Immediate and informative feedback during a pandemic: Using stated preference analysis to predict vaccine uptake rates

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Abstract
In response to an emerging pandemic, there is urgent need for information regarding individual evaluation of risk and preferences toward mitigation strategies such as vaccinations. However, with social distancing policies and financial stress during an outbreak, traditional robust survey methodologies of face-to-face, probabilistic sampling, may not be feasible to deploy quickly, especially in developing countries. We recommend a protocol that calls for a sensitive survey design, acceptance of a web-based approach and adjustments for uncertainty of respondents, to deliver urgently needed information to policymakers as the public health crisis unfolds, rather than in its aftermath. This information is critical to tailor comprehensive vaccination campaigns that reach critical immunity thresholds. We apply our recommendations in a regional study of 16 Latin American countries in the month following index cases of COVID-19. We use a split-sample, contingent valuation approach to evaluate the effects of cost, duration of immunity and effectiveness of the vaccine. Our results show that cost and duration of immunity are significant factors in the decision to vaccinate, while the degree of effectiveness is insignificant, unless the vaccine is 100% effective. Income as well as perceived risk and severity of the virus are important determinants also.

Keywords
contingent behavior, Latin America, pandemic, vaccine uptake rate, willingness to pay

1 | INTRODUCTION

In the early stages of a pandemic, it is critical for policymakers to understand individuals’ risk perceptions and responses to public health crises to inform policy recommendations for both short and long-term public health campaigns. This is particularly relevant in developing countries where resource constraints are stretched thin and the risk of viral burden may be highest due to insufficient public health infrastructure. Moreover, government bargaining power to secure personal protective equipment supplies or vaccines in these countries lags behind nations directly investing in their development and production (Evenet et al., 2021). For instance, 2 months after some COVID-19 vaccines were approved for distribution, 75% of all COVID-19 vaccines had been administered in 10 countries that account for 60% of the global gross domestic product (Acharya et al., 2021). While current vaccine distribution may yield immunity toward COVID-19, the
threat of novel mutations and transmission will continue into the future. It is therefore important to identify a parsimoni-
ous, sensitive and cost-effective strategy to solicit individuals’ risk perceptions and interest in vaccination as a long-term
strategy to combat continued pandemic spread of viruses.

Collecting data to examine the household demand for a vaccine in the context of a pandemic is particularly chal-
lenging, and even more so in developing countries. For instance, in-person interviews, one of the most reliable methods
to collect data (Arrow et al., 1993), are simply infeasible as they put the health of respondents and interviewers at risk.
Alternative methods such as mail and phone surveys tend to have low response rates, take a protracted period of time
to administer, and are expensive to implement (Sinclair et al., 2012; Szolnoki & Hoffmann, 2013). Choosing an appro-
priate preference elicitation technique is also complicated. When applied to health issues, traditional methods (e.g.,
choice experiments) often impose cognitive and emotional burdens on respondents (Araña et al., 2008; de Bekker-Grob
et al., 2012), which may be exacerbated when facing significant health risks and/or economic effects.

In this study, we address several issues associated with conducting studies on future immunization programs in
developing countries during times of unprecedented pandemic. First, we propose a protocol sensitive to the emotional
and cognitive burden on respondents that closely represents actual immunization decisions to investigate household
preferences for immunization, without increasing anxiety during a pandemic. Specifically, we recommend a contingent
valuation (CV) survey with split-sample treatments to understand how individuals respond to different levels of vaccine
effectiveness, duration of immunity, and out-of-pocket costs. Second, we discuss the viability of different preference
elicitation methods and survey modes in the context of a pandemic and the trade-offs for projects with limited grant or
institutional support (Section 2). A third contribution of this paper is the application of our protocol to estimate future
costs of new vaccine uptake rates across several Latin American countries in a case study of COVID-19 (Sections 3 and 4).
Our choice of Latin America as study site allowed us to investigate intended immunization behavior at the beginning of a pandemic.
By discussing methodological issues related to eliciting immunization preferences in developing countries and applying
the proposed protocol in Latin America, we provide a roadmap for researchers intending to predict vaccine uptake rates
amid a pandemic. Our study also provides critical insight into current discussions on how to mitigate morbidity, mor-
tality and economic damages through vaccination strategies that address the characteristics prioritized by households.

2 | CHALLENGES TO ELICITING PREFERENCES FOR IMMUNIZATION AMID A PANDEMIC

Predicting vaccine uptake rates amid a pandemic requires a sensitive survey design and implementation. It requires
an elicitation approach that can provide enough information on vaccination preferences without adding to the anxiety
that respondents may be experiencing due to prevalent health risks and restrictive public health policies (e.g., business
closures and social distancing measures) that could additionally impact their financial status. Furthermore, that survey
mode must (1) reach a large number of respondents, oftentimes with limited funding, while abiding by social distancing
policies, and (2) take into account potential uncertainties at personal and societal levels that can evolve over the course
of a pandemic.

2.1 | Preference elicitation approach

Nonmarket valuation methods are suitable for analyzing individual preferences for goods and services that are yet to be
developed. Recent studies on immunization preferences, most of which have been conducted in developed countries,
have relied on discrete choice experiments (DCEs) (e.g., de Bekker-Grob et al., 2010, 2018; Determann et al., 2016; Eilers
et al., 2017; Liao et al., 2019; Marshall et al., 2016; Veldwijk et al., 2014). This nonmarket valuation method consists of
choice tasks where respondents compare two or more alternatives that vary in relation to vaccine attributes and payment
levels. By choosing among alternative specifications of a vaccine, respondents state their preferences for different vaccine
attributes such as effectiveness and duration of immunity, among others (see Michaels-Igbokwe et al., 2017, for a review
of choice experiments on immunization preferences).

While highly effective in eliciting preferences and understanding trade-offs between different attributes, DCEs may
impose a cognitive burden on respondents, depending on the number of alternatives, attributes, and choice sets (de
Bekker-Grob et al., 2012; Hensher, 2006; Hoyos, 2010). Choosing among different specifications of a vaccine may also
seem unrealistic given that it does not mimic the take-it-or-leave-it way in which vaccines are provided in developing
countries, especially in periods of emergency such as a pandemic. Moreover, it has been shown that choice behaviors elicited in DCEs are subject to the emotional state of respondents regarding the health issues under investigation (Araña et al., 2008). It is unquestionable that the state of emotions during a pandemic is unusual, with likely exacerbated fears and uncertainty that, along with the complexity and unrealism of comparing among vaccine specifications, can impair the respondents’ cognitive skills required in DCEs.

Alternatively, household preferences for vaccines in developing countries have been assessed using CV methods (see Kim et al., 2014), although to our knowledge only one other study was conducted in initial stages of a pandemic (Taiwan & Taipei, Liu et al., 2005), prior to the COVID-19 pandemic. In the context of immunization programs, the CV method consists of a single task choice of whether or not to receive a vaccine, once it becomes available to the public. This approach demands less cognitive skills from respondents, keeping the complexity and emotional disturbance of the contingent choice at a minimum (compared to DCEs), while also mimicking more closely the current forms of vaccine distribution, particularly in developing countries. Moreover, comparisons between those preference elicitation methods suggest that the CV method yields more conservative estimates than the DCE method when valuing health services (Danyliv et al., 2012; Ryan & Watson, 2009), which is desirable for evidence-based policy design.

A disadvantage of the CV method relative to DCEs is that it does not depict preferences for specific attributes of the vaccine if the same CV scenario is presented to all respondents. Since it remains policy relevant to learn how the vaccine uptake rates vary with specific vaccine attributes, an alternative approach to attribute-based DCEs is a single CV question with a split-sample design for vaccine attributes (Haab et al., 2020). In this approach, researchers can randomly vary the vaccine specification across respondents to evaluate the effect of attributes. The flexibility of the split-sample treatment approach to examine different vaccine attributes comes at the expense of requiring a larger sample, which can be costly depending on the survey mode. Therefore, the number of attributes that can be examined will depend on resources available for recruiting respondents.

Vaccine effectiveness and duration of immunity are two attributes consistently relevant in the related literature on vaccine uptake decisions (e.g., de Bekker-Grob et al., 2018; Liao et al., 2019; Verelst et al., 2019). Under normal circumstances, side effects also affect vaccination decisions (de Bekker-Grob et al., 2010; Sadique et al., 2013). However, amid a pandemic, including side effects as a potential vaccine characteristic could further exacerbate the anxiety of respondents especially among a population that generally feels that vaccines are safe. Studying acceptance of vaccines for a hypothetical pandemic, Determann et al. (2014) found that, while severe side effects may influence the uptake decision, other characteristics such as fear of the outbreak and perceived vulnerability to the disease are more important attributes in the vaccination decision. The pros and cons of this attribute should be weighed against the public perceptions of the risk of vaccines in the design stage.

In addition to concerns of the emotional burden on them, respondents may also be uncertain regarding their impending immunization behavior, which may be substantial during a pandemic. That uncertainty can introduce hypothetical bias into elicited preferences for a vaccine. Using a follow-up question, researchers can evaluate the certainty levels of respondents regarding their answer to CV questions using a qualitative or ordinal scale of certainty (e.g., Blumenschein et al., 2008; List & Gallet, 2001; Ready et al., 2010; van den Berg et al., 2017; Vásquez & Rezende, 2019; Vásquez et al., 2021). A number of studies that have evaluated the external validity of uncertainty-corrected willingness-to-pay estimates against real purchases of the good in question show that hypothetical bias can be mitigated by recoding favorable responses as opposing when certainty levels are relatively low (e.g., Blumenschein et al., 2008; Ryan et al., 2017). Moreover, Blumenschein et al. (2008), Champ et al. (2009), and Morrison and Brown (2009) found that the certainty question was more effective than other methods for mitigating hypothetical bias in willingness-to-pay values. This approach, therefore, produces more conservative estimates that may more accurately reflect immunization intentions after accounting for perceived risks and uncertainty during a pandemic.

2.2 Survey mode

In the middle of a pandemic, policy-oriented research has to be conducted at an unusual speed, even if preliminary results reflect a higher level of imprecision than what is usually tolerable in scholarly circles because policymakers have to make urgent decisions in a rapidly changing environment (Thornton, 2020). Initial studies, like this one, will need to collect as much information as possible, in a short period of time, oftentimes with limited resources. Against that backdrop of urgency, researchers may need to rely on survey modes and respondent recruiting procedures that do not necessarily yield a representative sample.
While in-person interviews may still be the most preferred method to gather reliable data, that method is too risky for respondents and interviewers amid a pandemic. It may be practically impossible to visit homes to collect information when social distancing policies are implemented to control the pandemic. Alternative methods such as mail and phone surveys solve the issue of physical distancing. However, those survey modes are expensive and time consuming (e.g., Olson et al., 2018), and tend to have low response rates in developing countries (Durand-Morat et al., 2016; Kahn et al., 2017). While the mail method may seem straightforward, one challenge within select developing countries is the lack of address nomenclatures for sampling. As a result, postal services may not be effective in reaching all sampled households, particularly in irregular slums and rural areas. Sampling issues can also be expected for phone surveys given that landline phone coverage is far from universal in those countries (Statista Research Department, 2018) and, although mobile phone coverage has increased in recent years, answering machines and caller ID have contributed to declines in response rates (Kempf & Remington, 2007).

This leaves web-based surveys as a cost-effective alternative to gather data on immunization preferences in a short amount of time and without interruption due to changing public health policies. Yet, this survey mode has its own challenges. While access to mobile phones and social media has rapidly increased in developing regions, low income and educational levels imply that a large share of the population does not utilize the Internet (Durand-Morat et al., 2016) and young, male, single-person households tend to be overrepresented in web surveys in developing countries (Tijdens & Steinmetz, 2016). Moreover, in some developing countries, low literacy skills may represent an obstacle given that web-based surveys are self-administered. Consequently, cost-effective web-based surveys with convenience sampling strategies (i.e., not probability-based) will not yield a representative sample. Nevertheless, there exist a number of weighting adjustment procedures suitable to reduce the coverage bias of web-based surveys (e.g., raking, propensity scores, and matching). Moreover, there is evidence that convenience samples may yield accurate estimates when resulting CV models are calibrated using population means (Harrison & Lesley, 1996), and that web-based surveys may yield more conservative value estimates than in-person surveys (Marta-Pedroso et al., 2007).

Another concern with web-based surveys could be the level of respondents’ attention to instructions and questions, particularly when surveys are completed using small mobile devices (e.g., tablets and smartphones). Skeie et al. (2019) reported higher willingness-to-pay estimates for smartphone respondents relative to those using desk or laptop computers. Yet, data collected through mobile devices and computers seem to be of the same quality (Liebe et al., 2015; Skeie et al., 2019). Due to those concerns with respondents’ attention in web-based surveys, it is best practice to include several data quality controls and remove indifferent or disingenuous respondents (Liu & Wronska, 2018; Maronick, 2009; Oppenheimer et al., 2009). For instance, “trap” questions in which respondents are asked to choose a given option to go to the next question (e.g., “Select response B”) may help identify respondents who are likely not paying enough attention. Additionally, surveyors may identify suspicious outliers in open-ended questions (e.g., respondent’s age >100) who could be providing misleading information on other questions as well. One final suggestion is to build in sequential, open-ended questions that require the respondent to offer logically consistent responses, for example, household size should be equal to the sum of age-based groups of household members. Unreliable responses should be excluded from the analysis.

In summary, based on the safety of respondents and interviewers, survey costs, and potential to reach a large number of respondents, web-surveys represent a cost-effective alternative to investigate preferences for immunization programs amid a pandemic.

3 APPLICATION TO LATIN AMERICAN COUNTRIES DURING INITIAL COVID-19 OUTBREAK

Originating in Wuhan, China in December 2019, the COVID-19 disease resulting from the SARS-CoV-2 virus rapidly swept across the globe with evidence of community spread in Italy, Iran, Spain and the United States by early March 2020. Latin America was one of the last regions in the world to see the virus emerge. The first confirmed case in a Latin American country was in Brazil on February 26, 2020. El Salvador and Nicaragua were two of the last countries to report index cases on March 18, 2020. We therefore chose the Latin American region as an opportune study site to capture household responses, including immunization preferences, at the beginning of a pandemic.
3.1 Survey design and implementation

Following best practices for designing CV surveys (Boyle, 2017; Johnston et al., 2017), we developed a questionnaire based on iterative consultation with scholars and healthcare professional in our institutions and Latin America. We also conducted an extensive review of scholarly articles and news from the region. The culmination of our research design was a 28 question, web-based CV survey that gathered information regarding households' experiences, preventive measures, risk perceptions, beliefs, knowledge, and preferences for immunization in the context of the COVID-19 pandemic. We followed a snowball sampling approach, with initial recruitment based on listservs and paid advertising on Facebook, to recruit respondents from 16 Latin American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, and Uruguay. Respondent participation was voluntary, as we did not offer any incentives or compensation for completing the survey. We administered the survey between March 19 and April 5, 2020, generating a total of 4935 completed surveys. Table S1 shows the share of our sample in each selected country.

We developed a single, dichotomous CV question based on a vaccine against COVID-19 being available to the public. We asked respondents to make only one choice, whether to vaccinate, and additionally we implemented a split-sample treatment approach to investigate preferences for vaccine effectiveness and duration of immunization. Table 1 shows our experimental design. We randomly varied three attributes across respondents: (1) duration of immunity, (2) vaccine effectiveness, and (3) the cost of the vaccine. The vaccine would protect a person for 1 year, 5 years, or 10 years, with an effectiveness of 70%, 80%, 90% or 100% in preventing infection. The out-of-pocket cost of the vaccine could vary from $25 to $200. Before responding whether they would get the vaccine or not, respondents were reminded of their budget constraint to imprint realism to their choice. The (translated) CV question presented in the survey read as follows:

For the following question, please assume that there already is a vaccine that will protect you against the Coronavirus (COVID-19) for [1 year, 5 years, 10 years]. It is expected that the vaccine will protect [70%, 80%, 90%, 100%] of the people who gets it. The cost of that vaccine would be [$25, $50, $100, $150, $200]. Keep in mind that the money you spend on the vaccine will not be available for other needs at your home (e.g. food, clothes). Would you get the vaccine?

Table 1: Split-sample experimental design, average proposed fee, percentage of respondents willing to pay for the vaccine, and number of responses

| Effectiveness | Immunization duration | 1 Year | 5 Years | 10 Years | Total |
|---------------|-----------------------|--------|---------|----------|-------|
| 70%           |                       | $103.93| $105.08 | $105.87  | $104.95|
|               | Yes = 61.9%           | Yes = 62.2% | Yes = 64.8% | Yes = 62.9% |
|               | n = 407               | n = 418   | n = 392  | n = 1217 |
| 80%           |                       | $105.42 | $99.20  | $105.71  | $103.52|
|               | Yes = 62.8%           | Yes = 64.4% | Yes = 62.8% | Yes = 63.3% |
|               | n = 420               | n = 407   | n = 438  | n = 1265 |
| 90%           |                       | $100.74 | $107.08 | $102.14  | $103.27|
|               | Yes = 59.6%           | Yes = 60.5% | Yes = 63.6% | Yes = 61.2% |
|               | n = 441               | n = 413   | n = 409  | n = 1263 |
| 100%          |                       | $103.48 | $104.06 | $109.08  | $105.71|
|               | Yes = 62.7%           | Yes = 61.3% | Yes = 66.2% | Yes = 63.5% |
|               | n = 373               | n = 382   | n = 435  | n = 1190 |
| **Total**     |                       | $103.35 | $103.87 | $105.75  | $104.34|
|               | Yes = 61.7%           | Yes = 62.1% | Yes = 64.3% | Yes = 62.7% |
|               | n = 1641              | n = 1620  | n = 1674 | n = 4935 |

Note: The average fee presented in the contingent scenario is in US dollars. Recall that the presented fees were $25, $50, $100, $150, and $200, reported in the local currency of the respondent. Yes represents the percentage of respondents in each sample group who would be willing to pay the presented fee, and n represents the number of responses received for each vaccine specification.
Given that the hypothetical nature of the CV question can lead to a bias in stated responses, we included a follow-up certainty question based on a four-point scale, varying from “very unsure” to “very sure,” to reduce hypothetical biases. Respondents’ uncertainty is incorporated by recoding positive responses to the CV question as negative ones if the respondent is “unsure” or “very unsure” regarding her response. By correcting for response uncertainty, we can provide more conservative and presumably accurate estimates of the vaccine uptake rate (Blumenschein et al., 2008; Ryan et al., 2017). Recent CV studies have utilized similar certainty scales to reduce hypothetical biases (e.g., van den Berg et al., 2017; Vásquez & Rezende, 2019).

Consistent with recommendations in Section 2.2, we included data quality controls, such as a “trap” question and numeric entry for questions on age and number of household respondents (total, over 60, and with elevated health risks). Finally, we removed those observations that appeared to be providing invalid responses based on inconsistent household composition statistics, and age-based outliers.

3.2 | Empirical modeling

We modeled individual $i$’s choice of taking the vaccine ($Y_i$) using a Probit specification as follows:

$$
Y_i = 1 \text{ if } Y_i^* = \alpha \text{LN} \text{FEE} + X \beta + Z \delta + e_i > 0
$$

$$
Y_i = 0 \text{ Otherwise}
$$

where LN FEE is the natural logarithm of the out-of-pocket cost for the vaccine proposed in the contingent scenario, $X$ represents the set of vaccine attributes varied in the contingent scenario, and $Z$ is the vector of covariates. $\alpha$, $\beta$, and $\delta$ represent the coefficients to be estimated. The idiosyncratic error term is represented by $e$.

Table 2 introduces the variables included in vector $X$. The first eight variables reported are derived from the experimental design. The variable LN FEE, for instance, represents the out-of-pocket cost of the vaccine asked of the respondent in our CV question. This variable is expected to have a negative effect on the likelihood of taking the vaccine as it reduces income available for other household needs. The contingent scenario also includes different levels of vaccine attributes (i.e., duration of immunity and vaccine effectiveness) that may influence immunization decisions as they are directly associated with the perceived probability of experiencing and the magnitude of disease-related losses. Given that the lowest attribute levels are used as the base for comparison (i.e., effectiveness of 70% and immunity of 1 year), the effects of indicators representing higher levels of effectiveness (EFFECTIVE80, EFFECTIVE90, and EFFECTIVE100) and duration of immunity (IMMUNITY5 and IMMUNITY10) on vaccine uptake are expected to be positive.

| Variables     | Definition                                                                 | Mean  | S.D.  |
|---------------|---------------------------------------------------------------------------|-------|-------|
| LN FEE        | Natural logarithm of the out-of-pocket cost of the vaccine presented in the contingent scenario | 4.417 | 0.740 |
| IMMUNITY5     | If the immunization duration is 5 years in the contingent scenario (1 = Yes; 0 = Otherwise) | 0.328 | 0.470 |
| IMMUNITY10    | If the immunization duration is 5 years in the contingent scenario (1 = Yes; 0 = Otherwise) | 0.334 | 0.472 |
| EFFECTIVE80   | If the vaccine effectiveness is 80% in the contingent scenario (1 = Yes; 0 = Otherwise) | 0.253 | 0.435 |
| EFFECTIVE90   | If the vaccine effectiveness is 90% in the contingent scenario (1 = Yes; 0 = Otherwise) | 0.257 | 0.437 |
| EFFECTIVE100  | If the vaccine effectiveness is 100% in the contingent scenario (1 = Yes; 0 = Otherwise) | 0.246 | 0.430 |
| RISKMAJOR     | Standardized index of perceived risk of getting seriously ill or die from COVID-19 | 0     | 1     |
| RISKINFECTED  | Standardized index of perceived risk of getting infected with COVID-19        | 0     | 1     |
| FEMALE        | Respondent’s sex (1 = female; 0 = male)                                     | 0.587 | 0.492 |
| AGE           | Respondent’s age (in years)                                                | 39.944| 11.414|
| EDUCATION     | Respondent’s education (in schooling years)                                | 16.450| 5.245 |
| HHSIZE        | Number of household members                                                 | 4.176 | 2.929 |
| INCOME        | Monthly household income (in 1000s US$)                                     | 1.087 | 1.151 |

Note: The total number of observations in the sample is $n = 4935$. 
We also included two indices that measure perceived risks of getting infected with COVID-19 (RISKINFECTED) and having major complications if infected (RISKMAJOR). A priori, we expect these indicators to be directly associated with the likelihood of immunization as they reveal the perceived risks and losses of not being immune from COVID-19. We also include individual and household characteristics to control for potential heterogeneity among respondents (FEMALE, AGE, EDUCATION, HHSIZE, and INCOME), as well as country fixed effects. Following Kolenikov (2014), we applied an iterative proportional fitting (raking) procedure to generate weights that estimate the total population by country of residence, sex, and age, as provided by the United Nations (2019). In total, we divided the population in the selected Latin American countries in 204 groups (16 countries × 2 sex groups × 6 age groups: 18–24, 25–34, 35–44, 45–54, 55–64, and 65+).

4 | ESTIMATION RESULTS

The descriptive statistics shown in Table 2 provide a profile of the average respondent, after applying sample weights. In our sample, almost 59% of respondents were female. The average respondent was approximately 40 years old, with 16 years of education. The household of the average respondent had about four members, and earned approximately US$ 1000 in a month. The relatively high levels of education and household income can be partially explained by the usage of professional listservs and academic contacts as part of our respondent recruitment strategies.

Figure 1 shows the results of five Likert-type questions used to elicit perceived exposure, concern, and the risks of getting infected, seriously ill, or dying, all associated to COVID-19. At the time of our survey, a majority of respondents believed that their exposure to COVID-19 was nonexistent or relatively low (about 64%). In contrast, the level of concern was relatively high among a majority of respondents (54.5%), and only about 17.5% reported a low level of concern. Similar to perceived exposure, a majority of respondents believed themselves to have a small chance of getting infected with COVID-19 (54.4%). However, the perceived risk of getting seriously ill and dying once infected with COVID-19 was relatively high among the majority of respondents (about 57% and 54%, respectively).

In our preliminary analyses, we estimated Probit models of vaccine uptake including responses to those Likert-type questions. With the exception of concern levels, all risk perception measures were statistically insignificant presumably because of strong correlations among them, as suggested by polychoric correlation estimates of 0.213–0.645 and variance inflation factors varying from 1.97 to 11.52. Therefore, we conducted a factor analysis of individual responses to those questions on perceived exposure, risks, and concern (see Table 3). According to estimated Eigen values, there are two latent factors underlying risk perceptions. Rotated factor loadings provide further information to identify those latent factors, namely perceived risk of getting infected with COVID-19 and perceived risk of major consequences in the case of getting sick. We estimated two standardized indices representing those risk perceptions, RISKMAJOR and RISKINFECTED, which we used for estimating Probit models of vaccine uptake.

Table 4 shows estimated coefficients and corresponding marginal effects from two Probit models of vaccine uptake. We used estimated coefficients to predict the uptake rate, and marginal effects to measure the impact of covariates on the probability of taking the vaccine. We estimated Model 1 using the actual responses to the CV question. Additionally, to estimate Model 2, we recoded positive answers as negative if the respondent was not sure about her choice in the

![Figure 1](https://health.economics/Wiley_3129)

**Figure 1** Perceived risks from COVID-19. (i) For S1 and S2: L1 = Not at all, L2 = A little, L3 = Moderately, and L4 = Very. (ii) For S3–S5: L1 = Unlikely, L2 = A little likely, L3 = Likely, and L4 = Very likely
**TABLE 3**  
Factor analysis of perceived risks from COVID-19

| Model 1: Raw data | Model 2: Uncertainty corrected |
|-------------------|-------------------------------|
| Perceived exposure | 0.671 | 0.064 | 0.914 | -2.565 | 1.061 |
| Concern | 0.709 | 0.379 | 0.359 | 0.621 | 0.923 | 0.105 |
| Likelihood of infection | 0.617 | 0.311 | 0.834 | 0.588 | 0.901 | 0.216 |
| Likelihood of seriously sick | 0.617 | 0.311 | 0.834 | 0.621 | 0.923 | 0.105 |
| Likelihood of death | 0.681 | 0.064 | 0.914 | 0.064 | 0.914 | 0.064 |

Note: Alpha coefficient for the five-item scale = 0.693.

**TABLE 4**  
Probit models of vaccine uptake

| Estimated coefficients | Marginal effects | Estimated coefficients | Marginal effects |
|------------------------|-----------------|------------------------|-----------------|
| **LNFEE** | −0.541 | (0.044)*** | −0.178 | (0.013)*** |
| **IMMUNITY5** | 0.166 | (0.076)*** | 0.055 | (0.025)*** |
| **IMMUNITY10** | 0.188 | (0.075)*** | 0.062 | (0.025)*** |
| **EFFECTIVE80** | 0.021 | (0.088)*** | 0.007 | (0.029)*** |
| **EFFECTIVE90** | −0.070 | (0.087)*** | −0.023 | (0.029)*** |
| **EFFECTIVE100** | 0.169 | (0.089)*** | 0.055 | (0.029)*** |
| **RISKMAJOR** | 0.119 | (0.032)*** | 0.039 | (0.010)*** |
| **RISKINFECTED** | 0.068 | (0.033)*** | 0.023 | (0.011)*** |
| **FEMALE** | −0.032 | (0.066)*** | −0.011 | (0.022)*** |
| **AGE** | −0.000 | (0.002)*** | −0.000 | (0.001)*** |
| **EDUCATION** | −0.008 | (0.007)*** | −0.002 | (0.002)*** |
| **HHSIZE** | −0.012 | (0.011)*** | −0.004 | (0.004)*** |
| **INCOME** | 0.318 | (0.048)*** | 0.104 | (0.015)*** |
| **Constant** | 2.750 | (0.272)*** | - | (0.257)*** |

Note: Observations = 4935. Standard errors are reported in parentheses. Probit models are weighted using an iterative proportional fitting method and include country-level fixed effects. Respondents' uncertainty is incorporated into Model 2 by recoding positive responses to the CV question (used in Model 1) as negative ones if the respondent is "unsure" or "very unsure" regarding her response.

Abbreviation: CV, contingent valuation.

*, **, and *** imply statistical significance at 10%, 5%, and 1% levels, respectively.
that researchers must address is identifying a sensitive protocol; one that does not impose cognitive and emotional burdens on respondents. Traditional approaches (e.g., DCEs) may be too complex and emotionally charged for respondents who are going through unprecedented health and economic crises, especially during the upsurge of a pandemic. That is why we recommend an alternative CV question with a split-sample design suitable to investigate individual preferences for three vaccine attributes: (1) vaccine effectiveness, (2) duration of immunity, and (3) out-of-pocket cost, to predict uptake rates, while accounting for respondent uncertainty during a pandemic. 

While simplistic when compared to other techniques, our preference elicitation approach still requires a large number of respondents, especially when the researcher is interested in analyzing preferences across several vaccine attributes. That is the second challenge we encountered in this study: how do you reach a sufficient number of respondents without putting anyone’s health at risk? With in-person interviews out of the question, we chose a web-based survey combined with a snowballing recruitment strategy based on emails, social media, and professional associations. Similar strategies were employed by García and Cerda (2020), Harapan et al. (2020), and Vo et al. (2021) in assessments of country-specific willingness to pay (WTP) for COVID-19 vaccines using CV methods. This approach, unsurprisingly, did not yield a representative sample of our targeted population. To control for this issue, we used an iterative proportional fitting procedure (raking) to estimate weights that would match population totals according to country, sex, and age groups. Using this approach, we found several respondent characteristics that are traditionally observed to be biased in this sampling strategy were statistically insignificant, which suggest that predicted vaccine uptake rates may be less susceptible to sampling biases in periods of widespread anxiety and high demand for effective mitigation strategies. While this methodology may fall short of the probability-based sampling strategies “gold-standard” (Yeager et al., 2011), it is a parsimonious and cost-effective alternative that offers immediate and informative feedback for policymakers during a pandemic.

Estimated models can be utilized to predict the vaccine uptake rate for different scenarios. For instance, Figure 2 shows how vaccine uptake rates predicted for the average respondent vary with out-of-pocket costs for six specifications based on Model 1: (a) 70% effectiveness and 1-year immunity, (b) 70% effectiveness and 5-year immunity, (c) 70% effectiveness and 10-year immunity, (d) 100% effectiveness and 1-year immunity, (e) 100% effectiveness and 5-year immunity, and (f) 100% effectiveness and 10-year immunity. As one might expect, responses suggest that nearly universal vaccination coverage would be achieved if the vaccine is provided at zero cost. However, if people have to pay for the vaccine, the uptake rate decreases at a decreasing rate. At a cost of $25, the vaccine uptake rate is predicted to be 81%–89%, depending on the vaccine effectiveness and duration of immunity. In consideration of the extremes, a majority of respondents would not be willing to take the vaccine (1) with an effectiveness of 70% and 1 year of immunity if its cost were greater than $125, and (2) for a 100% effective vaccine with an immunity period of 10 years if the cost is greater than $250. We also accounted for respondent uncertainty to reduce potential hypothetical bias in uptake rates. Figure 3 shows more conservative uptake rates.
rates for the same vaccine specifications when responses are corrected for respondents’ uncertainty (i.e., based on Model 2). Depending on vaccine attributes, the uptake rate will be between 70% and 76% when $25 is charged for the vaccine. The uptake rate for all vaccine specifications is below 50% for an out-of-pocket cost of $150 or higher.

Alternatively, we can interpret these results as the value of the vaccine to Latin American residents, measured by their willingness-to-pay. Table 5 reports the 95% confidence intervals for the WTP of residents across the 12 specifications discussed in Figures 2 and 3 (two levels of effectiveness × three lengths of immunity × two categories—raw vs. uncertainty adjusted). We observe a median WTP of $139.69 for a 70% effective vaccine with duration of immunity for 1 year; the estimate grows to $191.01 for a 100% effectiveness. Our results are consistent with country-specific studies, for example, in Ecuador, Sarasty et al. (2020) finds WTP of $147.61-$152.96 for vaccines lasting 1 year in duration with 70% and 98% effectiveness, respectively; and in Chile, Garcia and Cerda (2020) find a WTP of $169.92 for a vaccine of unspecified effectiveness and duration. Our more conservative estimates that account for respondent uncertainty show a similar pattern $93.49 to $117.85, up to a maximum of $146.93 for a 100% effective, 10-year vaccine. These estimates indicate that Latin Americans are concerned about the risks of the COVID-19 outbreak and would be willing to pay a substantial fee to be protected.

What is additionally remarkable, is when we compare the magnitude of these WTP estimates against Liu et al. (2005). Liu et al. (2005) finds WTP estimates for a SARS vaccine among Taiwan residents to be approximately 13.8% relative to the sample average income. In our closest specification (raw data, 1-year immunity), we observe respondents would be willing to pay between 12.9% and 17.6% of their monthly income for a vaccine with 70%–100% effectiveness, respectively. These results suggest that for severe respiratory pandemics, the concerns and uncertainty facing citizens are borne similarly across diverse populations. Overall, our results suggest that politicians must be prepared to incorporate cost-subsidies in immunization campaigns to encourage participation by citizens with low income and low perceived-risks.

In summary, our study provides a methodological approach and guidance to researchers on how to conduct CV studies aimed at predicting vaccine uptake rates at the beginning of a pandemic. Additionally, the vaccine uptake rates predicted in this study represent valuable insights for designing and implementing future immunization programs.

![Figure 2](image-url) Predicted vaccine uptake rate—Raw data (95% confidence intervals). (a) Effectiveness = 70% and immunity = 1 year; (b) effectiveness = 70% and immunity = 5 years; (c) effectiveness = 70% and immunity = 10 years; (d) effectiveness = 100% and immunity = 1 year; (e) effectiveness = 100% and immunity = 5 years; and (f) effectiveness = 100% and immunity = 10 years. Vaccine uptake rates are estimated for the average respondent by setting covariates to their mean values.
against COVID-19 in Latin America. Yet, as any other study, our analysis has some limitations. In retrospect, we could have investigated the role of other vaccine attributes in the decision to get vaccinated. Vaccination schedules now seem particularly relevant given the availability of single- and double-dose vaccines, discussion of booster shots, as well as side effects given that some prominent vaccines’ distributions were paused in several countries to evaluate the risk of severe side effects related to blood clotting (Mahase, 2021a, 2021b). Logical extensions to our analysis also include studies on the stability of immunization preferences over the evolution of a pandemic. Since we administered our survey, individuals may have adjusted their risk perceptions as they have dealt with the pandemic for some time, which may have affected their vaccination intentions, as our results show. By understanding how individual and societal preferences toward immunization evolve over the course of a pandemic, we may be better prepared to quell the next pandemic
faster. We hope that our study will motivate research projects on immunization preferences in response to the current and future pandemics.

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CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

ETHICS STATEMENT
This research was approved by Fairfield University’s Institutional Review Board under protocol no. 3752-2020 and Sacred Heart University’s Institutional Review Board under protocol no. 200316A.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ENDNOTES
1 Concurrent with our research, additional studies have recently been published on willingness to pay for a COVID-19 vaccine using the contingent valuation (CV) in developing countries: Chile (Cerda & García, 2021), Ecuador (Sarasty et al., 2020), South Vietnam (Vo et al., 2021), and Indonesia (Harapan et al., 2020).

2 Researchers have used other CV question formats to elicit individuals’ preferences such as open-ended questions and payment cards. Open-ended questions on the maximum willingness to pay for the good in question often generate data with low internal validity. Payment cards where respondents report their maximum willingness to pay by choosing among a list of willingness-to-pay amounts are subject to range bias (Haab et al., 2020). In contrast to the dichotomous CV question format, open-ended questions and payment cards are not incentive compatible, and they do not mimic the take-it-or-leave-it nature of vaccine distribution in developing countries. For those reasons, the dichotomous CV question is the most preferred question format among researchers. See Boyle (2017) for a thorough discussion of CV question formats.

3 Alternatively, researchers can collect more information from each respondent by asking her/him to respond multiple dichotomous CV questions, each of them with different vaccine specifications. While advantageous for its reduced number of respondents relative to the split-sample design, repeated CV questions can cause response fatigue and confusion (Haab et al., 2020), which could be exacerbated amid a pandemic, and are likely to produced biased estimates (e.g., anchoring bias) (Araña & León, 2007).

4 Vaccines on the market are vetted by national agencies in the country of development, meeting standards for effectiveness and safety as demonstrated over the course of several years of clinical trials (United States Food and Drug Administration, 2015), for example, the Food and Drug Administration oversees products developed in the United States and the Medicare and Healthcare Products Regulatory Agency oversees the United Kingdom.

5 Past research in developing countries has been reactive, observing vaccination preferences in the aftermath of an epidemic, or in recurring incidences (e.g., Ebola in Nigeria, Ughasoro et al., 2015; Zika virus in Indonesia, Harapan et al., 2019, Brazil, Muniz Júnior et al., 2019, and Guatemala, Olson et al., 2018), when experience has informed best practices to prevent transmission. The COVID-19 pandemic presents a unique challenge in the asymptomatic transmission of virus through infective respiratory droplets (World Health Organization, 2020), in contrast to vector-borne (Zika) or body-fluid transmission (Ebola) for which mitigating strategies can be utilized (e.g., sampling indoors or wearing preventative gear, or sampling in low risk communities, Ughasoro et al., 2015).

6 See Schonlau and Couper (2017) for a discussion of weighting methods applied to web-surveys, Kolenikov (2014) for a theoretical discussion and Stata application of the iterative proportional fitting (raking) technique, and Alemi et al. (2018), Huang and Elslad (2019), and Yu et al. (2019) for recent applications. Yeager et al. (2011) challenges the reliability of non-probability sampling even after accounting for weights; however, given the urgent need for information on perceived risks and preferences for vaccinations in these developing countries that have limited funds for assessment and mitigation of the burden of the pandemic, this is the most timely and wide-reaching option.

7 Table 1 reports the average cost, number of respondents and the percent of respondents replying yes to purchasing the vaccine in each duration of immunity/effectiveness bin. Overall, 62.7% of respondents were willing to purchase the vaccine presented.

8 In the context of Latin America, the Wellcome Global Monitor 2018 study (Wellcome, 2019) found that for 88% of respondents in Central America and Mexico and 81% in South America “Strongly Agree” or “Agree” with the statement “Vaccines are safe” (Wellcome Global Monitor 2018). These regions rank third and ninth highest safety assessment in the Global Monitor’s 18 region ranking; compared against
the highest, Southeast Asia at 95%, and the lowest, Eastern Europe at 50%. Therefore, we opted against including side-effects in our vaccine attributes to avoid inducing any additional anxiety among respondents.

9 Other CV studies have used factor analysis to construct indices on latent factors such as consumer satisfaction with water service (Vásquez, 2014) and motivations for donating to environmental protections, a public good (Nunes & Schokkaert, 2003).

10 Differences in our approaches include definitions of risk perceptions and attribute levels (length of immunity; attribute infection/mortality risk versus effectiveness). While this is by no means an apples-to-apples comparison, the consistent effects are noteworthy.

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