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Michael Ruan
University of Pennsylvania

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Factors Affecting Vaccination Demand in the United States

Abstract

A multitude of healthcare economics research has been focused on determining the optimal vaccination rate in the United States; many of these studies propose taxes or subsidies as vehicles through which society can achieve the determined ideal uptake. However, there is no guarantee that price adjustments can necessarily change individuals' behavior. To reach a given target uptake, it is therefore necessary to understand what motivates their decision-making. This study applies the Berry, Levinsohn, and Pakes (1996) method to calculate price elasticity for vaccinations most commonly obtained by children to enter school and finds demand to be extremely price inelastic. Furthermore, regression analyses conducted in this study find that positive attitudes toward vaccination greatly improve the odds of vaccinating, and also discover strong correlation between certain demographic variables and attitudes towards immunizations.

Keywords

vaccination, demand, elasticity, demographics, attitudes

Disciplines

Business

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Factors Affecting Vaccination Demand in the United States

Michael Ruan

Wharton School, University of Pennsylvania

`mruan@wharton.upenn.edu`

Faculty Advisor:

Dr. Mike Abito, PhD

Assistant Professor of Business Economics and Public Policy

Wharton School, University of Pennsylvania

`abito@wharton.upenn.edu`

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1 INTRODUCTION

1.1 Background

Although not currently in a state of jeopardy, the unqualified success of vaccinations in preventing contagious disease epidemics within the United States is being jeopardized. Within the last fifteen years, a vocal minority has emerged to question the efficacy and safety of vaccinations, creating perceptions that vaccinations could pose greater risks to health relative to the benefits they provide.

This resistance to vaccinations is not unprecedented. The first anti-vaccination movement began in the 1700s, primarily founded on the theological belief that God deliberately sent illnesses to punish sin, a process that should not be interfered with. Throughout the following centuries, clinical studies of dubious scientific value have sporadically sparked the public's opposition to vaccinations as well.

In 1998, a study published by Andrew Wakefield and colleagues in *The Lancet* hypothesized that the measles, mumps, and rubella (MMR) vaccine caused autism, a neurodevelopmental disorder. The implications of Wakefield's study, later shown to be based on fabricated data and subsequently retracted by *The Lancet*, as well as a second study linking the measles virus to autism (Uhlmann et al., 2002) that could not be reproduced, are still apparent today. The U.S. experienced a record number of measles cases in 2014 (Centers for Disease Control and Prevention, 2015b), advocacy groups are persuading parents not to vaccinate their children, while vaccination proponents are litigating on the grounds that non-vaccination poses a public health hazard.

1.2 Research Problem

The scientific veracity of anti-vaccination claims is beyond the scope of this research. Rather, this study aims to inform policymakers so that they are enabled to respond to the status quo.

As further detailed in Section 2, much existing literature focuses on determining optimal vaccination uptake rates and offering recommendations for taxes or subsidies that will incentivize the public to achieve the given uptake rate. However, there is no necessary association between

prices and demand – that is, there is no guarantee that changing prices (via taxes and subsidies) can directly or effectively change demand. Such may be the case if price elasticity nears 0. It is necessary to empirically evaluate the strength with which prices can actually affect behavior; even though subsidies or bonuses may increase vaccination uptake, if demand for vaccinations is extremely inelastic, the amount necessary to generate significant change in uptake will be infeasible.

1.3 Research Question

What socioeconomic, demographic, and attitude factors affect demand for vaccination in the United States? What is the price elasticity of vaccinations?

1.4 Research Objectives

To study the extent to which factors such as demographics, socioeconomic status, and attitudes towards immunizations can affect an individual's decision to vaccinate.

1.5 Hypotheses

It is hypothesized that individuals with minority status, lower income, younger age, and less education are less likely to be vaccinated than those who are white, of higher income, older, and more educated. Non-significant factors are predicted to be gender and religion.

Demand is anticipated to be significantly price inelastic.

2 LITERATURE REVIEW

2.1 Role of Immunizations

The effect of vaccinations on public health is unequivocally clear – vaccines improve public health by reducing the incidence of disease. van Panhuis et al. (2013) use simulated models to estimate that 103 million cases of childhood diseases have been prevented since 1924. This figure represents

approximately 95% of cases that would have otherwise occurred. Within the last decade, 26 million cases, or 99% of cases that would have otherwise occurred, were prevented.

Such progress made would not be possible without the concerted effort of vaccination programs to mandate immunizations, provide access and funding, among other contributions. The study of a few highly prevalent diseases highlights the significance of vaccination programs. Following the introduction of the diphtheria vaccination program in 1924, 40 million cases of diphtheria have been prevented. With regards to measles, the disease with the highest prevalence rate when its vaccine and corresponding program were introduced (318 cases per 100,000 population per year), 35 million cases have been prevented. During the first 5 years of vaccine licensure, 22.2% more cases were being prevented each year, with a total of 95% case reduction by Year 5.

Throughout the last decade, the vaccination rates in the United States for MMR, pertussis, varicella, Hepatitis-b, and polio have consistently remained at or above 90%, the public health target. It is also surprising to many that the percentage of children receiving no vaccinations falls below 1%, despite the seeming popularity and availability of nonmedical exemptions from vaccination mandates. When outbreaks do occur, the Centers for Disease Control and Prevention (CDC) reports that the epidemics are often the consequence of ineffective vaccinations, not non-vaccination. This distinction is important because the perception disseminated by the media that low vaccination rates and anti-vaccination attitudes are common creates anxiety that reduces “reciprocal motivations to contribute to the collective good of herd immunity”; that is, fewer people in turn feel responsible for vaccinating.

2.2 Demographic Variables and Attitudes

Extensive research has been conducted to analyze the demographic variables correlated to vaccination behavior. However, reaching consensus has been difficult because different studies focus on different variables, largely because researchers draw conclusions from datasets that hold distinct demographic data.

For example, Abrevaya and Mulligan (2011) study American families and find that vaccination rates are higher for Hispanic children, older mothers, more educated mothers, and

families with higher incomes. Qiu-Schultz (2013) concludes that amongst mothers in Nevada, statistically significant factors in the parents' decision to vaccinate include not only typical demographic variables such as income, race, and education, but also insurance status, number of parents, number of children, among others.

Two issues arise: first, the statistical significance of factors found by Qiu-Schultz suggests that they actually affect the parents' decision to vaccinate their children – thus, Abrevaya's regression analysis may be incomplete or oversimplified by not including those variables (and vice versa with factors that Qiu-Schultz did not consider). Second, these researchers reach seemingly contradictory conclusions; for instance, Qiu-Schultz's logit regression concludes that lower income improves the odds of vaccinating, while Abrevaya's data shows that subjects in the highest income bracket had the highest vaccination rates.

Prislin et al. (1998) interpose an entirely new dimension, "beliefs," into the study of factors that affect vaccination uptake. In studying how demographics are correlated with 19 vaccination-related attitudes and, in turn, how these attitudes impact immunization rates, the authors find that: "all [ethnicity] groups believed in the protective value of vaccination"; those with more education trust more in the safety of vaccines; "the more positive the attitudes and the stronger the sense of personal control, the better the immunization status," meaning that attitudes significantly affect parents' decision-making. One important caveat is that attitudes tend to change with time – it may no longer be true, for example, that the wealthy trust vaccines most.

2.3 Elasticity, Subsidies and Taxes

Elasticity is not frequently researched in the field of vaccinations. This study, however, finds it imperative to investigate the demand elasticity of vaccinations to determine whether subsidies and taxes will be able to impact individuals' decisions. Two studies have made considerable progress thus far.

Alfonso et al. (2015) find that "the income elasticities for health care expenditure and vaccine expenditure are 0.844 and 0.336, respectively." Since the vaccine elasticity is <1 , vaccines are income *inelastic*, meaning that demand changes less than proportionally to changes in income.

While it is expected that one would spend more on health care if his or her income increased per the wealth effect, it is difficult to assert that increased purchasing power through increased income (perhaps analogous to decreased price) can greatly increase vaccination spending.

Geoffard and Philipson (1997) create an epidemiological model that simulates how diseases spread and how people respond in terms of their immunization behavior. Their primary finding is that “as the disease disappears, so too does the demand for vaccines, subsequently allowing the disease to return.” The *prevalence elasticity*, the change in demand in response to the proportion of people who have a certain illness, is positively elastic, ranging from 1.56 to 1.89 (Philipson, 1996). To illustrate, if diseases are more common because few people are vaccinated, then people are more likely to want an immunization.

So how does the prevalence elasticity relate to the price elasticity? Geoffard and Philipson (1997) explain in their study that a prevalence elastic demand for vaccinations will limit price elasticity. If the government is able to stimulate vaccination demand by offering Pigouvian subsidies, the prevalence of diseases will decrease because more of the vaccinated population is immune to them. However, since prevalence elasticity is found to be positive, the result is that fewer people will recognize the need to be vaccinated. The subsequent decrease in demand can significantly counteract the increase in demand attained through price subsidies, thus rendering price interventions an ineffective means of reaching higher vaccination uptake rates.

3 RESEARCH METHODOLOGY

The research methodology will discuss three parts: obtaining data, first round regressions, and final round regressions.

3.1 Source of Data

Three datasets were obtained for this study:

1. Gallup News Service Poll: Childhood Vaccines (2015)

2. CDC National Immunization Survey – Children (19-35 months) (2015c)
3. CDC Pediatric/Vaccines for Children Program (VFC) Vaccine Price List (2015a)

3.1.1 Gallup Poll: Childhood Vaccines (2015)

This dataset, collected by the Gallup Organization, contains the data necessary to determine how attitudes affect an individual’s decision to vaccinate. Collected during the period of February 28-March 1, 2015, the survey has a sample size of 1,015 respondents in the United States randomly sampled via landline and cellular phones.

The Gallup survey is useful because it contains both the respondents’ views on vaccination importance, benefits, and safety, as well as comprehensive demographic profiles of the respondents. From this acquired information alone, it is possible to run preliminary regressions that provide insight regarding which demographic factors are correlated with certain attitudes towards vaccinations. In particular, two attitudes are analyzed: “importance,” or how important it is to vaccinate children (on a scale from 1-5, with 5 being “extremely important”); and “danger,” whether “vaccines are more dangerous than the diseases they are designed to prevent” or vice versa.

To simplify the preliminary analysis of demographics presented in section 4.1, some variables were simplified. Race was simplified to white, black, or neither. Binary variables were created for the following characteristics: whether the respondent was religious, Christian, Republican, and a college graduate. Doing so reduced the complications arising from a multitude of responses given by an insignificantly small proportion of respondents.

3.1.2 National Immunization Survey – Children (2013)

This dataset contained the statewide mean vaccination rates for seven immunizations. Specifications such as immunization type and number of doses of that immunization received were determined after thorough consideration of states’ vaccination requirements for children entering any public school. The immunizations, along with number of doses, are: Diphtheria, Tetanus, Pertussis (DTaP, 3+); Polio (3+); Measles, Mumps, Rubella (MMR, 1+); Haemophilus

Influenzae Type b (Hib, 3+); Hepatitis B (HepB, 3+); Varicella (1+); Pneumococcal Conjugate Vaccine (PCV, 3+).

The National Immunization Survey (NIS) is conducted annually by the National Immunization Program and the CDC’s National Center for Health Statistics. Administrators first surveyed randomly selected respondents with age-eligible children via telephone and subsequently surveyed the children’s vaccination providers by mail to validate immunization information.

3.1.3 Pediatric/Vaccines for Children Program (VFC) Vaccine Price List (2015)

The CDC Vaccine Price Lists provide vaccine “contract prices” paid by government-sponsored providers that offer immunizations through the Vaccines for Children Program (VFC), as well as the prices paid by private sector physicians. Contract prices are established by CDC vaccine contracts specifically “for the purchase of vaccines by immunization programs that receive CDC immunization grant funds (i.e., state health departments, certain large city immunization projects).” Private providers and private citizens cannot directly purchase vaccines through CDC contracts, but instead must purchase at prices set by vaccine manufacturers.

3.2 First Round Regressions

The objective of the first round regressions is to obtain a predicted attitude for each state. Given that only market level vaccination rates are available and not individual decisions to vaccinate, it is necessary to aggregate individual attitudes x_i at the market level so that they can be linked to market level mean vaccination rates.

If we index individuals (households) as i , markets (states) as j , and vaccines as k , we can express the indirect utility of individual i in market j from getting vaccination k as

$$u_{ijk} = \alpha p_{jk} + \beta x_i + \eta_{jk}$$

where p_{jk} is the price of vaccine k in market j , x_i is a vector of individual-level attitudes regarding vaccination, and η_{jk} is an unobserved market-vaccine characteristic. Assume the vector of

individual level attitudes can be decomposed into

$$x_i = \hat{x}_j + v_j + \varepsilon_{ijk}$$

where $\hat{x}_j + v_j$ is a market-level component of attitudes and ε_{ijk} is the corresponding individual-level component.

Here, v_j is correlated with the unobserved market-vaccine characteristic η_{jk} , but \hat{x}_j is assumed to be orthogonal (i.e. uncorrelated) to η_{jk} and ε_{ijk} . The assumption is valid as long as the effect of demographics on attitudes is uncorrelated with the unobservable characteristics η_{jk} and ε_{ijk} . The vector \hat{x}_j is the market-specific average computed by aggregating predicted values obtained from a regression of an individual's demographics on his or her attitudes; v_j is the corresponding aggregated residual.

In summary, each attitude score was regressed on the set of demographics for each market (i.e. state) since attitudes are likely affected by market-vaccine factors that are not observed. From this procedure, a predicted numerical attitude has been obtained for each state. The results of the first round regression on the attitude “importance” can be seen in Figure 1.

3.3 Final Round Regressions

This study utilized the BLP method, developed by Berry et al. (1995) to empirically estimate consumer demand “using only widely available product-level and aggregate consumer-level data” within the United States automobile industry.

The BLP method is suitable in this study for a multitude of reasons, as it:

1. Estimates individual demand using aggregate data

Due to the limited availability of data, only figures pertaining to statewide vaccination rates could be obtained. Individual vaccination decisions, which ideally would have been linked to individual attitudes, are not observable. In this scenario, the best alternative is to use market level vaccination rates, and tie them to market level attitudes, which were the predicted attitudes obtained from the first round regressions. Despite these restraints, it is still possible to study individual demand patterns with the use of the BLP method.

2. Accounts for unobserved factors and corrects bias due to endogenous variables

It is frequently observed that one's decision is often influenced by those made by those belonging to the same group (Manski, 1999). However, this phenomenon introduces endogeneity, as unobserved factors that influence the decision maker also tend to influence the others within the same peer group, thus creating correlation between the composite term and the error. As Walker et al. (2011) say in a study regarding transportation choices:

“The problem arises when an explanatory variable is correlated with the unobserved factors, and such a situation leads to biased and inconsistent parameter estimates. Endogeneity surfaces due to errors in variables, simultaneous determination, and omitted attributes, among other causes.”

In this study, endogeneity is moved from the non-linear choice model to the linear regression model via constants (i.e. predicted attitudes found in Part 1) in order to employ the BLP technique. The technique is applied as follows:

Define the market-vaccine level composite error $\xi_{jk} = \beta v_j + \eta_{jk}$. As in the literature, ε_{ijk} is assumed to be a Type I Extreme Value idiosyncratic choice shock, and the indirect utility from not being vaccinated is normalized as equal to just a choice shock ε_{ijk_0} . Let s_{jk} be the observed vaccination rate in market j and vaccine k . Thus,

$$s_{jk} = \Pr(\varepsilon_{ijk_0} - \varepsilon_{ijk} < \alpha p_{jk} + \beta \hat{x}_j + \xi_{jk}) = \frac{\exp(\alpha p_{jk} + \beta \hat{x}_j + \xi_{jk})}{1 + \exp(\alpha p_{jk} + \beta \hat{x}_j + \xi_{jk})}.$$

The link between the data and the choice model can be written as

$$\ln\left(\frac{s_{jk}}{1 - s_{jk}}\right) = \alpha p_{jk} + \beta \hat{x}_j + \xi_{jk}.$$

This gives an estimating equation assuming $E[p_{jk} | \xi_{jk}] = E[\hat{x}_j | \xi_{jk}] = 0$.

The second and final step of BLP obtains market parameters through a two-stage instrumental variables regression with the use of the statistical software Stata. For a discussion of how private prices are used as an instrument for public prices, please see Appendix A.

4 RESULTS

4.1 Results of Demographic Analysis

The first analysis conducted was a regression of attitudes on demographic variables. It is important to underscore the fact that correlation is not causation. Thus, the findings presented below are intended to facilitate one's understanding of the situation at hand ("Christians are more likely to be vaccinated") and are not prescriptive ("Thus, more people should be Christian").

Figure 2 shows the results of the regression of the attitude "important" on demographic variables. The statistically significant factors are gender, age, race, and religion. Males do not believe as strongly as females do that vaccinations are important. Results also suggest that the older the respondent is, the more important he or she will believe vaccinations are. Respondents that are white or black believed that vaccinations were less important than those who were neither. Lastly, those who were religious perceived vaccinations as less important; however, Protestant Christians (who are categorized as "religious") in particular viewed vaccinations with greater importance.

Regarding one's perception of "danger," the only statistically significant variables were race and income. Respondents who identified as black were more likely than those who identified as whites to believe that the risks of vaccinating outweighed the danger of the diseases they were designed to prevent. With regards to income, those who earned more were stronger believers that the benefits received from vaccinating outweighed the danger of the immunization itself. Results are shown in Figure 3.

4.2 Results of Elasticity Analysis

Figure 4 shows the key findings of the final round regressions. As expected, the more important one perceives vaccinations to be, the more likely he or she will actually obtain a vaccination. This is indicated by the positive mean coefficient of 0.7966. On the other hand, someone who believes that "vaccines are more dangerous than the diseases they are designed to prevent" is less likely to be vaccinated, indicated by the negative mean coefficient of -0.7682.

The unexpected result was the mean coefficient for price. The regression analysis showed a coefficient of -0.0009, a figure so nominal that it could essentially be regarded as 0. However, this nonlinear regression produces coefficients that are difficult to interpret, so it is useful to examine them as odds and elasticities, which are more intuitive to understand.

The mean price elasticity was calculated to be -0.0001 with a standard deviation of <0.0001. As the elasticity is <1, demand is extremely inelastic with regard to price. For every one percent increase in the price, demand falls by only 0.0001%.

Demand for vaccinations can also be understood through analysis of the odd ratios produced. Calculations show that:

- Improving the attitude “important” by one standard deviation would improve odds of being vaccinated from 10:1 to 16:1. This would bolster the mean vaccination rate amongst states from 90.9%, the current figure, to approximately 94.1%.
- Changing the attitude “dangerous” to “not dangerous” would improve odds of being vaccinated from 10:1 to 44:1. This would raise the state average vaccination rate from 90.9% to approximately 97.8%.
- Changing the attitude “dangerous” to “don’t know” would improve odds of being vaccinated from 10:1 to 21:1. This would raise the state average vaccination rate from 90.9% to approximately 95.5%.

4.3 Discussion

This study yielded results that conform to the observable reality of the United States. While its near-zero magnitude is unprecedented, the negative, low elasticity is understandable and consistent with the findings of previous research.

As previously mentioned, Alfonso et al. (2015) find that increased purchasing power creates nominal changes in vaccine expenditure. Kahan (2014) offers a simple, yet compelling reason for this phenomenon. In his empirical assessment of vaccine risk perceptions, Kahan uses the terms “general affective orientation” and “latent disposition” to describe people’s strong, unobserved,

and inherent inclinations towards a certain belief. Family tradition, for instance, may contribute to one's latent disposition towards not vaccinating, and unlike for goods such as new clothing, price has minimal effect on demand for vaccinations. Many of those studied in Kahan's research displayed the "affect heuristic," a human tendency (especially for non-experts) to involuntarily allow their emotions to influence their decisions, leading them to reach conclusions quickly. As a result, individuals may forgo opportunities to carefully weigh evidence and instead choose to accept or deny information based on their "cognitive disposition." That neither evidence nor prices can easily change individuals' behavior presents a challenge to achieving universal vaccination in this country.

The implementation of the Affordable Care Act in recent years has potential to increase vaccination rates throughout the United States, although challenges abound in the way of creating a significant impact. This is because the ACA focuses on reducing enrollees' cost-sharing burdens (the cost borne by patient) – however, as this study's findings would suggest, changing the price of vaccinations, even to the point of providing them for free, may not greatly influence vaccination behavior. Fortunately, the ACA does bring positive change to the immunization landscape. In addition to increased payments to Medicaid providers for primary care, which have been shown to improve appointment availability, the ACA established the Community Health Center Fund, which is providing \$11 billion over 5 years to operate, expand, and construct community health centers (CHC) in underserved areas. By 2019, CHC patients are predicted to double to 35 million. This progress entails improved access to immunizations for millions of underserved Americans who would otherwise not have been able to receive immunizations or stay up-to-date on their vaccination schedules due to difficult circumstances. Furthermore, as a greater number of non-VFC eligible children will be covered by insurance plans in the coming years, more funds from Section 317 of the Public Health Service Act will be freed up to provide immunization services to uninsured adults. It will be possible to specifically evaluate how effectively the ACA has induced change as more data is collected and made available.

4.4 Limitations

This study is limited primarily due to data-related constraints. First, it is important to note that one's attitudes are not perfect indicators of how he or she will actually behave. There may be a multitude of factors that prevent those who view vaccinations positively from actually obtaining them, such as limited access to health care providers. Likewise, a parent who is slightly mistrustful or skeptical of immunizations may still comply with school immunization mandates instead of completing the Personal Beliefs Exemption process to opt out, which requires doctor or nurse approval. Second, Gallup survey respondents were given the option to refuse a question. It is possible that participation bias exists if those who hold a certain belief are less likely to provide a response for a question. Lastly, this study examined only a few of the countless demographic and socioeconomic determinants that affect individuals' decisions to vaccinate. Significant variables may have been omitted, thus restricting the scope of this research.

5 SUMMARY AND RECOMMENDATIONS

5.1 Summary

This study utilizes the Berry, Levinsohn, and Pakes (1995) method to understand individual level behavior using market level data. The BLP method was used for two reasons. First, it helped address difficulties related to data limitations, as only statewide vaccination rates were available. Second, the method accounts for unobserved social influences and helps correct bias created by endogenous variables. Constants (i.e. predicted attitudes) were determined for each state to capture social influences and then moved into the final regression where they were easier to manipulate.

After running the instrumental variable two-stage least squares regression using private vaccine prices as an instrumental variable for public prices, it was determined that demand and extremely inelastic. Further analysis suggests that changing attitudes by emphasizing the benefits and safety of vaccinations may have a greater effect towards increasing vaccination rates than changing immunization prices through taxes or subsidies will.

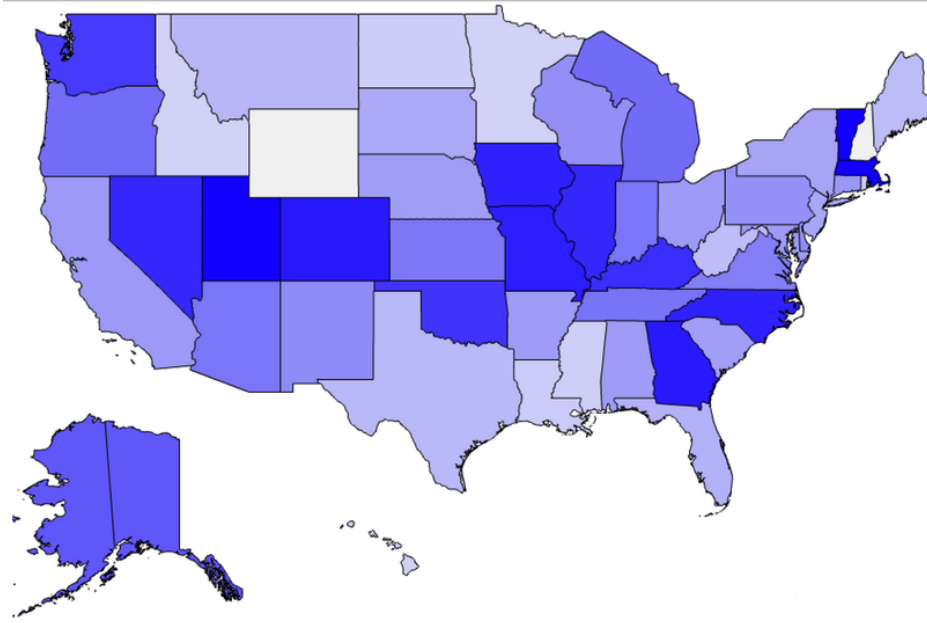
5.2 Recommendations for Further Study

Two recommendations can be implemented to improve the accuracy of this study.

First, it is recommended that a further study use actual immunization records, as it not only allows for the direct link between attitudes and behavior at the individual level, but also holds as the most accurate data available. As Kahan (2014) admonishes researchers, self-reported measures have been found to be highly inaccurate and unreliable for the purposes of drawing inferences. Researchers with appropriate resources should attempt to source individuals' vaccination history, although without identifying contact information to maintain confidentiality.

Second, subsequent research could improve this study by using vaccine price levels that differ by state. Currently, the CDC only provides nationwide vaccine prices for public programs such as VFC, in addition to nationwide prices that vaccine manufacturers charge to providers. Knowing what patients actually pay from state-to-state would help researchers more accurately understand how the prices determine demand in each state.

Figure 1: Heat map of predicted attitude “importance” by state



Shown are the results of the regression determining the unobserved predicted value of “importance.” Darker shades represent states with more favorable attitudes. No geographical pattern is evident.

Figure 2: Regression of “importance” on demographics

important	Coef.	Robust Std. Err.	t	P> t
male**	-0.1628	0.0695	-2.34	0.02
age***	0.0062	0.0020	3.13	0.002
race_white***	-0.5108	0.1873	-2.73	0.007
race_black**	-0.4925	0.2072	-2.38	0.018
totchild	-0.0066	0.0048	-1.39	0.166
income_monthly	0.0214	0.0153	1.4	0.162
religious**	-0.4091	0.1940	-2.11	0.035
religious_christian**	0.3933	0.1932	2.04	0.042
republican	-0.0878	0.0701	-1.25	0.211
college*	0.1328	0.0705	1.88	0.06

The statistically significant factors affecting the perceived importance of vaccinations are gender, age, race, and religion. *, **, *** signify corresponding p-values of <.10, <.05, <.01, respectively.

Figure 3: Regression of “danger” on demographics

danger	Coef.	Robust Std. Err.	t	P> t
male	0.0161	0.0468	0.34	0.732
age	-0.0004	0.0012	-0.38	0.706
race_white*	0.2172	0.1296	1.68	0.094
race_black**	0.4554	0.1650	2.76	0.006
totchild	-0.0001	0.0045	-0.02	0.987
income_monthly**	-0.0207	0.0097	-2.14	0.033
religious	0.2359	0.1496	1.58	0.115
religious_christian	-0.2145	0.1519	-1.41	0.158
republican	0.0020	0.0447	0.05	0.964
college	-0.0400	0.0414	-0.97	0.333

The statistically significant factors affecting the perceived “danger” of vaccinations are race and income. *, **, *** signify corresponding p-values of <.10, <.05, <.01, respectively.

Figure 4: Regression showing effects of attitudes and prices on likelihood of vaccinating

	Mean	SD	z-score
Coefficient–Importance***	0.7966	0.0900	8.85
Coefficient–Danger**	-0.7682	0.3522	-2.18
Coefficient–Price**	-0.0009	0.0004	-2.22

The positive coefficient of “importance” suggests that increased perceptions of importance raises vaccination rates; increased perception that vaccinations are more dangerous than the diseases they are designed to prevent induce the opposite. The near-zero price elasticity indicates that taxes and subsidies could be inadequate incentives for people to change their behavior.

Appendices

A PRIVATE PRICES AS INSTRUMENTAL VARIABLE FOR PUBLIC PRICES

While data for public and private vaccine prices are obtainable, it is not possible to observe the actual perceived price of the vaccine, which is the mismeasured variable. It is assumed that the private and public costs are different from, but still correlated with, the perceived price. This measurement issue is addressed by instrumenting public prices with private prices – only under the condition that the measurement errors for the two prices are not correlated.

Let p_{jk} be the actual perceived price of the vaccine and define p_{1jk} and p_{2jk} as the public and private prices. Assume classical measurement error, i.e.

$$p_{1jk} = p_{jk} + \tau_{1jk}$$

$$p_{2jk} = p_{jk} + \tau_{2jk}$$

where τ_{1jk} and τ_{2jk} are both independent of ξ_{jk} and of each other. Originally, p_{1jk} , the public prices, is used in the regression. The estimating equation is:

$$\begin{aligned} \ln\left(\frac{s_{jk}}{1-s_{jk}}\right) &= \alpha(p_{1jk} - \tau_{1jk}) + \beta\hat{x}_j + \xi_{jk} \\ &= \alpha p_{1jk} + \beta\hat{x}_j + (\xi_{jk} - \alpha\tau_{1jk}). \end{aligned}$$

Since p_{1jk} is correlated to τ_{1jk} by construction, the regressor p_{1jk} will be correlated with the composite error term $(\xi_{jk} - \alpha\tau_{1jk})$. Thus, the regression coefficient results will be biased and inaccurate. To resolve this error, p_{2jk} can be used as an instrument for p_{1jk} because $E[p_{2jk}|\xi_{jk} - \alpha\tau_{1jk}] = 0$, since it was assumed that p_{2jk} is independent of τ_{1jk} and ξ_{jk} . This strategy is implemented through the two-stage least squares method.

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