaccines dramatically reduced COVID-19 mortality risk and may have led people to utilize fewer substitutable health inputs (Huang and Kuan 2022). Therefore, an analysis of the response to the rollout allows us to test the model and the role of prayer as a perceived health input.

We estimate the impact of vaccine eligibility using a difference-in-differences approach that compares the change in outcomes for early-eligible and late-eligible respondents. Given the staggered timing of eligibility, we implement the imputation-based difference-in-differences estimator of Borusyak et al. (2024).

$$y_{it} = \alpha_i + \gamma_{te} + \beta E_{it} + \varepsilon_{it} \tag{12}$$

In this expression, $i$ indexes the individual and $t$ indexes the survey date. $e$ indicates time-constant categories of perceived vaccine effectiveness.[9] $E_{it}$ is an indicator that the respondent is eligible for the vaccine on date $t$. We incorporate post-stratification weights to align the sample with the demographic characteristics of US adults. Standard errors are clustered by individual.

Identification requires that the eligibility date is not correlated with differential trends in the outcome variables. In this context, eligibility criteria also directly induce level differences in the characteristics that were the basis for eligibility. As we describe above, authorities first offered the vaccine to older people and members of prioritized professions. Dividing the sample at the median eligibility date (March 8, 2021), Columns 5-6 of Table 1 illustrate that, as expected, early-eligible people are older and more likely to be employed in health and education fields. Eligibility is weakly associated with gender and years of schooling. The table also shows that people with early eligibility are modestly more religious. The individual fixed effects also absorb other level differences, such as local disease conditions or

[9] Allowing time fixed effects, $\gamma$ to vary by $e$ improves the precision of the estimates and allows for a direct comparison with estimates that examine heterogeneity by $e$, however results are similar under a single common time trend.

media coverage.

To assess the possibility of pre-eligibility trends in the primary outcomes, Figure 4 plots the patterns in vaccination, mortality risk, prayer, and avoidance for 24 weeks before and 12 weeks after eligibility. We divide the sample into two-week periods and estimate coefficients on these periods within the Borusyak et al. (2024) framework. For all outcomes, pre-eligibility trends appear flat, and in all cases we fail to reject that the coefficients are jointly zero. Appendix A.4 shows robustness by perceived vaccine effectiveness and religiosity. As an additional check, Table A.2 reports similar results with hypothetical eligibility dates that are shifted forward or backward by 14 days, suggesting that deviations right before eligibility are not a serious threat.

# 5 Results

## 5.1 Overall Estimates and Heterogeneity by Perceived Vaccine Effectiveness

Overall estimates of the impact of vaccine eligibility appear in Panel A of Table 3, and the signs of these results align with the theoretical predictions Table 2 (Panel A). In Columns 1 and 2, vaccination rises by 14 p.p. and perceived mortality risk declines by 1.6 p.p. (8 percent). In Columns 3 and 4, prayer declines by 1 p.p. and avoidance falls by 0.05 s.d. Scaling by the first-stage effect on vaccination yields Wald estimates of 6.5 p.p. for prayer and 0.36 s.d. for avoidance among people induced to vaccinate.[10]

Panel B of Table 3 shows estimates of heterogeneity by perceived vaccine effectiveness. As predicted, estimates are larger for people who perceive that vaccines are effective. For this group, vaccination increases by 16 p.p., subjective mortality risk declines by 1.9 p.p., prayer declines by 1 p.p. and avoidance falls by 0.05 s.d. Since this group makes up 82 percent of the sample, these estimates resemble the overall estimates in Panel A. By contrast, results are small and insignificant for people who perceive that the vaccines are ineffective, although differences for prayer and avoidance are not statistically significant. These patterns align with the predictions in Panel B of Table 2, and therefore support the model.

[10]We should interpret these estimates cautiously because vaccine eligibility could influence these outcomes through anticipatory, informational, or social channels in addition to actual vaccination.

Next we assess the robustness of these results. With individual fixed effects, our main specification controls for individual time-constant attributes, however differential trends that are correlated with vaccine eligibility remain a threat to validity. Figure 5 reproduces the estimates in Table 3 and then controls sequentially for the interaction of time indicators with political party indicators, age groups, census regions, and education categories.[11] In general, allowing for more flexible time trends does not substantially change the estimates.[12]

Appendix A.4 carries out additional robustness tests. Table A.2 shows that results are robust if we shift the eligibility date 14 days forward or backward. Results are not sensitive to these shifts. This result is reasonable because once someone becomes eligible, it takes time to get vaccinated and then for risk perceptions and behavior to adjust. The appendix also shows that results are robust under alternative ways of constructing perceived vaccine effectiveness and avoidance.

### 5.2 Heterogeneity by Religiosity

Heterogeneity estimates by religiosity appear in Table 4. Despite the notion of vaccine hesitancy among religious people, the impact on vaccination only varies slightly by religiosity in Column 1. The effect is 0.15 for weakly religious people, 0.13 for moderately religious people, and 0.14 for strongly religious people. This pattern suggests that differences by religiosity in perceived vaccine effectiveness are not large enough to generate detectable differences in vaccination. In Column 2, the effect on perceived mortality risk is smaller for strongly religious people, which is consistent with the model, although this difference is not statistically significant ($p = 0.15$).

Next we turn to prayer and avoidance. Column 3 shows that prayer falls by 1.6 p.p. (27

[11] Education is divided into four categories. The first category includes education levels equal to or less than a high school graduate or GED; the second category includes some college with no degree and associate college degree and occupational/vocational programs; the third category consists of associate college degree academic programs and Bachelor's degree. Master's degree, professional school degree, and doctorate degree make up the fourth category. Observations are grouped into three age categories: 18–39, 40–59, and 60+. There are four census regions: Northeast, Midwest, South, and West. Political party affiliation is divided into four categories: (1) Democrats or some other party, (2) Republicans or Libertarians, (3) Independents (no political party), some other party, or not aligned with any political party, and (4) missing values.

[12] Eligibility is mechanically determined by age, occupation, chronic health status, and state rollout timing. Fully interacting time trends with these characteristics would absorb part of the identifying variation. Instead, identification relies on parallel pre-trends across eligibility cohorts, which we assess directly in Figure 4. Appendix A.4 reports additional robustness checks interacting time with pre-determined covariates.

percent) for weakly religious people, by 1.2 p.p. (2 percent) for moderately religious people, and 0.1 p.p. (0.1 percent) for strongly religious people ($p = 0.05$ for this difference). This pattern is consistent with two mechanisms in the model: smaller perceived health gains from vaccination and inframarginality of prayer among strongly religious respondents. In Column 4, less religious people also have larger effects on avoidance, however the difference is not statistically significant.[13,14]

One concern is that weekly prayer is measured as a binary indicator, which could obscure within-week adjustments among more religious people. Using Supplementary data on the frequency of prayer within the week, Figure 6 shows that moderately and strongly religious people have substantial mass at one instance per week, indicating that many remain marginal at the weekly level. This evidence suggests that the lack of a prayer response among strongly religious people is unlikely to be an artifact of the binary measurement of prayer.

An analysis by religious denomination can help us understand the strong effects for weakly religious people. As we describe above, atheists/agnostics and NPR people are the two main subcategories within this group. Figure 7 examines heterogeneity across these categories and "other religious denominations" across all religiosity levels.[15] Atheists and agnostics have particularly strong impacts on vaccination and subjective mortality risk, while the NPR group perceives a smaller and insignificant decline in risk. We observe an interesting contrast between the behavioral responses of these groups. Prayer falls by 1.9 p.p. among people with no particular religion (nearly twice the overall impact on this outcome), while it does not change significantly for atheists and agnostics ($p = 0.31$ for this difference). By contrast, avoidance declines sharply for atheists and agnostics, while it does not change for people with no particular religion ($p < 0.001$ for this difference). While it

[13]Since we measure the perceived effectiveness of prayer, it is also possible to estimate heterogeneity along this margin. In practice, religiosity and perceived prayer effectiveness are highly correlated. 13 percent of weakly religious people think prayer is effective and 92 percent of strongly religious people hold this belief. Analyzing heterogeneity on this margin instead of religiosity leads to similar results. People who believe that prayer is ineffective show larger absolute impacts on vaccination ($p = 0.03$) and mortality risk ($p < 0.001$). People who believe that prayer is ineffective have larger point estimates for prayer and avoidance but the differences are not statistically significant ($p = 0.13$ for prayer and $p = 0.44$ for avoidance).

[14]Figure A.10 shows heterogeneity by religiosity after controlling sequentially for the interaction of time indicators with several sets of controls, as in Figure 5. Estimates are robust with these controls, suggesting that heterogeneity by religiosity is not simply an artifact of these factors.

[15]The subgroup-only regression fails to converge given sample size and fixed-effect structure.

may seem paradoxical that perceived health does not improve for NPR people, mortality is endogenous to input utilization, and the model does not imply that both mortality risk and input utilization must fall. Modest vaccine uptake combined with imperfect substitution could cause behavioral adjustment even without reducing perceived mortality risk. These results help to explain why we observe the strongest prayer response among the weakly religious group, which ostensibly relies the least on prayer.

### 5.3 Interpretation

The estimates above indicate that prayer functions as a perceived health input whose responsiveness depends on its marginal status. Among weakly religious people, prayer behaves as a discretionary input that adjusts with the effective price of biomedical protection. Despite its modest perceived effectiveness, the low cost of prayer can justify its use when disease risk is high. By contrast, prayer may be more inframarginal for strongly religious people because it is integrated into daily life.

In this way, prayer may operate alongside other situational coping behaviors, reinforcing a sense of safety or control during times of distress. To assess this possibility, we estimate the impact of vaccine eligibility on indices of positive and negative coping in Columns 1 and 2 of Table 5.[16] Results for positive coping are qualitatively similar to prior results for prayer. Vaccine eligibility reduces the positive coping index by 0.02 s.d. ($p = 0.03$). As with prayer, this effect is concentrated among people who perceive that the vaccine is effective, for whom the effect is 0.03 s.d. ($p = 0.002$). The effect on positive coping is largest for low-religiosity respondents. Column 2 shows a different pattern for negative coping. Here effects are insignificant, except for a strong increase in negative coping among people who perceive that vaccination is ineffective. In sum, prayer and positive coping behaviors appear to respond similarly to changes in perceived risk, suggesting that prayer is part of a broader protective response to uncertainty.

An alternative explanation is that vaccination facilitated a return to in-person worship,

[16] Research on coping distinguishes between positive and negative behaviors, concluding that they arise from distinct psychological factors (Park et al. 2008). Positive coping includes relaxation, meditation, and exercise, while negative coping includes the use of alcohol, tobacco, cannabis, vaping, and other drugs. For each variable, the survey records the number of days in the past week that the respondent has done the activity. We compute the first principal component of the included outcomes within each grouping.

reducing reliance on private prayer. Column 3 of Table 5 reproduces our main specifications for an indicator for weekly in-person worship. Estimates, which are small and statistically insignificant, cannot account for the observed decline in prayer.

Our results also support the assumption of substitutability between prayer and biomedical health inputs. Self-reports from two distinct elicitation methods do not suggest a complementarity: few people believe that prayer enhances the impact of science-based behaviors. Consistent with these beliefs, we do not observe an *increase* in prayer following vaccine eligibility. We also do not observe a stronger vaccination response among strongly religious people. These patterns reinforce the interpretation that prayer is a substitute for biomedical protection.

## 6 Discussion

This paper shows that religious practice can function as a perceived health input that responds to changes in objective disease risk in a manner consistent with economic optimization. Exploiting staggered vaccine eligibility as a discrete reduction in mortality risk, we show that prayer declines when biomedical protection becomes available, consistent with substitution across perceived health inputs. The heterogeneity in this response clarifies the economic structure underlying religious practice. Among weakly religious people, prayer behaves as a discretionary and situational input. For strongly religious people, prayer is unresponsive to short-run changes in objective risk. This pattern is consistent with inframarginality: inputs that are central to identity or daily routine remain stable when relative prices change, while marginal inputs adjust.

We do not find evidence that effects on vaccination or other science-based health behaviors vary by religiosity. The impact on vaccination is nearly the same across religiosity groups, which challenges the common conception of vaccine hesitancy among religious people. The impact of avoidance is substantially smaller for strongly religious people, although the difference is not statistically significant. The lack of heterogeneity in responses aligns with the similarity of effectiveness beliefs for vaccination and avoidance across religiosity groups.

These findings suggest that we can apply economic reasoning to culturally embedded practices. When modeled as perceived inputs into health production, religious practices can exhibit standard marginal substitution patterns. At the same time, the lack of responsiveness among strongly religious people shows the limitation of a purely production-based lens, which abstracts from the spiritual and identity-based dimensions of prayer. For strongly religious people, prayer may be embedded in daily life rather than contingent on acute risk. More generally, practices that are deeply integrated into identity may be inframarginal and therefore resistant to economic incentives.

More broadly, the results underscore the importance of subjective production technologies. Individuals act on their beliefs about how actions translate into outcomes and adjust behavior when objective risk or relative prices change. Similar dynamics may arise outside of health. For instance, superstitions may influence financial portfolio choices and beliefs about predestination may shape investment in child human capital. Incorporating these behaviors into a subjective production framework allows us to analyze their responsiveness using standard economic tools.

Table 1: Pre-Rollout Sample Characteristics by Religiosity and Vaccine Eligibility

| | | Religiosity | | | Vaccine Eligibility | | P-values | |
|---|---|---|---|---|---|---|---|---|
| | All | Weak | Moderate | Strong | Early | Late | Relig. | Elig. |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| *A: Demographics* | | | | | | | | |
| Age | 49.8 | 45.6 | 50.1 | 52.4 | 58.0 | 41.6 | 0.00 | 0.00 |
| Female | 0.51 | 0.44 | 0.51 | 0.57 | 0.51 | 0.51 | 0.00 | 0.75 |
| Married | 0.56 | 0.50 | 0.54 | 0.62 | 0.59 | 0.53 | 0.00 | 0.00 |
| Education | 10.9 | 11.3 | 10.8 | 10.7 | 11.0 | 10.7 | 0.00 | 0.00 |
| Employed | 0.53 | 0.55 | 0.55 | 0.50 | 0.43 | 0.65 | 0.02 | 0.00 |
| Healthcare/education field | 0.11 | 0.10 | 0.10 | 0.12 | 0.18 | 0.03 | 0.09 | 0.00 |
| Republican | 0.27 | 0.15 | 0.26 | 0.38 | 0.31 | 0.23 | 0.00 | 0.00 |
| Northeast census region | 0.18 | 0.20 | 0.19 | 0.14 | 0.23 | 0.13 | 0.00 | 0.00 |
| Midwest census region | 0.21 | 0.24 | 0.21 | 0.19 | 0.22 | 0.19 | 0.01 | 0.01 |
| South census region | 0.38 | 0.27 | 0.36 | 0.48 | 0.36 | 0.40 | 0.00 | 0.01 |
| West census region | 0.23 | 0.29 | 0.23 | 0.20 | 0.19 | 0.28 | 0.00 | 0.00 |
| *B: Health and Religion* | | | | | | | | |
| Chronic health condition | 0.55 | 0.52 | 0.54 | 0.59 | 0.75 | 0.35 | 0.00 | 0.00 |
| Subjective COVID mortality risk | 0.07 | 0.06 | 0.07 | 0.08 | 0.08 | 0.06 | 0.00 | 0.00 |
| COVID infection (last 2 weeks) | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.63 | 0.00 |
| Perceived vaccine effectiveness | 2.82 | 2.88 | 2.82 | 2.78 | 2.86 | 2.78 | 0.00 | 0.00 |
| Perceived avoidance effectiveness | 3.51 | 3.55 | 3.52 | 3.47 | 3.55 | 3.46 | 0.06 | 0.00 |
| Perceived prayer effectiveness | 4.60 | 4.52 | 5.12 | 3.93 | 4.63 | 4.56 | 0.01 | 0.88 |
| Pew Religiosity Index | 0.40 | -2.89 | 0.17 | 2.95 | 0.59 | 0.21 | 0.00 | 0.00 |
| Prays weekly about COVID | 0.60 | 0.06 | 0.61 | 0.94 | 0.63 | 0.56 | 0.00 | 0.00 |
| Avoidance index | -0.03 | -0.00 | -0.02 | -0.06 | 0.02 | -0.08 | 0.16 | 0.00 |
| Number of Observations | 139,400 | 33,351 | 60,911 | 45,138 | 66,107 | 73,243 | – | – |

Note: The table reports sample means for the period from March 11-December 10, 2020. All statistics use post-stratification weights to ensure that the sample is representative of US adults in terms of gender, race, age, marital status, and education, as explained in the text. Vaccine eligibility categories are split at the median of March 8, 2021.

Table 2: Theoretical Sign Predictions for Vaccine Eligibility Effects

| | Outcome | | | | |
|---|---|---|---|---|---|
| | Vaccination | Subjective Mort. Risk | Prayer | Avoidance | Conditions for Signed Effect |
| | (1) | (2) | (3) | (4) | (5) |
| *A: Direct effect* | + | − | − | − | Eligibility lowers the price of vaccination; $x$ and $v$ are sufficiently substitutable; Assume the behavioral compensation effect dominates. |
| *B: Vaccine effectiveness interaction* | + | − | − | − | Assume $\alpha$ is small or moderate; Eligibility lowers the price of vaccination; $x$ and $v$ are sufficiently substitutable; $x$ is inframarginal. |
| *C: Religiosity interaction* | − | + | + | 0 | No religiosity gradient for effectiveness of avoidance; Assume $\alpha$ is small or moderate; Eligibility lowers the price of vaccination; $x$ is inframarginal; $x$ and $v$ are sufficiently substitutable. |

Note: This table summarizes the theoretical sign predictions for vaccine eligibility effects derived in Sections 3.2 and 3.3, along with the conditions required for each prediction to hold.

Table 3: Difference-in-Difference Estimates of the Impact of Vaccine Eligibility

| | Vaccination | Mortality Risk | Prays Weekly | Avoidance Index |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *A: Overall Impact* | | | | |
| Overall | 0.14*** | -0.016*** | -0.0091** | -0.050*** |
| | (0.0073) | (0.0022) | (0.0039) | (0.013) |
| Pre-rollout mean | 0.00 | 0.19 | 0.60 | -0.04 |
| Observations | 183,545 | 183,545 | 183,545 | 164,283 |
| *B: Impact by Perceived Vaccine Effectiveness* | | | | |
| Vaccine not effective | 0.027*** | 0.0018 | 0.0043 | -0.022 |
| | (0.0093) | (0.0038) | (0.0094) | (0.038) |
| Vaccine effective | 0.16*** | -0.019*** | -0.0099** | -0.052*** |
| | (0.0087) | (0.0025) | (0.0043) | (0.013) |
| Pre-rollout mean | | | | |
| Vaccine not effective | 0.00 | 0.17 | 0.70 | -0.34 |
| Vaccine effective | 0.00 | 0.20 | 0.58 | 0.06 |
| Equality of coefficients (p-value) | 0.00 | 0.00 | 0.17 | 0.45 |
| Observations | 183,545 | 183,545 | 183,545 | 164,283 |

Note: Regressions are based on the specification: $y_{it} = \alpha_i + \gamma_{te} + \beta E_{it} + \varepsilon_{it}$ in which $i$ indexes the individual, $t$ indexes the two-week time period, $e$ is perceived vaccine effectiveness, and $E_{it}$ is the individual's vaccine eligibility. Estimates follow the difference-in-difference imputation approach of Borusyak et al. (2024). Estimates are weighted to be nationally representative in terms of sex, race, age, marital status, and education, as explained in the text. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: The Impact of Vaccine Eligibility by Religiosity

| | Vaccination | Mortality Risk | Prays Weekly | Avoidance Index |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Weakly religious | 0.15*** | -0.023*** | -0.016*** | -0.070*** |
| | (0.012) | (0.0038) | (0.0048) | (0.019) |
| Moderately religious | 0.13*** | -0.014*** | -0.012 | -0.044** |
| | (0.010) | (0.0033) | (0.0073) | (0.019) |
| Strongly religious | 0.14*** | -0.014*** | -0.0011 | -0.028 |
| | (0.011) | (0.0034) | (0.0041) | (0.020) |
| Pre-rollout mean | | | | |
| Weakly religious | 0.00 | 0.17 | 0.06 | -0.00 |
| Moderately religious | 0.00 | 0.20 | 0.61 | -0.02 |
| Strongly religious | 0.00 | 0.20 | 0.94 | -0.06 |
| Equality of coefficients (p-value) | 0.51 | 0.15 | 0.05 | 0.33 |
| Observations | 183,545 | 183,545 | 183,545 | 164,283 |

Note: Regressions are based on the specification: $y_{it} = \alpha_i + \gamma_{te} + \beta E_{it} + \varepsilon_{it}$ in which $i$ indexes the individual, $t$ indexes the two-week period, $e$ is perceived vaccine effectiveness, and $E_{it}$ is the individual's vaccine eligibility. Estimates also include the interaction between time indicators and religiosity or religious affiliation categories, as applicable. Estimates follow the difference-in-difference imputation approach of Borusyak et al. (2024). Estimates are weighted to be nationally representative in terms of sex, race, age, marital status, and education, as explained in the text. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Pathways for the Impact of Vaccine Eligibility on Prayer

| | Positive Coping Index | Negative Coping Index | Attends Rel. Services |
|---|---|---|---|
| | (1) | (2) | (3) |
| *A: Overall Impact* | | | |
| Overall | -0.022** | 0.012 | 0.0047 |
| | (0.010) | (0.010) | (0.0036) |
| *B: Impact by Perceived Vaccine Effectiveness* | | | |
| Vaccine not effective | 0.034 | 0.077*** | 0.00022 |
| | (0.025) | (0.029) | (0.011) |
| Vaccine effective | -0.035*** | -0.0031 | 0.0055 |
| | (0.011) | (0.010) | (0.0038) |
| Equality of coefficients (p-value) | 0.01 | 0.01 | 0.64 |
| *C: Impact by Religiosity* | | | |
| Weakly religious | -0.053*** | 0.030* | -0.00065 |
| | (0.018) | (0.018) | (0.0024) |
| Moderately religious | -0.047*** | 0.018 | 0.0048 |
| | (0.015) | (0.016) | (0.0045) |
| Strongly religious | 0.036** | -0.0016 | 0.0016 |
| | (0.017) | (0.014) | (0.0078) |
| Equality of coefficients (p-value) | 0.00 | 0.38 | 0.56 |

Note: Regressions are based on the specification: $y_{it} = \alpha_i + \beta_{te} + \gamma E_{it} + \varepsilon_{it}$ in which $i$ indexes the individual, $t$ indexes the two-week time period, $e$ is perceived vaccine effectiveness, and $E_{it}$ is the individual's vaccine eligibility. Positive coping includes meditation, exercise and relaxation. Negative coping includes the use of cannabis, tobacco, vaping, drinking alcohol, and using drugs. For both indices, we compute the first principal component of the included variables and then standardize this index. Estimates follow the difference-in-difference imputation approach of Borusyak et al. (2024). Estimates are weighted to be nationally representative in terms of sex, race, age, marital status, and education, as explained in the text. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

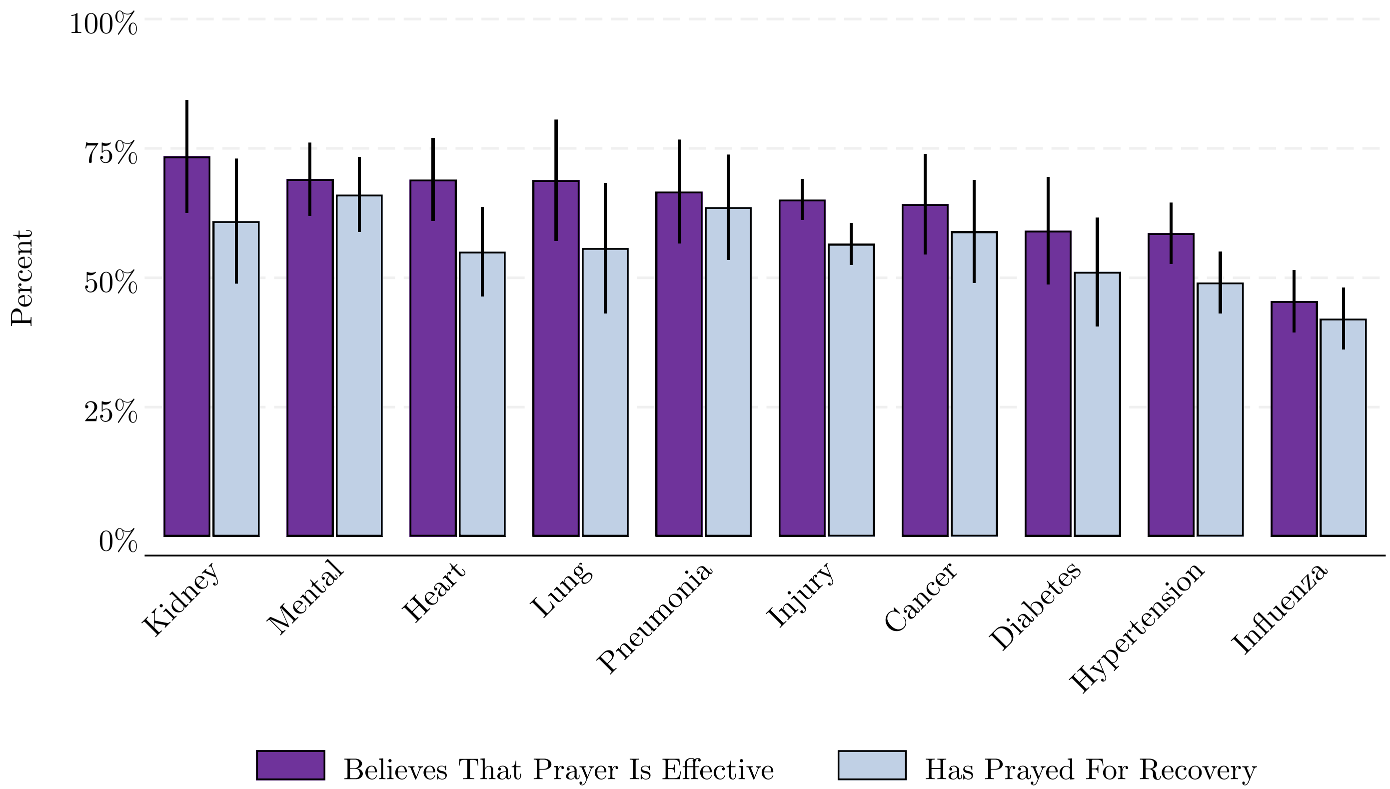



*Figure 1: Perceived Effectiveness and Utilization of Prayer across 10 Health Problems*

Note: The figure shows perceived effectiveness and utilization of prayer across 10 health problems. Error bars show 95 percent confidence intervals. Blue bars report the percentage of respondents who perceive prayer as an effective way to recover for health problems, while the purple bars report the percentage of respondents who have prayed as a way to recover from health problems. The sample is based on a survey of 1563 participants in the Understanding America Study that was conducted from December 18, 2024 to February 09, 2025.

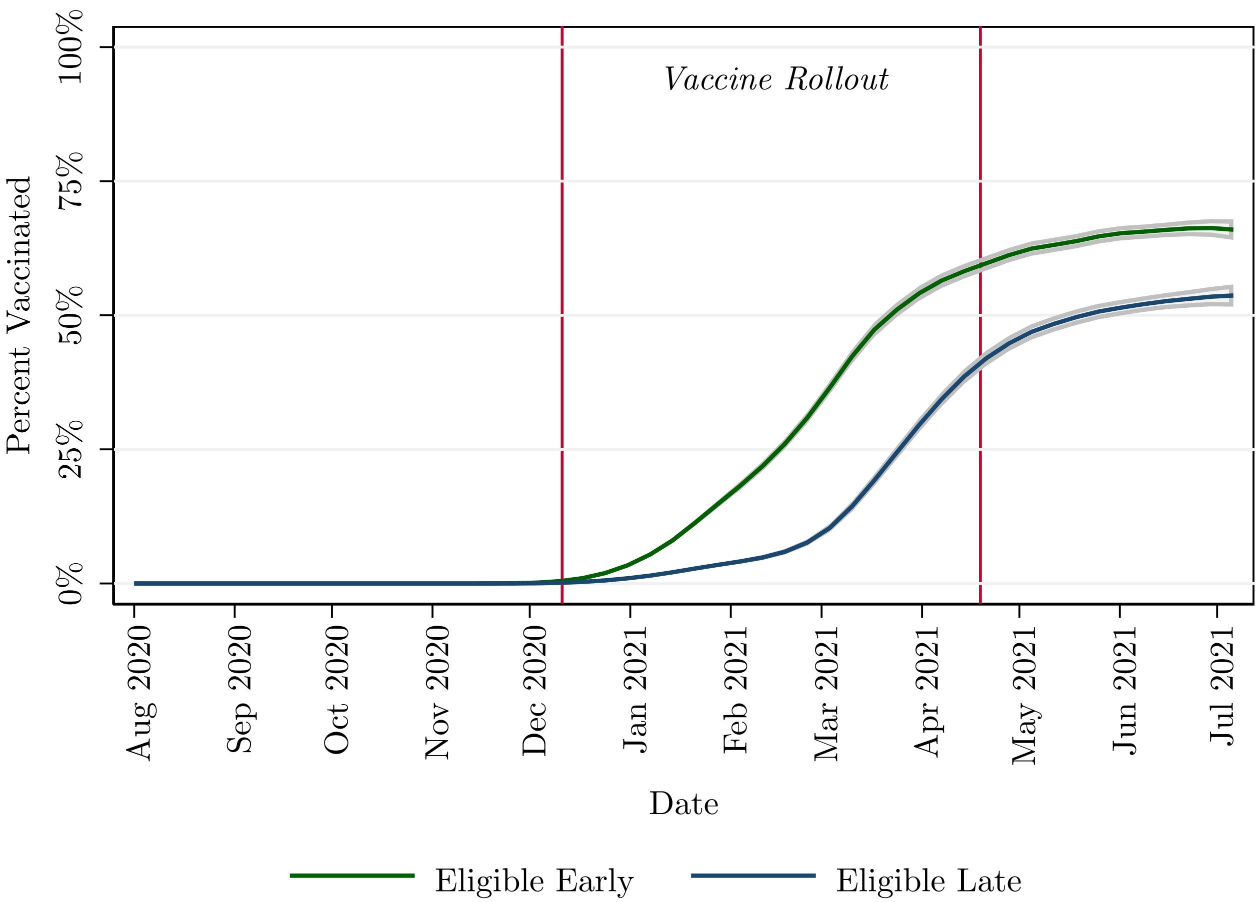
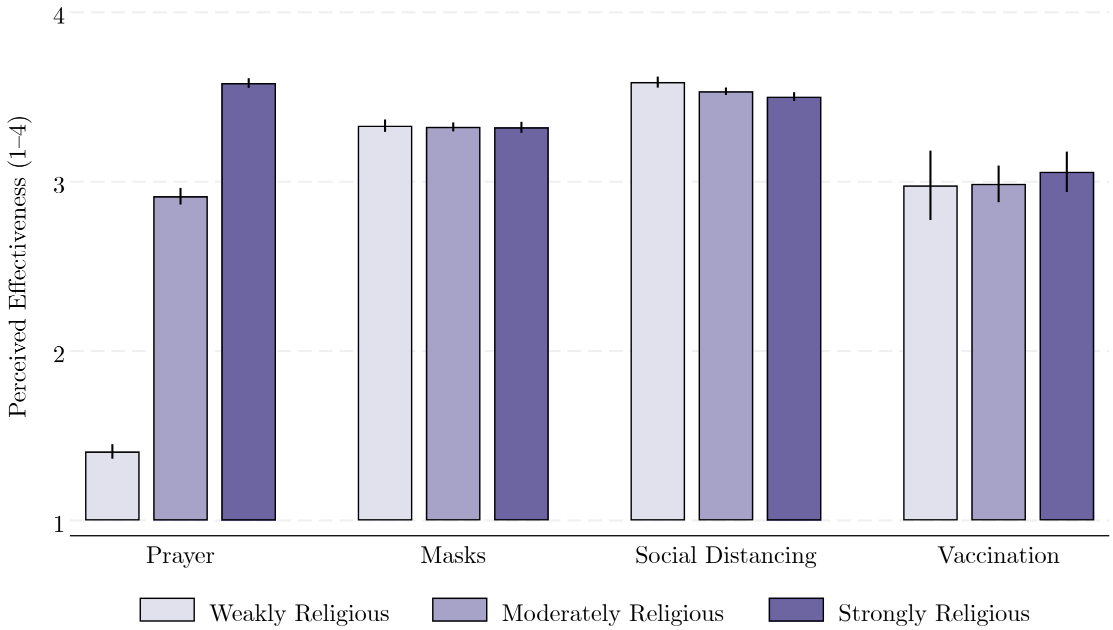



*Figure 2: Vaccine Eligibility and the Timing of the Vaccine Rollout*

Note: The figure divides the sample according to the median date of vaccine eligibility. Error bars show 95 percent confidence intervals based on individual-clustered standard errors. Estimates are weighted to be nationally representative of US adults, as explained in the text.



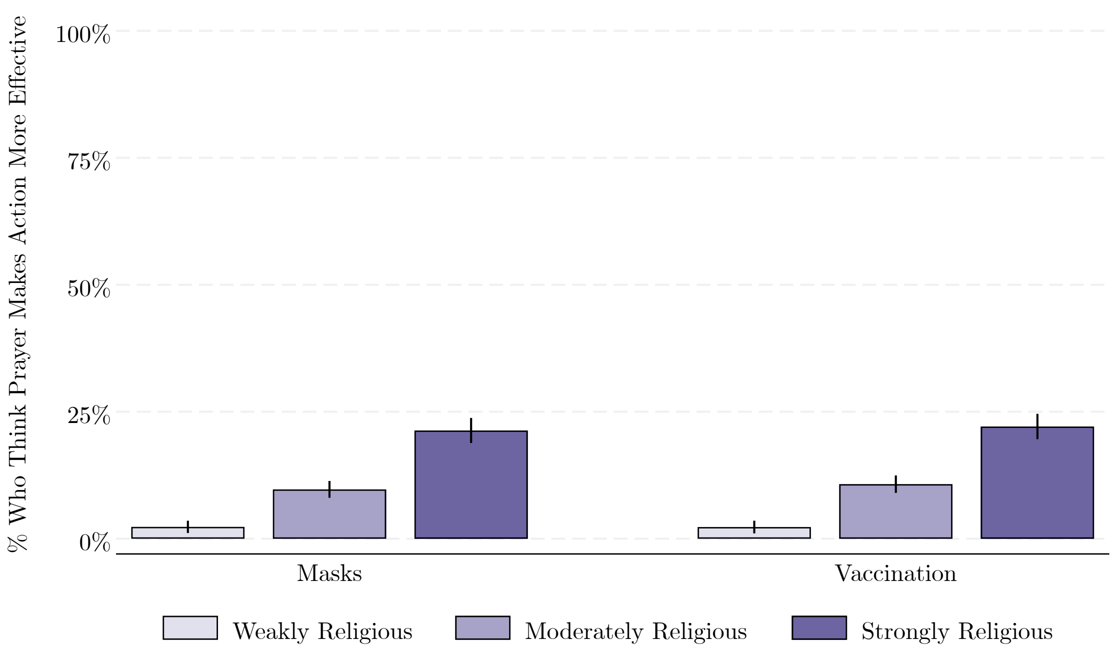




*Figure 3: Perceptions About the Effectiveness and Complementarity Between COVID-19 Prevention Behaviors*

Note: The figures divide the sample into religiosity categories. Error bars show 95 percent confidence intervals. Estimates are weighted to be representative of US adults, as described in the text. Panel A reports the average perceived effectiveness of prayer, masks, social distancing, and vaccination against COVID-19 on a four-point Likert scale. Panel B shows the percent of respondents who perceive a complementarity between prayer and other health inputs.

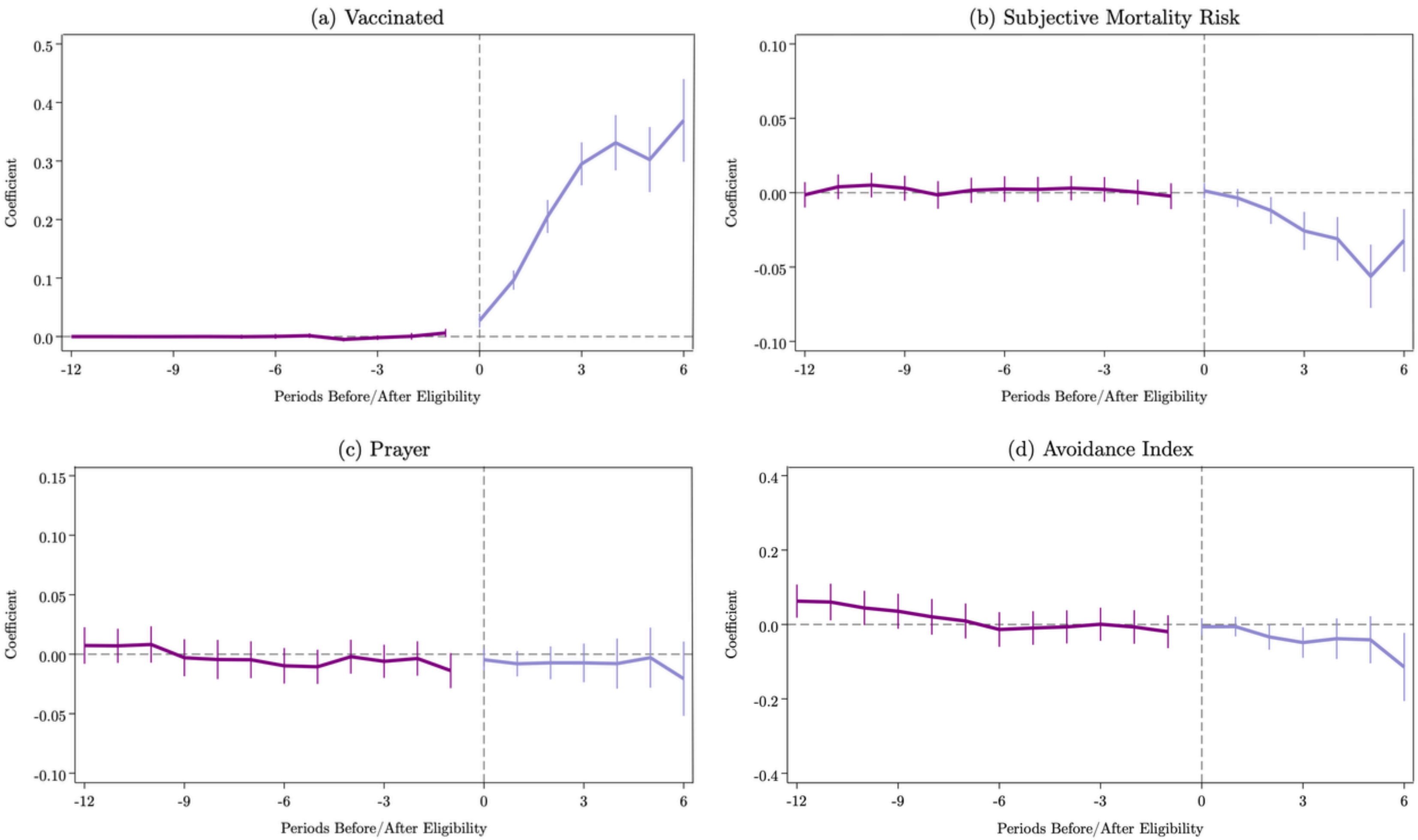



*Figure 4: Pre-Trends in Key Outcomes*

Note: The figure estimates biweekly pre- and post-eligibility trends for key outcome variables. Estimates are based on the DID imputation method of Borusyak et al. (2024). Variables are defined as in the text. Periods are two weeks long. Error bars indicate 95 percent confidence intervals based on individually-clustered standard errors. Estimates are weighted to be nationally representative.

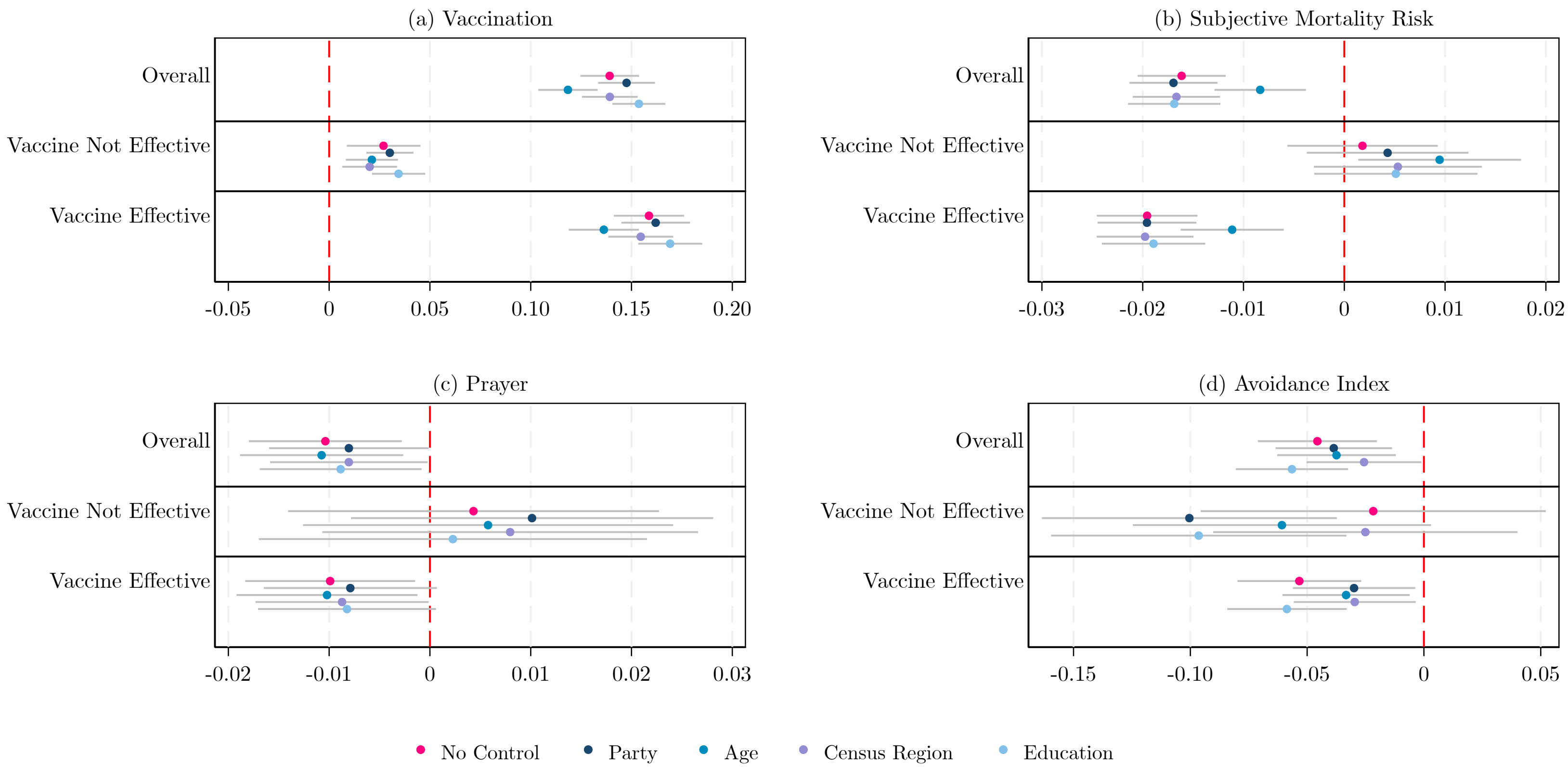



*Figure 5: Point Estimates with Different Controls by Perceived Vaccine Effectiveness*

Note: The figure presents point estimates for key outcome variables by perceived vaccine effectiveness. Within each outcome-effectiveness combination, it includes coefficients from five regressions: one with no controls and four with an interaction between the time indicator and one of the following variables: political party, age, census region, or education. In each graph, the grid line indicating a coefficient of zero is marked with a red dashed line. Error bars represent 95 percent confidence intervals based on individually clustered standard errors.

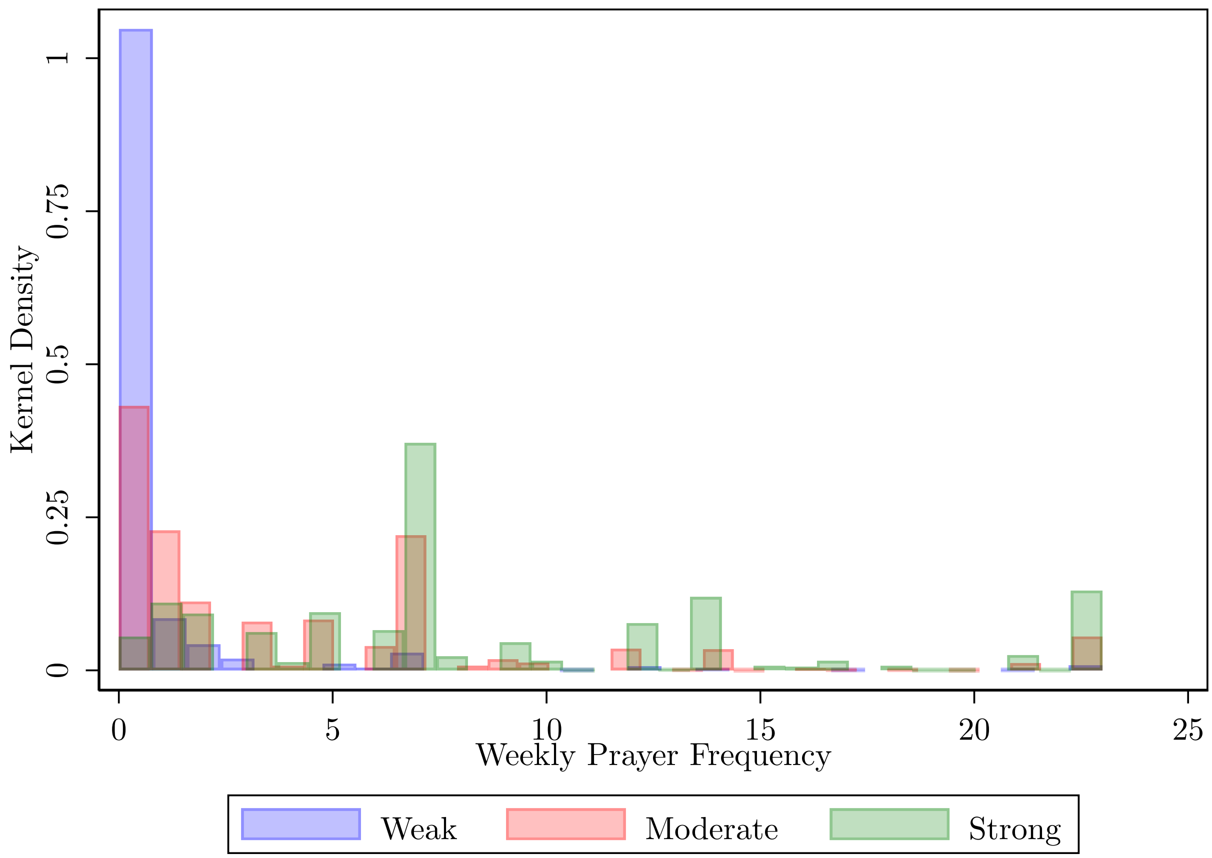



*Figure 6: Distribution of Prayer Frequency By Religiosity*

Note: The figure shows the frequency distribution of prayer within a week by religiosity based on survey data from January 2025.

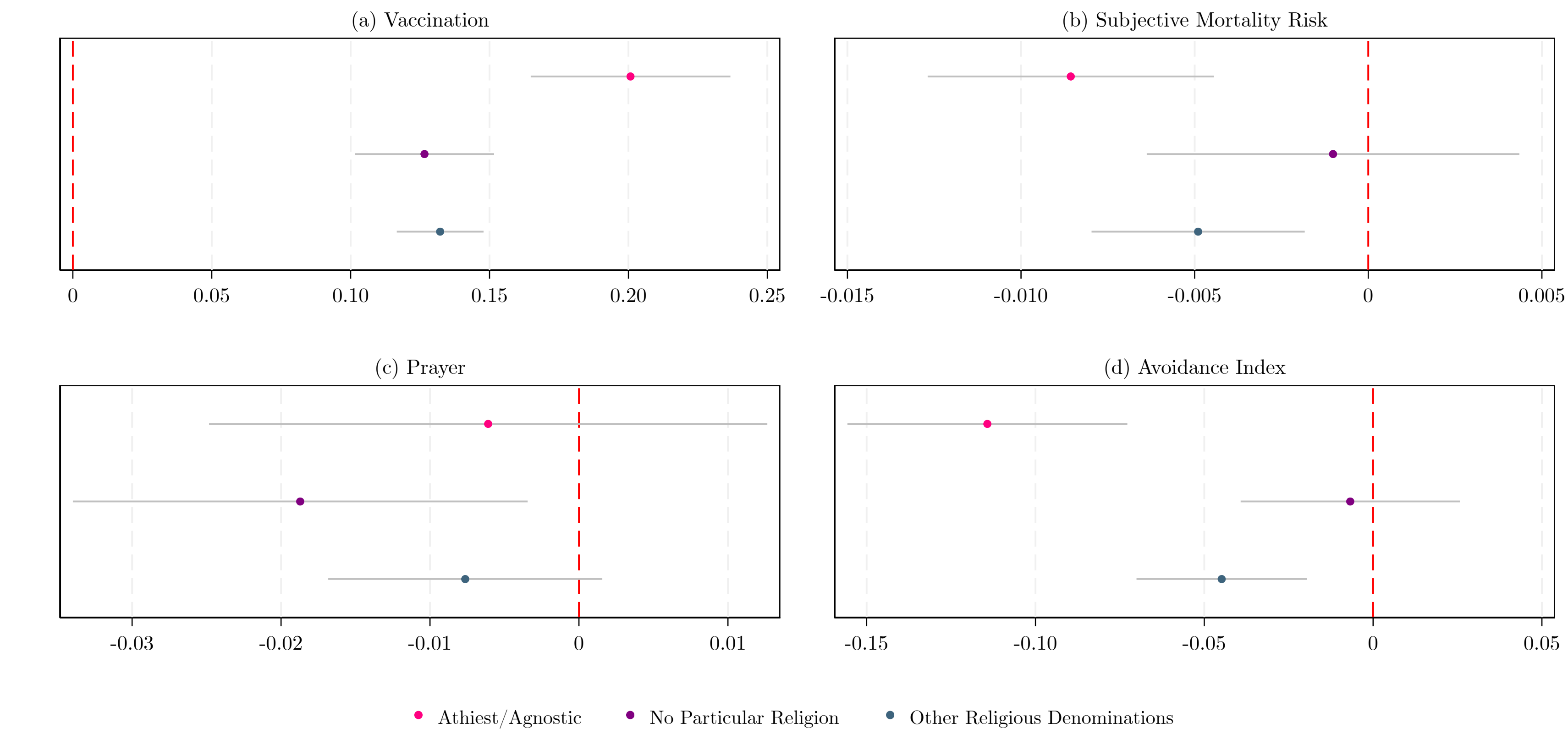



*Figure 7: Estimates for Atheists/Agnostics and People with No Particular Religion*

Note: The figure shows estimates by denomination for the full sample.

# A Appendix

## A.1 Additional Data Sources

To further investigate attitudes toward prayer, the survey incorporated additional variables related to religion and prayer in February and March of 2022. These questions measure whether the respondent perceives that prayer makes other COVID-19 prevention strategies, including wearing a mask and receiving a vaccination, to be more or less effective. An additional cross-sectional survey in January and February of 2025 measures the importance of prayer for a broader array of health domains and collects more detail on the frequency and nature of prayer in general. An important caveat for these data is that they were collected a year after the vaccine rollout. Therefore it is possible that experiences with the rollout could have influenced the way that people responded to these questions.

## A.2 Additional Evidence Regarding Input Substitutabilty

Figure A.1 presents data from the Understanding America Study in a survey collected between December 17, 2024 and February 6, 2025 (Survey UAS 673). Respondents were asked to estimate COVID-19 infection risk under hypothetical scenarios. We elicited how many out of 100 people similar to themselves would contract COVID-19 within a year when engaging in different combinations of protective behaviors, including prayer, vaccination, and non-pharmaceutical interventions such as mask use and avoiding public places. Responses were recorded on a 0–100 scale, and the order of scenarios was randomized. If two behaviors are complements, then practicing them in combination should have an effect that is larger than the sum of the effects of practicing them separately. Taken alone, vaccination reduces risk by 17 p.p. , prayer reduces risk by 5 p.p. , and avoidance reduces risk by 22 p.p. . The combination of vaccination and prayer has a similar effect to vaccination alone. Combining vaccination and avoidance reduces risk by an additional 5 points compared to vaccination alone, which is much less than the sum of the effects of the two activities. These patterns further reinforce that people do not perceive these health inputs to be complementary.

## A.3 Variable Definitions

- The variable "avoidance index" incorporates social distancing and mask wearing behaviors over the past week in various contexts. The variables that are available are different in the three distinct time periods below. Within each period, we compute the first principal component of the available variables. We normalize the index within each period.
  - **March–June 2020:** The index includes basic avoidance behaviors: (1) avoiding high-risk individuals, (2) avoiding public spaces, (3) avoiding restaurants, (4) working or studying from home, (5) wearing a face mask, and (6) washing hands. These questions were asked in binary form: "Yes" or "No".

- **July 2020–June 2021:** PCA expands to include detailed avoidance behaviors, such as avoiding the following activities in the past seven days: (1) gatherings of 10+ people, (2) crowded places such as bars and clubs, (3) grocery stores or pharmacies, (4) close contact with non-household members, (5) visiting others' homes, (6) outdoor activities (e.g., walking, hiking, or exercise), (7) air travel, (8) public transportation, and (9) having visitors at home. These expanded questions had three response options: "Yes," "No," or "Unsure." The index also includes face mask usage during these activities, measured on a 6-point Likert scale: "Always," "Most of the time," "Sometimes," "Rarely," "Never," or "Unsure."
- **September 2021–May 2023:** PCA employs only the expanded set of detailed avoidance variables and face mask usage introduced in the previous period (July 2020–June 2021), excluding the basic behavioral measures used in the initial period.

- Following the 2014 Pew Research Center Religious Landscape Study (Pew Research Center 2018), we constructed a measure of "Religiosity" as the sum of four components. Each component is categorized into three levels: high, medium, and low.
  - **Importance of Religion in Life**: This component is derived from UAS 15 (June 2015–January 2016) and UAS 37 (February 2016–October 2022). The question asked was: "How important is religion in your life?" The original question had six response options: "The most important thing," "Very important," "Somewhat important," "Not too important," "Not at all important," and "Don't know".
  - **Church Attendance**: Similar to the first component, this component is derived from UAS 15 (June 2015–January 2016) and UAS 37 (February 2016–October 2022). The question asked was: "How often do you attend religious services besides weddings and funerals?" The original question had seven response options: "Daily," "Multiple times a week," "Once a week," "One to two times a month," "Less than once a month," "Never," and "Don't know".
  - **Belief in God**: This component is derived from UAS 351 (February 2022–March 2022). The question asked was: "Which of the following comes closest to your beliefs?" The original question had four response options: "I believe in God," "I believe in some other higher power or spiritual force," "I do not believe in any higher power or spiritual force," and "I'm not sure".
  - **Prayer Frequency**: This component is constructed using responses from waves 1-21 of the UAS Coronavirus Tracking Survey (i.e. before the vaccine rollout). The relevant question asked: "Which of the following have you done in the last seven days to keep yourself safe from coronavirus?" "Prayer" is one of the 16 response options, and the measure is defined as the average frequency of reporting prayer across waves.
- 25 percent of people responded to some questions that contribute to the religiosity index after the vaccine rollout. Estimates are similar if we exclude these people from the analysis, as we explain below.

## A.4 Additional Estimates

Figures A.2 and A.3 distinguish categories by perceived vaccine effectiveness and religiosity, respectively. The Borusyak et al. (2024) approach does not allow us to estimate separate pre-trends by heterogeneity category. Prayer shows a small dip from Period -2 to Period -1; however, the figure suggests that this pattern is driven by individuals who perceive the vaccine as ineffective and by those who are weakly religious. Avoidance shows a downward trend from Period -12 to Period -6; however, the series is flat in the weeks immediately prior to eligibility.

Table A.2 presents estimates using three alternative treatment-timing shifts, showing that the main results in Table 3 remain robust when allowing vaccination to occur up to 14 days before or after eligibility. Vaccine eligibility statistically significantly increases vaccination by 11 p.p. when the eligibility date is advanced by two weeks, and by 16 p.p. when the eligibility date is delayed by two weeks, compared to 14 p.p. when there is no shift in treatment timing. Although the estimates differ slightly when the treatment timing is changed, these differences are intuitive and small in magnitude. We therefore conclude that even if some individuals were vaccinated several days before or after their eligibility date, our estimation results remain robust. Similar patterns are observed for the other three outcomes.

Table A.3 further confirms robustness by restricting the sample to respondents whose religiosity index was measured prior to the vaccine rollout. More than 75 percent of the sample remains in the estimation. Estimates closely resemble our main results in Tables 3 and 4.

Figure A.4 decomposes the Avoidance Index into 22 individual components, showing that the primary effect of vaccine eligibility is driven by mask-wearing during close contact with non-household members and during outdoor activities such as walking, hiking, or exercise. Figure A.5 similarly examines the components of positive and negative coping strategies in Table 5, suggesting that prayer may serve as a form of exercise or relaxation for some individuals.

In the paper, we collapse perceived vaccine effectiveness into two categories. In fact, this variable takes five possible values, as we illustrate in Figure A.6. To assess the robustness of this approach, Figure A.7 shows estimates of the effects of vaccine eligibility for all possible vaccine effectiveness categories. The resulting patterns are broadly consistent with those obtained using the two-category classification in Table 3 and Table 5. Similarly, we collapse religiosity into three categories, however Figure A.8 shows the full distribution of the index. To assess the sensitivity to this categorization, Figure A.9 presents estimates by nine categories of religiosity, yielding patterns comparable to those based on the three-category classification in Table 4 and Table 5.

## A.5 Impacts on COVID infection

Table A.1 reproduces our main estimates for COVID-19 infection. Respondents may be coded as positive for COVID-19 through three possible channels: a positive COVID-19 test, a doctor's diagnosis, or a subjective belief that they contracted COVID-19. This flexibility is important because the availability of COVID-19 tests varies over the course of the pandemic. Patterns in the table are not consistent with estimates for perceived mortality risk in the paper. In Panel A, we find no overall effect of vaccine eligibility on COVID-19 infections. This pattern could reflect the fact that vaccines did more to reduce the severity of COVID-19 infections rather than to prevent them. In Panel B, vaccine eligibility reduces COVID-19 infections significantly for those who perceive that the vaccine is not effective, while it appears to have no effect on infections among those who perceive the vaccine to be effective. The difference between the change of these two groups of people are statistically significant ($p < 0.01$). Finally, in Panel C, we find no significant effects for any religiosity subgroups. Results are not consistent with our findings in Table 4, which shows that all groups reduce perceived COVID-19 mortality risk.

### A.6 Determination of Vaccine Eligibility

We calculate vaccine eligibility by combining individual characteristics with state-specific eligibility criteria. As described in the text, the Federal government purchased vaccine doses from drug manufacturers and then relied on state health departments to distribute vaccines. Following CDC guidelines, these agencies prioritized providing vaccines to first responders and vulnerable individuals, including the elderly and those with compromised health situations. States set rollout dates based on their interpretation of these guidelines, access to vaccine doses, and local infrastructure for vaccine delivery. Multistate, a government relations firm, maintained a list of state-specific eligibility dates and criteria. We combine these data with information on individual UAS respondents to determine each person's eligibility. These characteristics include age, chronic health conditions, residence in a nursing home, occupation, and state of residence. Where possible, we rely on responses that occurred prior to the vaccine rollout. However occupation data were collected during February-April 2021, during the vaccine rollout. Occupation data are based on six-digit o*net codes, which is the highest level of granularity. We applied for access to these confidential data and utilized a secure data enclave to construct the eligibility variable.

One concern with reliance on occupation data that were collected during the vaccine rollout is that some people might sort into occupations that give them earlier eligibility. This concern seems unlikely given the training and experience needed to enter many of the relevant occupations (e.g. first responders, health care workers and educators). As an additional test of possible occupational sorting, we examine whether vaccine eligibility is associated with any unusual employment patterns early in the vaccine rollout. We do not find evidence of sorting. From December 11, 2020 to March 7, 2021 (the median eligibility date), 98 percent of employed early-eligible people remained in the same job while 97 percent of employed late-eligible people did so. This suggests that it is unlikely people chose occupations to hasten vaccine eligibility.

Table A1: The Impact of Vaccine Eligibility on COVID Infection

| | COVID-19 |
|---|---|
| | (1) |
| *A: Overall Impact* | |
| Overall | -0.0026 |
| | (0.0020) |
| *B: Impact by Perceived Vaccine Effectiveness* | |
| Vaccine not effective | -0.020*** |
| | (0.0054) |
| Vaccine effective | 0.0017 |
| | (0.0021) |
| Equality of coefficients (p-value) | 0.00 |
| *C: Impact by Religiosity* | |
| Weakly religious | -0.0023 |
| | (0.0044) |
| Moderately religious | -0.0023 |
| | (0.0027) |
| Strongly religious | -0.0041 |
| | (0.0036) |
| Equality of coefficients (p-value) | 0.92 |

Note: Regressions are based on the specification: $y_{it} = \alpha_i + \gamma_{te} + \beta E_{it} + \varepsilon_{it}$ in which $i$ indexes the individual, $t$ indexes the two-week time period, $e$ is perceived vaccine effectiveness, and $E_{it}$ is the individual's vaccine eligibility. Estimates follow the difference-in-difference imputation approach of Borusyak et al. (2024). Estimates are weighted to be nationally representative in terms of sex, race, age, marital status, and education, as explained in the text. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A2: The Impact of Vaccine Eligibility with a Shifted Treatment Timing

| | Vaccination | Mortality Risk | Prays Weekly | Avoidance Index |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *A: Vaccine Eligibility Date Advanced by 14 Days* | | | | |
| Overall | 0.11*** | -0.011*** | -0.008** | -0.054*** |
| | (0.0060) | (0.0021) | (0.0037) | (0.012) |
| Observations | 178,815 | 178,815 | 178,815 | 160,238 |
| *B: Vaccine Eligibility Date Delayed by 14 Days* | | | | |
| Overall | 0.16*** | -0.018*** | -0.010** | -0.051*** |
| | (0.0079) | (0.0024) | (0.0042) | (0.012) |
| Observations | 180,692 | 180,692 | 180,692 | 161,822 |
| *C: Drop Observations from 14 to 1 Days Before Eligibility* | | | | |
| Overall | 0.14*** | -0.014*** | -0.0085** | -0.060*** |
| | (0.0071) | (0.0023) | (0.0042) | (0.013) |
| Observations | 174,551 | 174,551 | 174,551 | 156,452 |

Note: Regressions are based on the specification: $y_{it} = \alpha_i + \gamma_{te} + \beta E_{it} + \varepsilon_{it}$ in which $i$ indexes the individual, $t$ indexes the two-week time period, $e$ is perceived vaccine effectiveness, and $E_{it}$ is the individual's vaccine eligibility. In the regressions, the treatment date $E_{it}$ is hypothetically shifted 14 days earlier or later for each treated unit. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: The Impact of Vaccine Eligibility Using the Pre-Rollout Religiosity Index

| | Vaccination | Mortality Risk | Prays Weekly | Avoidance Index |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *A: Overall Impact* | | | | |
| Overall | 0.14*** | -0.013*** | -0.0093** | -0.041*** |
| | (0.0083) | (0.0027) | (0.0042) | (0.014) |
| Pre-rollout mean | 0.00 | 0.19 | 0.60 | -0.03 |
| Observations | 136,511 | 136,511 | 136,511 | 122,600 |
| *B: Impact by Religiosity* | | | | |
| Weakly religious | 0.16*** | -0.021*** | -0.017*** | -0.036* |
| | (0.013) | (0.0041) | (0.0059) | (0.019) |
| Moderately religious | 0.12*** | -0.0010** | -0.012 | -0.027 |
| | (0.013) | (0.0044) | (0.0080) | (0.021) |
| Strongly religious | 0.14*** | -0.011*** | 0.0031 | -0.027 |
| | (0.011) | (0.0039) | (0.0046) | (0.022) |
| Pre-rollout mean | | | | |
| Weakly religious | 0.00 | 0.16 | 0.10 | -0.04 |
| Moderately religious | 0.00 | 0.22 | 0.75 | -0.04 |
| Strongly religious | 0.00 | 0.18 | 0.96 | -0.12 |
| Equality of coefficients (p-value) | 0.07 | 0.12 | 0.02 | 0.93 |
| Observations | 136,511 | 136,511 | 136,511 | 122,600 |

Note: Regressions are based on the specification: $y_{it} = \alpha_i + \gamma_{te} + \beta E_{it} + \varepsilon_{it}$ in which $i$ indexes the individual, $t$ indexes the two-week time period, $e$ is perceived vaccine effectiveness, and $E_{it}$ is the individual's vaccine eligibility. About 78 percent of the sample remains in the estimation. Estimates follow the difference-in-difference imputation approach of Borusyak et al. (2024). Estimates are weighted to be nationally representative in terms of sex, race, age, marital status, and education, as explained in the text. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: Pre-Rollout Religious Denominations by Religiosity and Vaccine Eligibility

| | | Religiosity | | | Vaccine Eligibility | | P-values | |
|---|---|---|---|---|---|---|---|---|
| | All | Weak | Moderate | Strong | Early | Late | Relig. | Elig. |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Evangelical Protestant | 0.09 | 0.00 | 0.07 | 0.19 | 0.12 | 0.07 | 0.00 | 0.00 |
| Non-Evangelical Protestant | 0.08 | 0.04 | 0.09 | 0.08 | 0.11 | 0.05 | 0.00 | 0.00 |
| Catholic | 0.14 | 0.05 | 0.15 | 0.18 | 0.16 | 0.11 | 0.00 | 0.00 |
| Other religion | 0.18 | 0.08 | 0.17 | 0.28 | 0.19 | 0.18 | 0.00 | 0.21 |
| Atheist or agnostic | 0.27 | 0.54 | 0.27 | 0.10 | 0.25 | 0.30 | 0.00 | 0.00 |
| No particular religion (NPR) | 0.21 | 0.32 | 0.23 | 0.10 | 0.18 | 0.23 | 0.00 | 0.00 |
| Number of Observations | 139,400 | 33,351 | 60,911 | 45,138 | 66,107 | 73,243 | – | – |

Note: The table reports sample means for the period from March 11-December 10, 2020. All statistics use post-stratification weights to ensure that the sample is representative of US adults in terms of gender, race, age, marital status, and education, as explained in the text. Vaccine eligibility categories are split at the median of March 8, 2021.

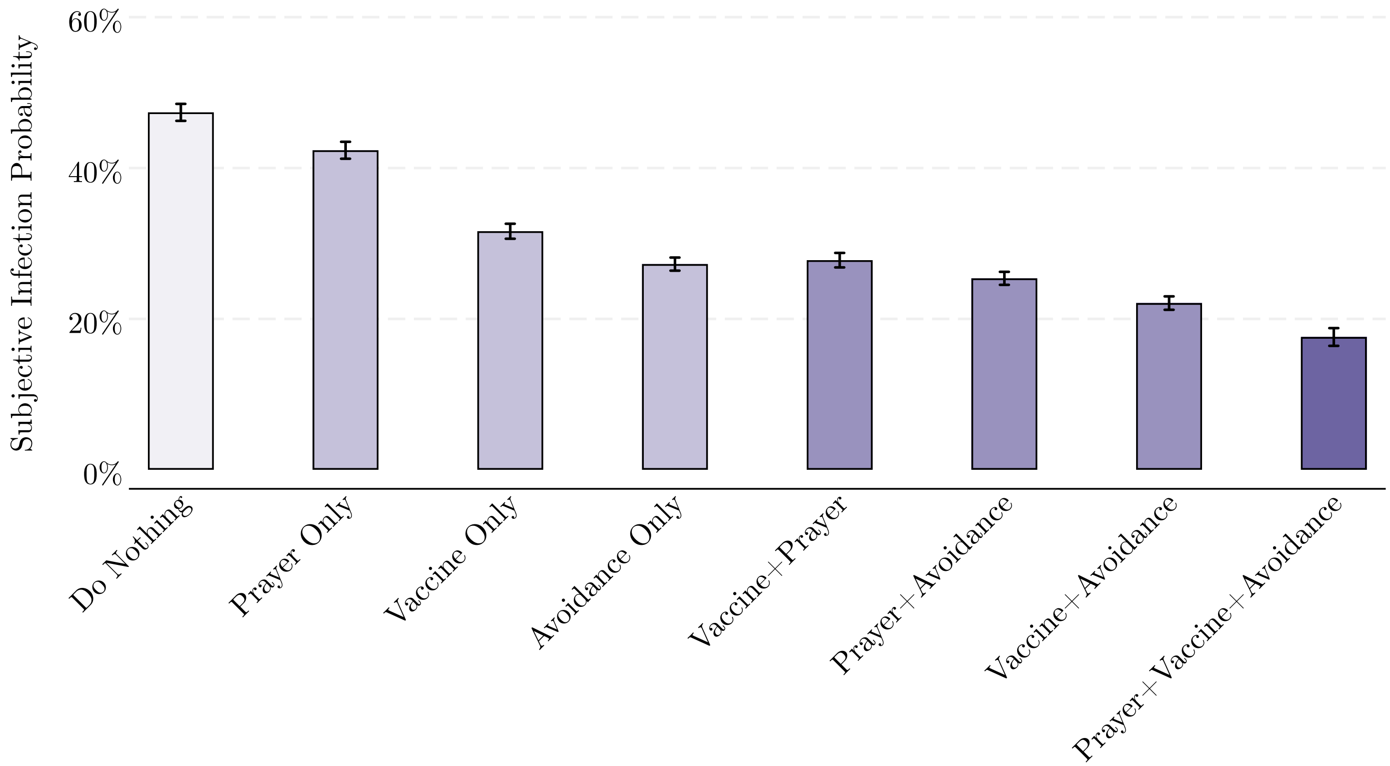



*Figure A.1: Perceptions About the Complementarity Between COVID-19 Prevention Behaviors*

Note: The figure presents point estimates for subjective infection probability when using different preventive behaviors.

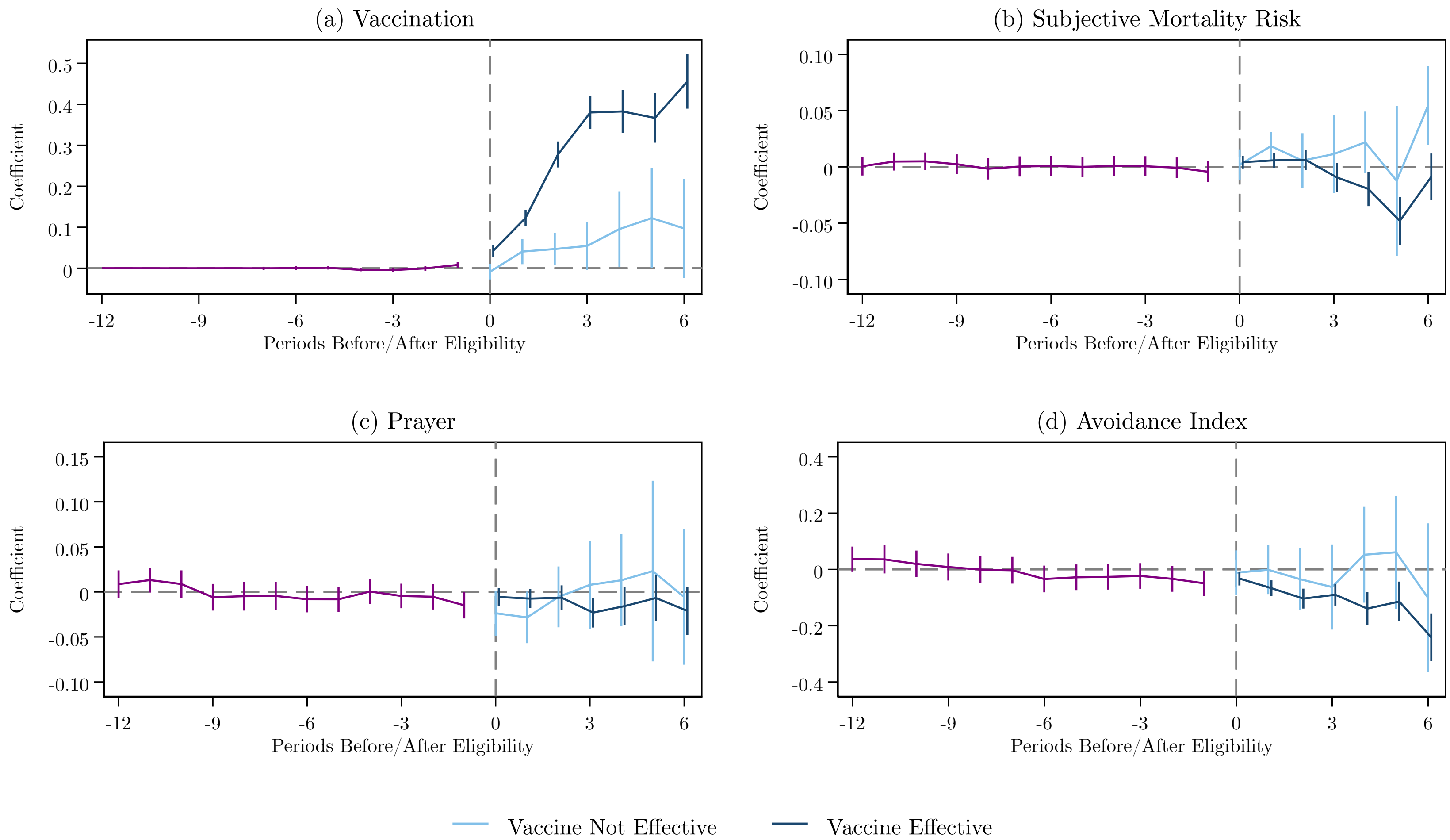



*Figure A.2: Trends by Perceived Vaccine Effectiveness*

Note: The figure estimates biweekly pre- and post-eligibility trends for key outcome variables. Post-eligibility trends are estimated separately by perceived vaccine effectiveness. Estimates are based on the DID imputation method of Borusyak et al. (2024). Variables are defined as in the text. Error bars indicate 95 percent confidence intervals based on individually-clustered standard errors. Estimates are weighted to be nationally representative.

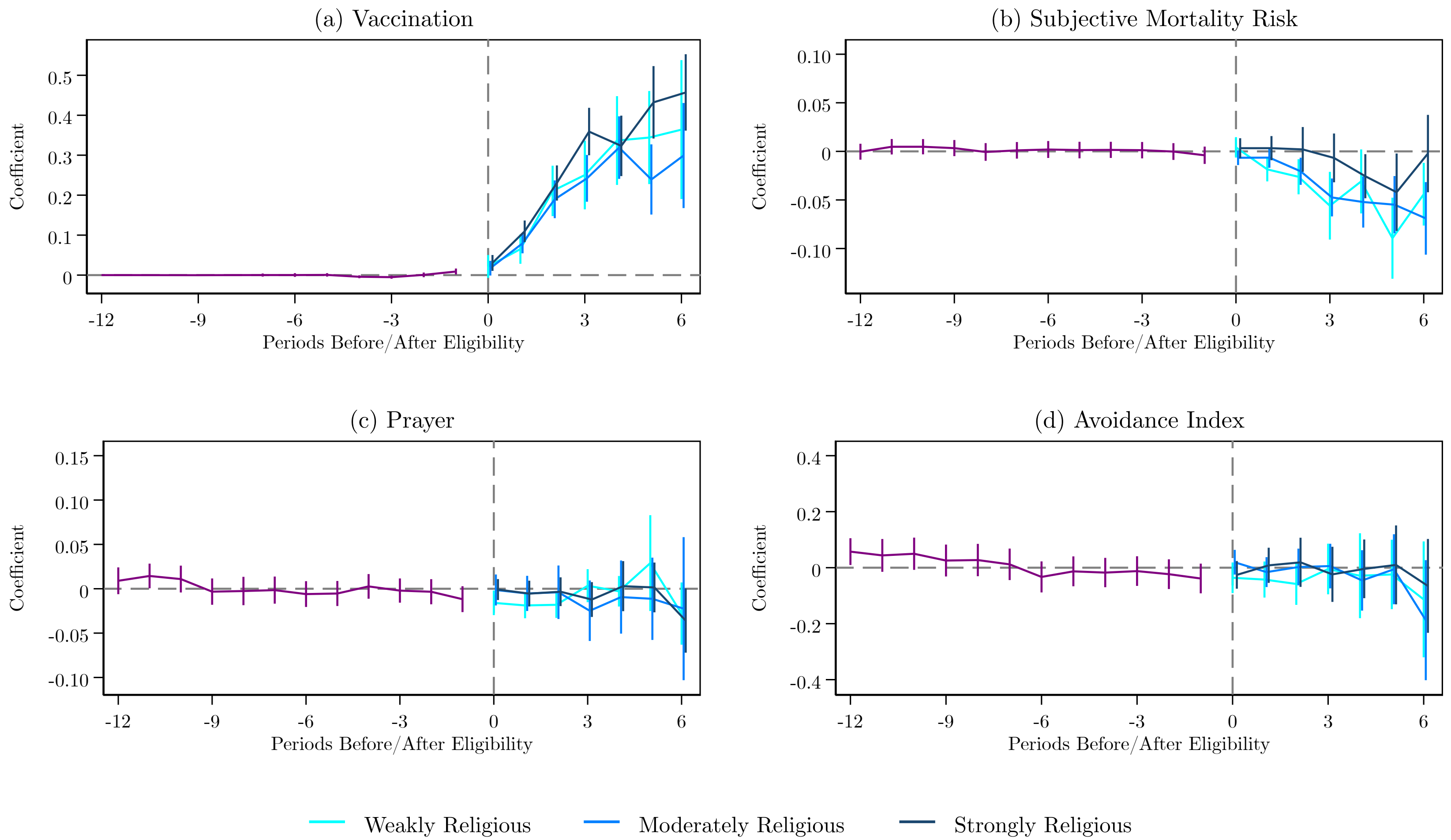



*Figure A.3: Trends by Religiosity*

Note: The figure estimates biweekly pre- and post-eligibility trends for key outcome variables. Post-eligibility trends are estimated separately by religiosity. Estimates are based on the DID imputation method of Borusyak et al. (2024). Variables are defined as in the text. Error bars indicate 95 percent confidence intervals based on individually-clustered standard errors. Estimates are weighted to be nationally representative.

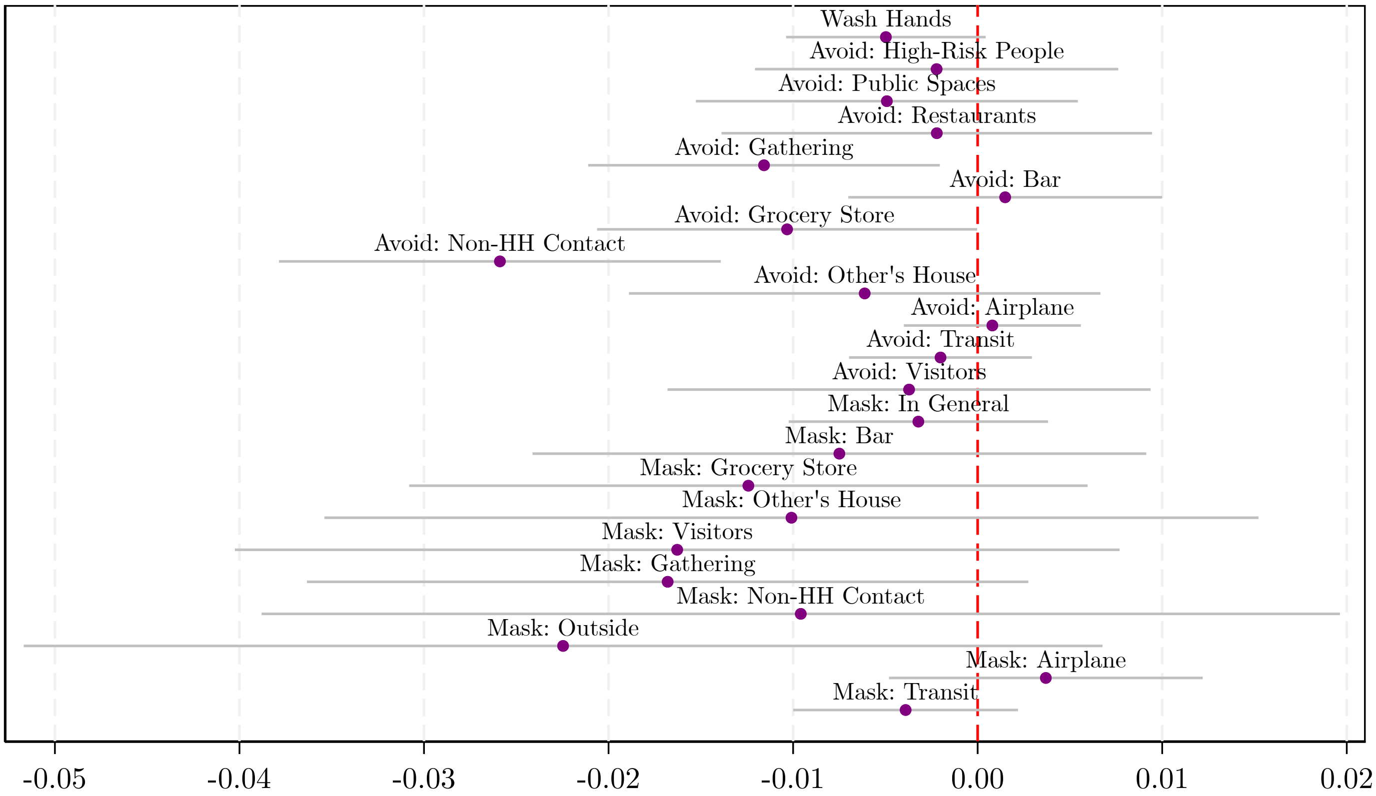



*Figure A.4: Effects of Vaccine Eligibility on Components of Avoidance Index*

Note: This figure shows the estimated impact of vaccine eligibility on the individual components of Avoidance Index. The index captures a range of behaviors, including avoiding high-risk individuals, public spaces, restaurants, and social gatherings, as well as engaging in personal protective practices such as mask wearing and handwashing.

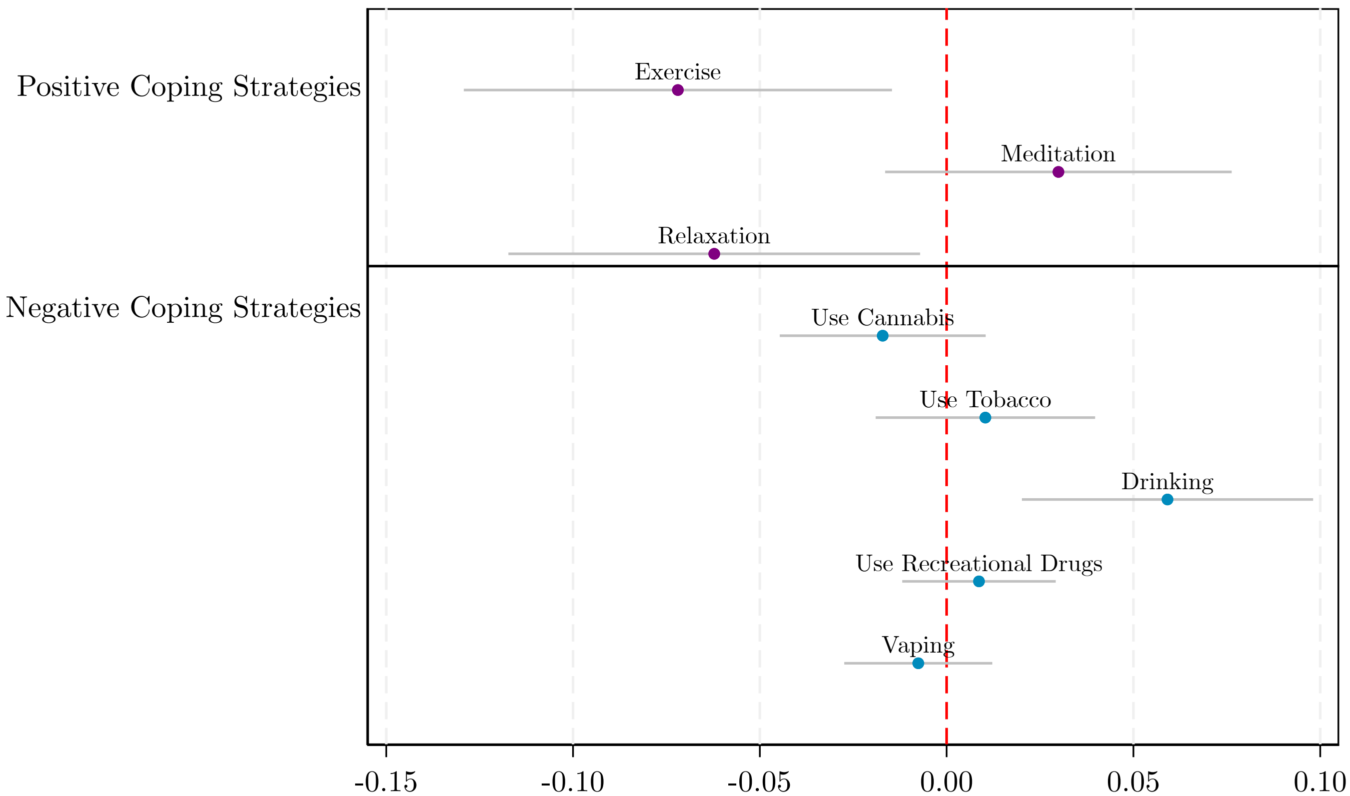



*Figure A.5: Effects of Vaccine Eligibility on Coping Behaviors*

Note: This figure shows the estimated impact of vaccine eligibility on coping behaviors.

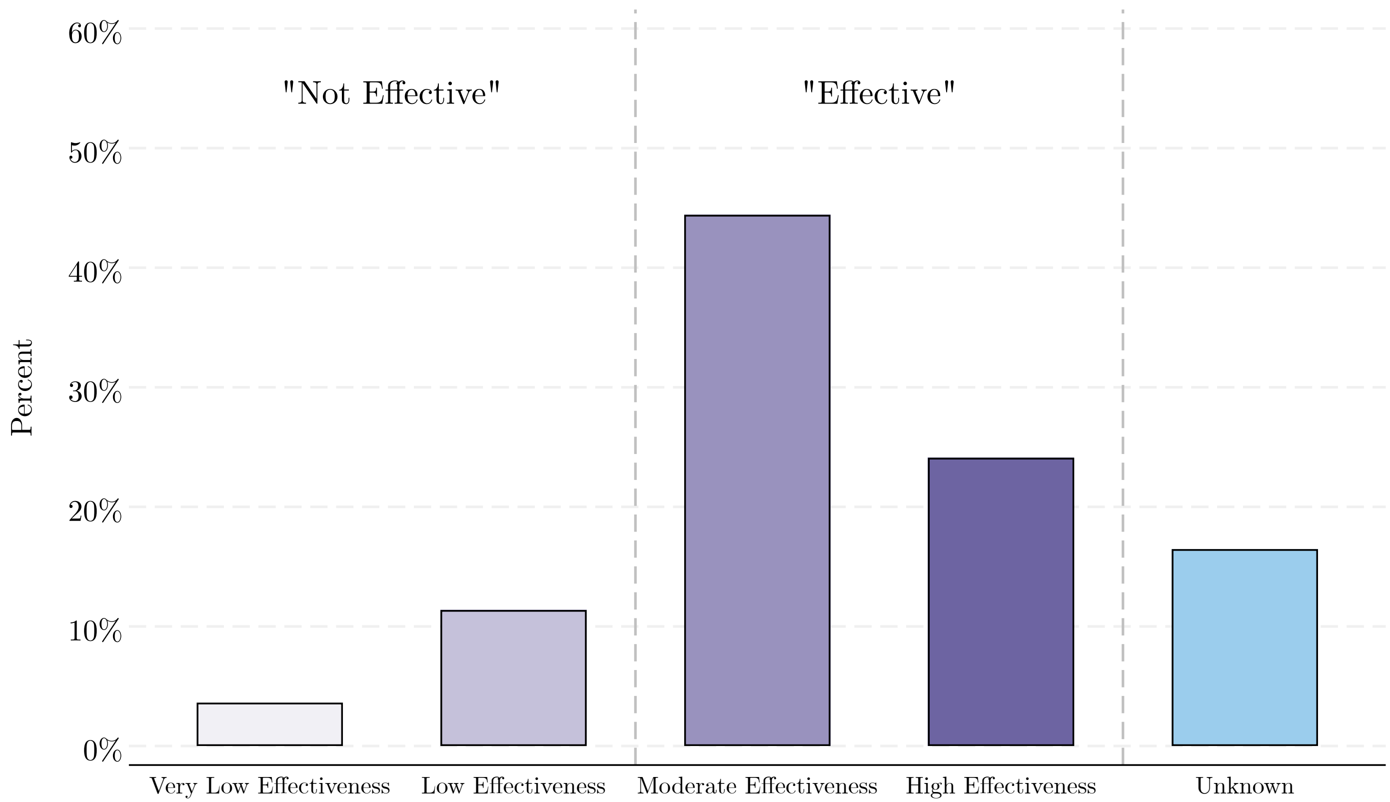



*Figure A.6: Distribution of Effectiveness of Vaccine*

Note: The figure presents the distribution of respondents' perceived vaccine effectiveness across the full set of five categories and illustrates how these were collapsed into two groups for the main analysis.

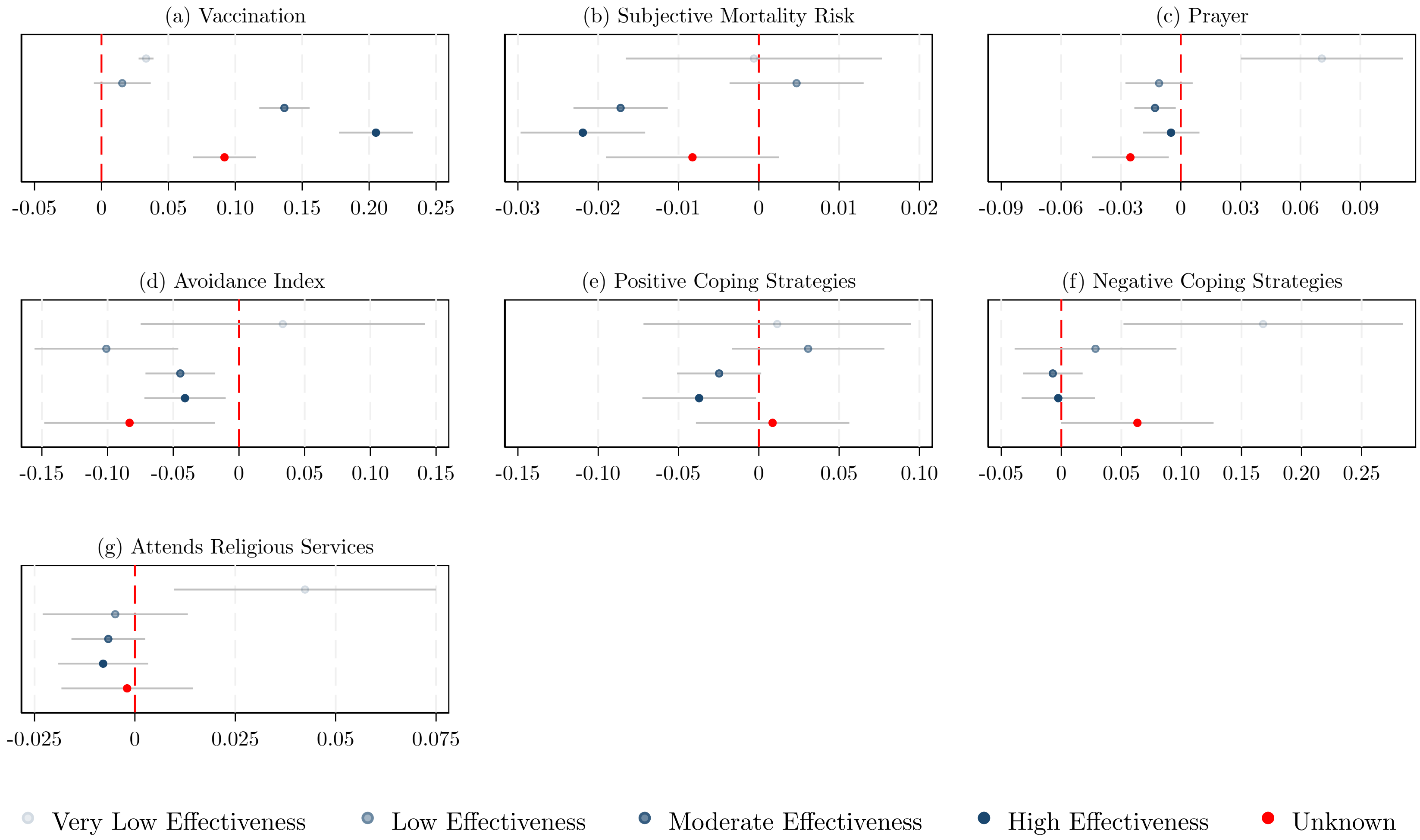



*Figure A.7: Effects of Vaccine Eligibility on Outcomes by Full Categories of Effectiveness of Vaccine*

Note: The figure shows the estimates for the main outcomes across the five categories of perceived vaccine effectiveness.

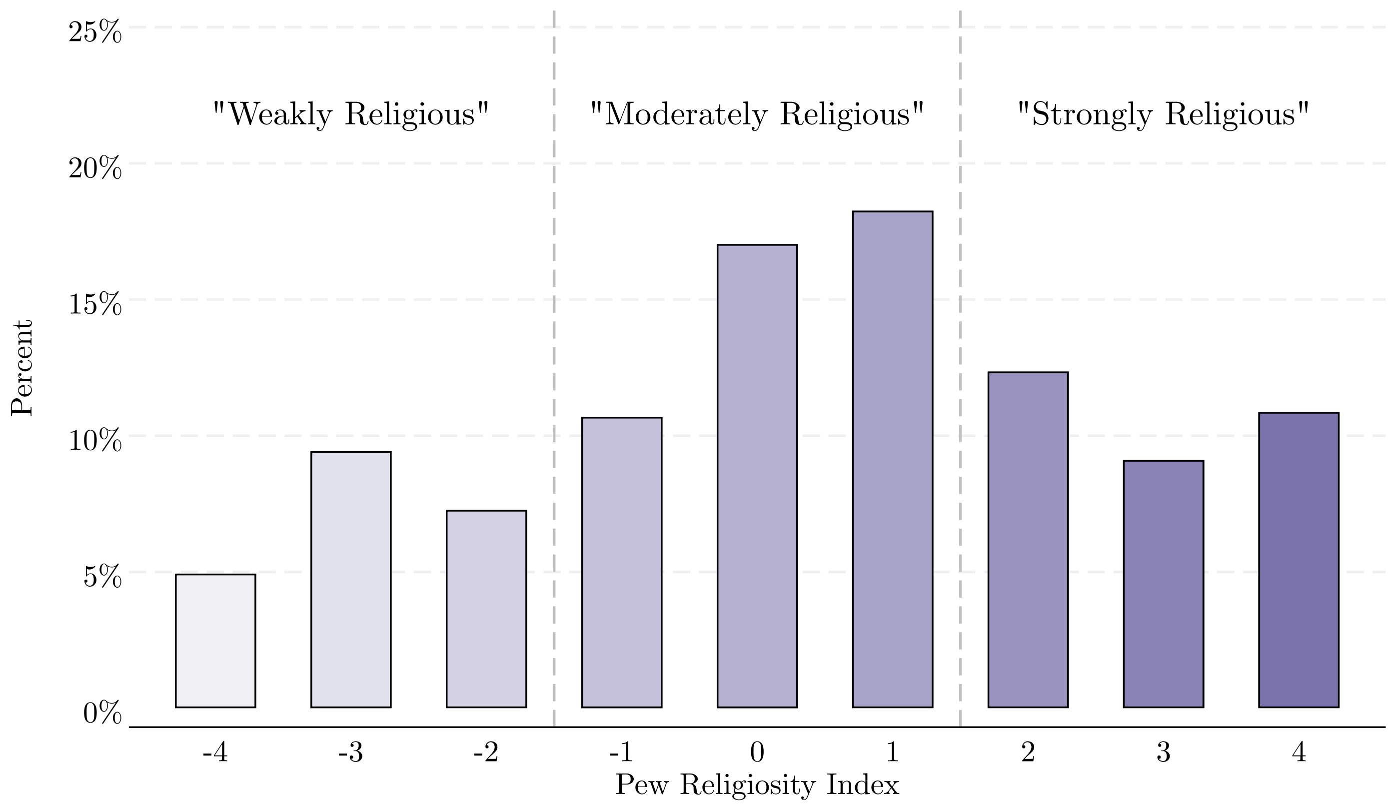



*Figure A.8: Distribution of Religiosity*

Note: The figure presents the distribution of respondents' religiosity across the full set of nine categories and illustrates how these were collapsed into three groups for the main analysis.

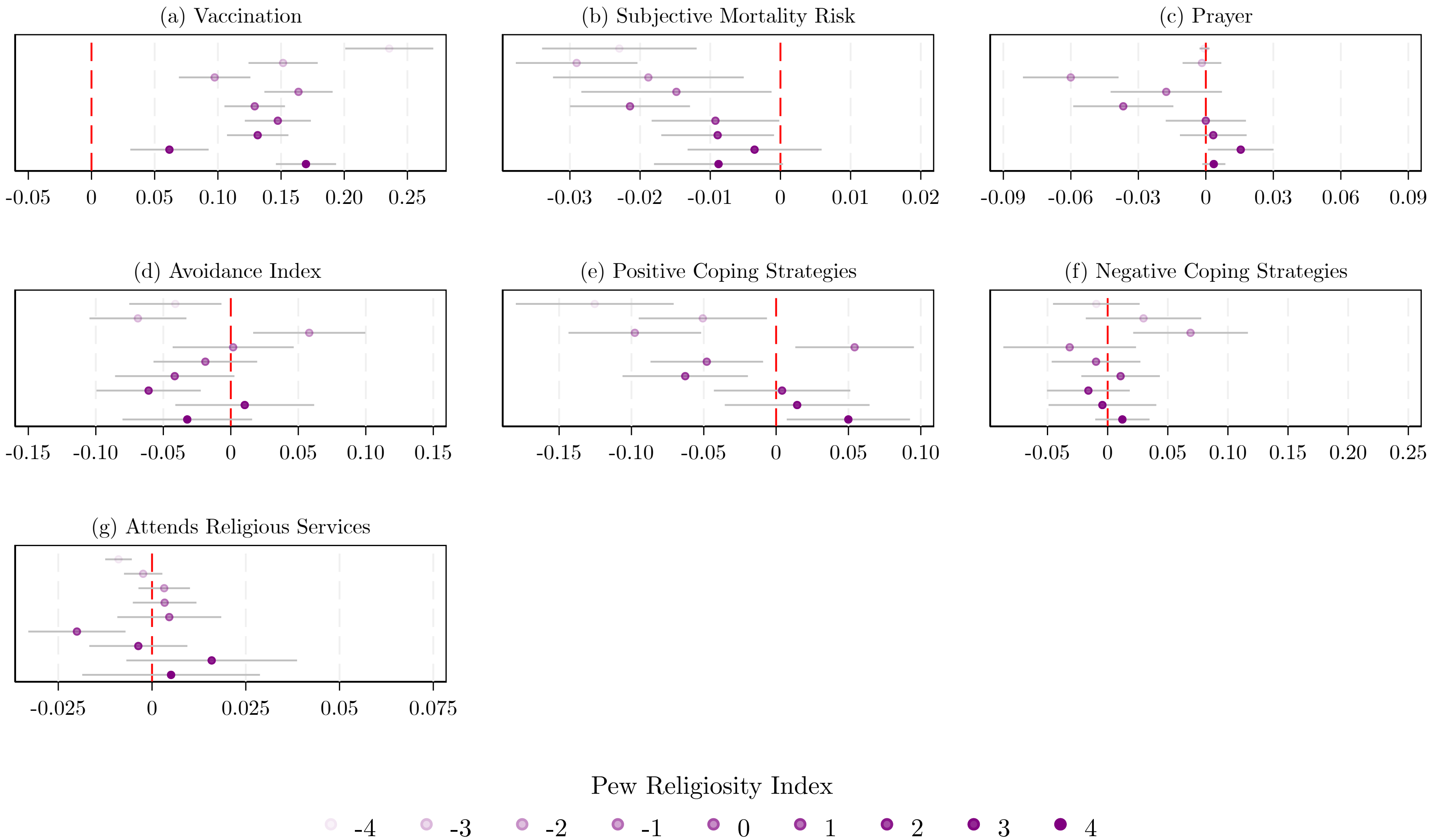



*Figure A.9: Effects of Vaccine Eligibility on Outcomes by Full Categories of Religiosity*

Note: The figure shows the estimates for the main outcomes across the nine categories of religiosity.

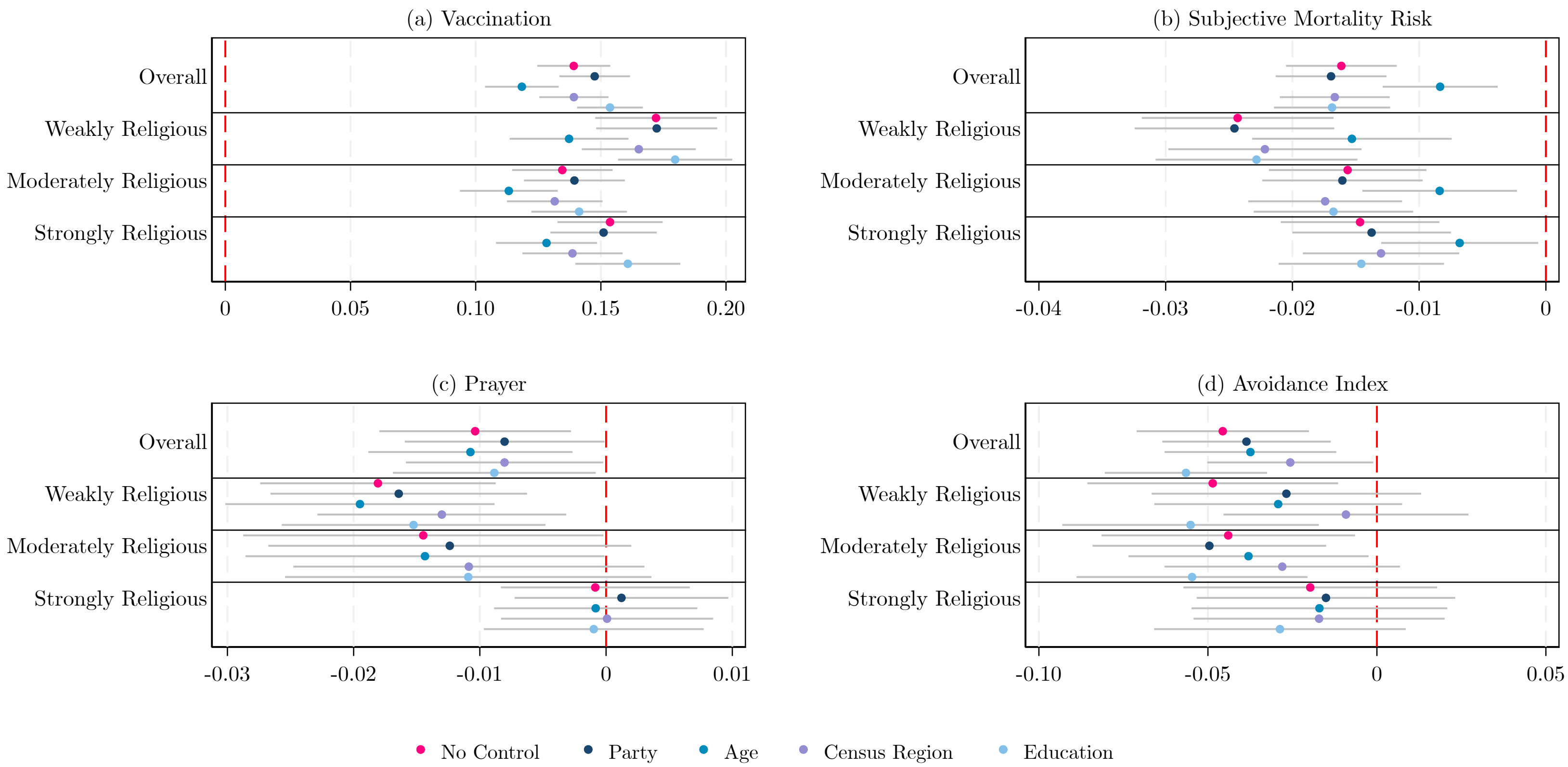



*Figure A.10: Point Estimates with Different Controls by Religiosity*

Note: The figure presents point estimates for key outcome variables by religiosity. Within each outcome-religiosity combination, it includes coefficients from five regressions: one with no controls and four with an interaction between the time indicator and one of the following variables: political party, age, census region, or education. In each graph, the grid line indicating a coefficient of zero is marked with a red dashed line. Error bars represent 95 percent confidence intervals based on individually clustered standard errors.

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