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Public health spending, primary care, and perceived risk promoted vaccination against H1N1

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ABSTRACT

The purpose of this study is to examine factors affecting the intent to vaccinate during the 2009 H1N1 pandemic and to leverage the results to inform public health policy decisions aimed at increasing vaccine uptake during the COVID-19 pandemic. Using the National 2009 H1N1 Flu Survey data and state-level administrative data, we employ logistic regression and mediation models to estimate the association between vaccine uptake and state level public health spending, political ideology, and H1N1 case and death rates as well as a set of individual and household characteristics. We find that higher public health spending can significantly increase the intent to vaccinate, mainly through raising concerns about the pandemic and promoting vaccine relevant doctor patient interactions. We conclude that physicians, especially primary care physicians, should play more important roles in the ongoing vaccination efforts against the COVID-19 virus.

1. Introduction

As of writing this paper, there have been approximately 44.2 million cases and 711 thousand deaths in the United States due to COVID-19 [1]. Characteristics of the virus, such as airborne transmission, has made its spread vicious and rapid [2]. After one year of the pandemic, 187.2 million Americans have been fully vaccinated, but there are serious concerns about vaccine hesitancy, defined by the World Health Organization [WHO] as a “delay in acceptance or refusal of vaccination despite availability of vaccination services” [1,3]. The Biden administration has listed addressing vaccine uptake as a major goal in its COVID-19 response plan and is increasing public health spending to support public education campaigns regarding the vaccine [4]. For these policies to be effective, it is imperative to target public health spending on the most important factors influencing vaccine uptake. For example, there are already calls for increased involvement of primary care physicians in the ongoing vaccination process in order to overcome vaccine hesitancy [5].

Although COVID-19 is unprecedented in recent history and poses unique challenges to vaccination, valuable lessons from past pandemics, most notably H1N1, can help understand factors contributing to public acceptance of the vaccines and inform approaches to promoting vaccination against the COVID-19 virus. The 2009 H1N1 pandemic, also known as the swine flu, has some similarity to the COVID-19 pandemic in terms of global spread and the presence of vaccine-based countermeasures. There were around 60.8 million cases of the H1N1 virus in the United States in 2009, and while the mortality rate was not as severe as that of COVID-19, H1N1 elicited dramatic nation-wide public health responses and involvement by high-levels of the federal government [6]. The H1N1 pandemic response also faced the problem of vaccine hesitancy [7]. At the beginning of the pandemic, approximately half of the public indicated they would receive the vaccine, but a year later, only 24% of adults had received the vaccine – a percentage that is even lower than the uptake rate of the seasonal influenza vaccine [7]. Political affiliation also played an important role in vaccine hesitancy during both pandemics. In the H1N1 pandemic, Democrats had higher intent to vaccinate than Republicans, a phenomenon that has also been observed during the COVID-19 pandemic [8].
There is a sizable literature examining the potential factors that could have affected vaccine uptake during the H1N1 pandemic [7,9–11], including pregnancy, socio-demographic characteristics such as race and gender, and level of trust towards the vaccine [10–12]. In this paper, we control for these individual characteristics and a rich set of others but focus on the role of state level public health spending, and highlight two main channels through which it affects vaccination, namely by increasing patient-doctor interaction and raising concerns about the pandemic. Compared with individual characteristics, public health spending and the two mediating factors have more direct implications for policy design.

2. Methods

Fig. 1 shows our conceptual framework. Our main variables of interest, Public Health Spending and the two mediators, are bordered by ovals. We control for other state level variables as they might influence both vaccine uptake and public health spending. For example, Obama Vote Share precedes public health spending and could therefore potentially affect both local public health spending and intent to vaccinate. Political affiliation has been shown to affect the amount of public health spending at a local level as in the case of the Prevention and Public Health Fund [the Fund]. Republicans were against authorizing the Fund while Democrats were supportive of it [13]. By including the variable Obama Vote Share in the regression, we control for the potential confounding effects it may have. Since we examine individuals’ intent to vaccinate, we also control for a rich set of individual characteristics. The control variables are bordered by parallelograms.

3. Data

The data used in this study was obtained from the publicly available National 2009 H1N1 Flu Survey [NHFS] conducted by the NORC at the University of Chicago on behalf of the CDC [14]. The survey was designed to examine the public’s attitudes towards the H1N1 vaccine during the 2009–10 flu season. Survey questions included the vaccination status of both adults and children, flu-related behaviors, opinions about the safety of the vaccine and its effectiveness, pre-existing conditions such as respiratory illness, and individual demographic characteristics. The survey sampled 56,656 adults and 14,288 children across all 50 states and the District of Columbia and was conducted from October 2009 through June 2010 through random telephone digit dialing. In this study, we only use the responses of adults, i.e., individuals aged 18 and above.

Sample weights are provided in the 2009 NHFS data file. Because the weights are determined by independent variables, non-weighted regressions are used throughout this study leading to consistent estimators with smaller standard errors [15]. The summary statistics using the weighted data are similar in magnitude to the non-weighted summary statistics.

State level per capita public health spending data is obtained from the State Health Access Data Assistance Center [SHADAC] [16]. Each state’s H1N1 case and death rates are calculated using population data from the 2010 U.S. census and the number of H1N1 cases and deaths in 2009 from each state’s public health department. Data on state level voting results during the 2008 presidential election is obtained from the Federal Election Commission [17]. We use the percentage of votes for Obama to represent the degree to which a state is blue.

4. Main regression model

The main regression specification is a logit model:

\[ y' = \beta_0 + \beta_1 X + u \]

where \( y' \) is the latent variable representing the intent to receive the H1N1 vaccine. There is no intent to receive the vaccine, or \( y = 0 \), if \( y' \leq 0 \), and an intent to receive the vaccine, or \( y = 1 \), if \( y' > 0 \). In the NHFS data, respondents were asked about their H1N1 vaccination history, as well as their intent to receive the vaccine, for which the responses included definite intent, probable intent, improbable intent, and definite no intent. Intent to Vaccinate equals 1 if the response was definite or probable intent or if the respondent has already received the vaccine and equals 0 otherwise.
The explanatory variables X are chosen based on the previous literature and our focus on public health spending. The first set of explanatory variables is about individual characteristics. Doctor’s Recommendation indicates whether or not an individual has received a recommendation for the H1N1 vaccine. It equals 1 if a recommendation was received and 0 if no recommendation was received. Concern About H1N1 measures an individual’s level of concern about the H1N1 pandemic, drawn from answers to the following interview question, “How concerned are you about the H1N1 flu.” It takes values of 1 to 4 for answers of “not at all concerned,” “not very concerned,” “somewhat concerned,” and “very concerned.” Similarly, Knowledge About the Virus measures one’s subjective knowledge about the H1N1 flu based on answers to the question, “How much, if anything, do you know about the 2009 H1N1 flu.” It takes values of 1–3 for answers of “none”, “a little,” and “a lot.” Chronic Condition, a binary variable, measures whether an individual has a chronic medical condition including asthma or other lung condition, diabetes, a weakened immune system, or heart, kidney, liver, neurological or neuromuscular conditions. The previous literature has shown that these conditions influence the intent to receive the H1N1 vaccine [7,9–11]. Contact with Child is a binary variable measuring whether an individual has regular close contact with a child under six months old, and healthcare worker is a binary variable that equals 1 if a respondent is a health worker. Age measures an individual’s age and is coded as a dummy variable for five groups [18–34, 35–44, 45–54, 55–64, and 65 and older] where the first group [18–34] is the reference group. Finally, Level of Education is a binary variable that equals 1 if the respondent has received college education and 0 otherwise.

The second category of explanatory variables includes household characteristics. Specifically, Household Income is coded as dummy variables for seven income brackets [below $10,000, $10,001–$15,000, $15,001–$25,000, $25,001–$35,000, $35,001–$50,000, $50,001–$75,000, and $75,001–$100,000] where the lowest income bracket is used as a reference group.

The third category of explanatory variables includes state characteristics, including the amount of per capita public health spending in 2009 [Public Health Spending], the H1N1 death rate [H1N1 Death Rate], and a state’s political orientation [Obama Vote Share], which equals the percentage of votes Barack Obama received in the 2008 presidential election.

We assume that the error term u follows an extreme value distribution. The model presented in Table 2 accounts for clustering of the error terms at the state level to control for the two-level hierarchical structure. This allows for correlated residuals across individuals within the same state. During a robustness check, we compared estimation results from both clustered and unclustered models and found that all statistically significant findings were consistent with each other across both models.

Furthermore, we separately ran a two-level multilevel regression model with random intercept and found that the results were also similar to the main specification in Table 2.

We also conduct mediation analyses using a linear specification to explore the associations through which Public Health Spending can affect Intent to Vaccinate. Fig. 1 shows the associations of the two mediators Doctor’s Recommendation and Concern About H1N1. For each mediator, the analysis involves three sets of regressions; we first regress the intent on vaccinating on Public Health Spending and with and without the mediator Concern About H1N1 or Doctor’s Recommendation, and then regress the mediator on Public Health Spending. Associations of the two mediators exist when Public Health Spending is significant in influencing the mediator, and when the effect of Public Health Spending on the outcome Intent to Vaccinate decreases as the mediator is included in the main regression.

5. Results

Table 1 provides the summary statistics of the variables discussed above, Table 2 presents the estimation results of six model specifications for the logistic regression, and Table 3 presents the estimated relative risks of the logistic regression. The following discussion will be based on Tables 2 and 3.

The six models in Tables 2 and 3 share a common set of explanatory variables but differ in the inclusion of Obama Vote Share, Concern About H1N1, Doctor’s Recommendation, and H1N1 Death Rate. The estimated marginal effects of individual characteristics are similar across all six models, showing that the effects of these characteristics are robust to the model specifications. We will use Model VI, which considers the effect of all individual and state-level variables, as the main specification in discussing the marginal effects which are presented in Table 3. For other variables such as Public Health Spending, we will rely on cross-model comparisons of the estimation results to draw conclusions.

Because we are using cross-sectional data, the results of the regression and mediation should be interpreted as identifying associations rather than causal relationships between intent to vaccinate and the individual and state-level variables. Further, the estimated effects of the individual and state-level variables are on vaccine intent. Since not all individuals intent on receiving a vaccine follow through, these effects could differ from the effects on actual vaccine uptake [18].

To examine the differences between the effects, we ran another regression using a new, binary dependent variable, Already Vaccinated, where 1 represents individuals who have already received the vaccine and 0 represents all other individuals. We found that the relative risks of each variable on Public Health Spending across the two regressions are in the same direction with similar magnitudes and significance levels [Table 5].

Since the data were collected over a period of nine months, the intent to vaccinate might vary over time. However, as shown in Table 6, controlling the survey month does not affect the estimation results and is therefore not included in the main specification.

6. Effects of individual and household characteristics

Individuals with chronic medical conditions [Chronic Condition] or those regularly coming into close contact with children [Contact with Child] less than six months old are about 1.1 to 1.3 times more likely than others to be intent on vaccinating [RRR = 1.10, 95% Confidence Intervals [CI] [1.08, 1.12]; RRR = 1.27, [1.08, 1.14] respectively]. Similarly, an individual with a college degree is about 1.1 times more likely to be intent on vaccinating [RRR = 1.06, [1.03, 1.09]]. Healthcare workers are about 1.3 times [RRR = 1.27, [1.24, 1.30]] more likely than others to get vaccinated, and individuals who have received a physician recommendation for the H1N1 vaccine are about 1.9 times more likely to be intent on vaccinating [RRR = 1.85, [1.80, 1.90]], demonstrating the importance of exposure to medical experts in promoting vaccination.

Age is another important factor influencing the intent to vaccinate, and its effects are nonlinear. Evaluating the relative risks of different age intervals [35–44, 45–54, 55–64, 65 and up], we find that when an individual is between 35 and 54, they are less likely to be intent on vaccinating compared to individuals 18 to 34 [RRR for 35–44 = 0.94, [0.91, 0.97]; RRR for 45–54 = 0.93, [0.90, 0.96]]. As age increases above 55, individuals become more likely to be intent on vaccinating than individuals 18 to 34 [RRR > 1]. Household Income also has a significant and nonlinear effect on the vaccination intent. We find that relative to the lowest income bracket of less than $10,000, individuals with higher income are less likely to be intent on vaccinating [RRR < 1]. However, the relationship
between Intent to Vaccinate and Household Income is U-shaped and is monotonically increasing once income reaches the bracket $45,001–75,000, which also corresponds to the median income in the sample.

The relative risks of Concern About H1N1 and Knowledge About the Virus are both above 1 and significant at 1% level. A one-scale increase in Concern About H1N1 and Knowledge About the Virus are above 1 and significant at 1% level. Therefore, individuals living in blue states tend to have a greater intent to vaccinate than those in red states.

### 7. Effects of state-level characteristics

The state level H1N1 Death Rate has a positive and weakly significant effect on the intent to vaccinate, with the RRR being significant at 5% or 10% level in some specifications [III, VI]. Obama Vote Share has a positive and significant effect on the intent to vaccinate: individuals in states with votes for Obama 10 percentage points higher than others are 1.03 times [RRR = 1.03, [1.01, 1.05]] more likely to be intent on vaccinating. Therefore, individuals living in blue states tend to have a greater intent to vaccinate than those in red states.

### 8. Effects of public health spending

The impact of public health spending on vaccination depends to a large extent on whether a certain set of other control variables are included in the regression. In Model [I], the RRR of Public Health Spending is greater than 1 [RRR = 1.05, [1.01, 1.08]] and significant – a result that is consistent with the literature [10]. However, in Models [II] – [VI] where Obama Vote Share is included, the effect of Public Health Spending becomes much smaller and statistically insignificant. In contrast, the effect of Obama Vote Share is always significant. Although there is a positive correlation between Obama Vote Share and Public Health Spending, i.e., states leaning more towards democrat tend to spend more on public health, a variance inflation factor [VIF] analysis indicates that there is little to no multicollinearity in the model. Thus, when Obama Vote Share is not controlled for, the effects of Public Health Spending on vaccination are partly capturing the effects of Obama Vote Share and are over-estimated.

As control variables Concern About H1N1 and Doctor’s Recommendation are added to the model, i.e., going from Models [II] to [III] and [IV], the RRR of Public Health Spending decreases. When both Concern About H1N1 and Doctor’s Recommendation are included, the RRR of Public Health Spending decreases to nearly 1 [RRR = 1.07, [0.56, 2.05]]. Moreover, as shown in Table 4, when Concern About H1N1 and Doctor’s Recommendation are separately

### Table 1

| Variable                  | Description                                                                 | Obs  | Mean  | Std. Dev. | Min  | Max  |
|---------------------------|-----------------------------------------------------------------------------|------|-------|-----------|------|------|
| Intent to Vaccinate       | Intent to receive the vaccine (=1 if already received, definite intent, or probable intent, ≠0 if have not received, no intent, or improbable intent) | 31,576 | 0.44  | 0.49      | 0    | 1    |
| Income Range less than or equal to $10,000 | Income level up to 10 K (=1 if income not within this range), 8% of respondents in range | 31,576 | 0.082 | 0.27      | 0    | 1    |
| Income Range $10,001–15,000 | Income level between 10,001–15,000 (=1 if income not within this range), 5% of respondents in range | 31,576 | 0.051 | 0.22      | 0    | 1    |
| Income Range 15,001–25,000 | Income level between 15,001–25,000 (=1 if income not within this range), 11% of respondents in range | 31,576 | 0.11  | 0.31      | 0    | 1    |
| Income Range 25,001–35,000 | Income level between 25,001–35,000 (=1 if income not within this range), 11% of respondents in range | 31,576 | 0.097 | 0.30      | 0    | 1    |
| Income Range 35,001–50,000 | Income level between 35,001–50,000 (=1 if income not within this range), 11% of respondents in range | 31,576 | 0.15  | 0.36      | 0    | 1    |
| Income Range 45,001–75,000 | Income level between 50,001–75,000 (=1 if income not within this range), 11% of respondents in range | 31,576 | 0.18  | 0.38      | 0    | 1    |
| Income Range 75,001–100,000 | Income level between 75,001–100,000 (=1 if income not within this range), 11% of respondents in range | 31,576 | 0.33  | 0.47      | 0    | 1    |
| Concern about H1N1       | Concern regarding the H1N1 pandemic (=1 if no Concern, ≠2 if not very concerned, ≠3 if somewhat concerned, ≠4 if very concerned) | 31,576 | 2.66  | 0.88      | 1    | 4    |
| Doctor’s recommendation  | Recommendation by a doctor to receive the H1N1 vaccine (=1) or no recommendation for the H1N1 vaccine (≠0) | 31,576 | 0.23  | 0.42      | 0    | 4    |
| Knowledge about virus    | Knowledge regarding the H1N1 virus (=1 None, ≠2 a little, ≠3 a lot) | 31,576 | 2.31  | 0.61      | 1    | 3    |
| Ages 18–34               | Participants aged 18–34 (=1 if participants are within the age range, ≠0 if not), 19.54% of respondents | 31,576 | 0.20  | 0.40      | 0    | 1    |
| Ages 35–44               | Participants aged 35–44 (=1 if participants are within the age range, ≠0 if not), 14.60% of respondents | 31,576 | 0.15  | 0.35      | 0    | 1    |
| Ages 45–54               | Participants aged 45–54 (=1 if participants are within the age range, ≠0 if not), 19.58% of respondents | 31,576 | 0.20  | 0.40      | 0    | 1    |
| Ages 55–64               | Participants aged 55–64 (=1 if participants are within the age range, ≠0 if not), 20.68% of respondents | 31,576 | 0.21  | 0.41      | 0    | 1    |
| Ages 65*                 | Participants aged 65+ (=1 if participants are within the age range, ≠0 if not), 25.59% of respondents | 31,576 | 0.26  | 0.44      | 0    | 1    |
| Chronic Condition        | Presence of a chronic medical condition (i.e. lung condition, heart condition, kidney condition) = 0 if no presence, ≠1 if yes | 31,576 | 0.31  | 0.46      | 0    | 1    |
| Contact with child       | If an individual is in regular close contact with a child under 6 months old = 0 if no regular contact, ≠1 if yes | 31,576 | 0.07  | 0.26      | 0    | 1    |
| Healthcare Worker        | If an individual is a healthcare worker = 0 if not, ≠1 if yes | 31,576 | 0.11  | 0.32      | 0    | 1    |
| Level of Education       | Whether or not an individual has received a college education (=1 if yes, ≠0 if not) | 31,576 | 0.43  | 0.49      | 0    | 1    |
| Public health spending   | The public health spending rate in each state | 31,576 | 0.0406 | 0.031 | 0.004 | 0.17 |
| Obama vote share         | The percentage of votes for Barack Obama (multiplied by 10) | 31,576 | 5.2   | 1.1       | 3.3  | 9.2  |
| H1N1 death rate          | H1N1 deaths per capita in each state | 31,576 | 0.011 | 0.0061 | 0 | 0.029 |
regressed on Public Health Spending, the effect of spending is positive and significant, suggesting that public health expenditures might have contributed to increased intent to vaccinate through raising concerns about H1N1 and increasing vaccination relevant doctor patient interactions. A Sobel-Goodman test shows that 64% and almost 57% of the effects of Public Health Spending on the intent to vaccinate are mediated through Concern About H1N1 and Doctor’s Recommendation respectively. Because we are estimating association rather than causal effects, the mediation effect represents the associations of the mediators.

9. Discussions and conclusions

While this study examines factors that influence the intent to vaccinate during the H1N1 pandemic, the findings have important policy implications for promoting vaccination against the COVID-19 virus. Now, as back in 2009, there are uncertainties and doubts about the effectiveness and risks associated with the newly available vaccines. If the vaccination rate against COVID-19 is as low as that during the H1N1 pandemic, which was slightly over 40%, the US may not reach the threshold required for herd immunity [19]. With the Biden Administration committing significant public health spending towards the vaccination campaign in its COVID-19 response plan, it is imperative that the spending target the most effective measures [4].

Among the individual characteristics examined, our results demonstrate that concern about the H1N1 pandemic is more effective than knowledge about the virus at increasing the intent to vaccinate. The narratives surrounding COVID-19 indicate that there is indeed a lack of concern in certain demographics about the serious consequences of COVID-19, and risk perception studies reveal
there is a correlation between vaccine hesitancy and a belief that COVID-19 is less threatening [8]. Individuals who refuse the vaccine believe that the COVID-19 virus is harmless and as a result, there is no need for the vaccine [20]. There are also widespread reports in the news media about young people holding “COVID parties,” about hospitalized COVID patients who refuse to acknowledge its existence, and about people denying that they can contract COVID [21,22]. Partly propagated by political leaders [23], such lack of concern represents a major roadblock to vaccination against COVID-19.

When communicating with the public, public health officials should emphasize the seriousness of the pandemic by bringing attention to the death rate – shown in our results to have a significant effect on vaccine uptake – and the struggles and stories of patients who have contracted COVID-19. Associating names and faces with the pandemic rather than statistics can help people realize that the consequences of the pandemic are real and affecting the lives of everyday people [24]. News media can also aid in the effort to spread stories and raise concern about the pandemic by providing affected families and doctors with a platform to make their voices heard. Past public health communication campaigns, such as Tips from Former Smokers, can inform current communication methodology and spending allocation [25].

However, solely relying on communication by government agencies and news media is not enough. Although there were federal vaccine recommendations in place in 2009 for the seasonal H1N1 flu, only 36.2% and 29.5% of covered adults were aware of this recommendation [26]. Interactions with a healthcare provider through a recent appointment or through a direct recommendation significantly increased awareness [26]. In our study, we found that receiving a doctor’s vaccination recommendation significantly increased the intent to vaccinate against H1N1, suggesting that, in the case of COVID-19, receiving medical advice from trusted medical experts might significantly increase the probability of vaccination. There are widespread reports about distrust of the government, especially in minority communities that have been hardest hit during the pandemic [25]. Their distrusts often result in disregard towards public health advice and vaccine hesitancy. There are widespread reports about distrust of trusted medical experts might significantly increase the probability of vaccination. There are widespread reports about distrust of the government, especially in minority communities that have been hardest hit during the pandemic [25]. Their distrusts often result in disregard towards public health advice and vaccine hesitancy. There are widespread reports about distrust of trusted medical experts might significantly increase the probability of vaccination.
Table 4
Mediation Results of Concern about H1N1 and Doctor’s Recommendation for Vaccine on Intent to Vaccinate.

|                      | (1) Concern about H1N1 | (2) Concern about H1N1 | (3) Doctor’s Recommendation | (4) Doctor’s Recommendation |
|----------------------|------------------------|------------------------|----------------------------|-----------------------------|
| Public health spending | 0.64**                 | 0.59*                  | 0.38***                    | 0.26                        |
| Obama Vote Share     | (0.25)                 | (0.33)                 | (0.12)                     | (0.13)                      |
| Income Range $10,001–15,000 | –0.085***             | –0.085***              | 0.0058                     | 0.0057                      |
| Income Range 15,001–25,000 | –0.13***               | –0.13***               | 0.0070                     | 0.0071                      |
| Income Range 25,001–35,000 | –0.12***               | –0.12***               | –0.0060                    | –0.0062                     |
| Income Range 35,001–50,000 | –0.21***               | –0.22***               | –0.0035                    | –0.0035                     |
| Income Range 45,001–75,000 | –0.23                  | –0.23                  | 0.0070                     | 0.0067                      |
| Income Range 75,001–100,000 | –0.22***               | –0.23                  | 0.022***                   | 0.020**                     |
| Ages 35–44            | 0.23***                | 0.23***                | –0.0091                    | –0.0088                     |
| Ages 45–54            | 0.24***                | 0.26**                 | 0.0061                     | 0.0061                      |
| Ages 55–64            | 0.24***                | 0.24***                | –0.033**                   | –0.033**                    |
| Chronic Condition     | 0.17**                 | 0.17**                 | –0.016**                   | –0.016**                    |
| Contact with Child    | 0.15***                | 0.15***                | 0.10**                     | 0.10**                      |
| Healthcare worker     | 0.10**                 | 0.10**                 | 0.14**                     | 0.14**                      |
| College Degree        | –0.025*                | –0.026**               | 0.0087*                    | 0.0071                      |
| _cons                 | 2.54**                 | 2.52*                  | 0.14*                      | 0.11*                       |
| N                    | 42,971                 | 42,971                 | 39,873                     | 39,873                      |

Standard errors in parentheses.
*p < .10, ** p < .05, *** p < .01.

Table 5
Estimation Results of Individual- and State-level Factors on Dependent Variables Intent to Vaccinate and Already Vaccinated.

|                     | Coefficient Estimates | RRR | Coefficient Estimates | RRR |
|---------------------|-----------------------|-----|-----------------------|-----|
|                     | Intent to Vaccinate   | Already Vaccinated | Intent to Vaccinate   | Already Vaccinated |
| Public health spending | 0.29                 | 0.69 | 1.07                 | 1.36  |
| Concern about H1N1 | 0.80***               | 0.56*** | 1.47**               | 1.35**  |
| Doctor’s Rec for vaccine | 1.59**               | 2.10** | 1.85**               | 3.09**  |
| Obama Vote Share | 0.056**               | 0.041* | 1.03*                | 1.024  |
| H1N1 death rate   | 8.76**                | 12.64** | 32.24**              | 324.50** |
| Knowledge about Virus | 0.13***              | 0.28*** | 1.06**               | 1.16***  |
| Income Range $10,001–15,000 | –0.093                | –0.025 | 0.96*               | 0.97  |
| Income Range 15,001–25,000 | –0.16                 | –0.059 | 0.95*               | 0.98  |
| Income Range 25,001–35,000 | –0.28                | –0.11  | 0.89*               | 0.95  |
| Income Range 35,001–50,000 | –0.29                | –0.12  | 0.89*               | 0.94  |
| Income Range 45,001–75,000 | –0.27                 | –0.014 | 0.90*               | 0.99  |
| Income Range 75,001–100,000 | –0.17                | 0.099  | 0.94*               | 1.05  |
| Ages 35–44          | –0.13                 | –0.15  | 0.94*               | 0.92*  |

(continued on next page)
of the broader lack of integration between PCPs and the public health system [27,28]. While extensive research has shown the importance of and the need for better collaboration between the two in improving overall health of the population [27], our study demonstrates that public health spending can be the most effective when it helps increase vaccination relevant doctor patient interactions.

There are several limitations to this study. The response rate in the NHFS survey was low – only 34.7% of contacted landlines and 27.0% cell phones responded to the survey. Our results might be subject to selection bias; it is possible that vaccine uptake is different between non-respondents and respondents. A number of variables, such as knowledge of the H1N1 virus, are self-reported, and measurement errors might arise from over-confidence and from low health literacy. It is also possible that there are unobserved variables that influence the intent to vaccinate and are correlated with the observable variables in the model resulting in omitted-variable bias. Examples include public health messaging, social capital, and political will. States with high public health spending and more concern about H1N1 might also have more social capital, so that the estimated coefficients could be biased.

**Declaration of Competing Interest**

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

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