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The social value of a SARS-CoV-2 vaccine: Willingness to pay estimates from four western countries

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Abstract

SARS-CoV-2 vaccines give rise to positive externalities on population health, society and the economy in addition to protecting the health of vaccinated individuals. Hence, the social value of such a vaccine exceeds its market value. This paper estimates the willingness to pay (WTP) for a hypothetical SARS-CoV-2 vaccine (or shadow prices), in four countries, namely the United States (US), the United Kingdom, Spain and Italy during the first wave of the pandemic when COVID-19 vaccines were in development but not yet approved. WTP estimates are elicited using a payment card method to avoid "yea saying" biases, and we study the effect of protest responses, sample selection bias, as well as the influence of trust in government and risk exposure when estimating the WTP. Our estimates suggest evidence of an average value of a hypothetical vaccine of 100–200 US dollars once adjusted for purchasing power parity. Estimates are robust to a number of checks.

KEYWORDS

payment card, positive externalities, protest responses, sample selection, social value, vaccine attitudes, vaccine value, willingness to pay

JEL CLASSIFICATION

H23, H42, I18

1 | INTRODUCTION

Vaccine-preventable diseases are major causes of illness and death across the world, making vaccination critical to protect individuals' health. However, their social value exceeds the private value of these individual "protective effects". This is because vaccines exert large externalities on society, including the unvaccinated and other vulnerable individuals, as vaccine uptake increases the probability of reaching herd immunity (e.g., the point at which a sufficient proportion of the population is immune to a disease thus conveying "community" protection to susceptible individuals). This has direct impacts on others by reducing contagion, preventing morbidity and mortality, and diminishing the need for restrictions that hamper economic activity and social life. Vaccine availability does not, however, necessarily entail widespread vaccination demand as some share of the population might be unwilling to vaccinate. Hence, the population perceives a social value of vaccination, and this social value depends, in part, on individual-level preferences. Thus, social and individual estimates of the social value of a vaccine might not necessarily coincide.

The gravity of the deadly COVID-19 pandemic spurred rapid investment in vaccine development, with the first SARS-CoV-2 vaccine candidate entering clinical trials a mere 66 days after the virus was initially sequenced. Subsequently, multiple SARS-CoV-2 vaccines have been found to be safe and produce a sufficient immune response to gain approval for population-level vaccination with very few exclusionary criteria. However, the value of a vaccine to individuals and society is impacted by individuals' perceptions about multiple topics (e.g., the vaccine itself, the development process, regulatory agencies). Although some vaccines such as the H1N1 vaccine during the 2009 influenza pandemic are highly accepted (Blasi et al., 2012), the World Health Organization (WHO) declared vaccine hesitancy as one of the top 10 global health threats in 2019, and vaccine hesitancy and acceptability varies in part due to the social value of a vaccine as perceived by individuals.

This paper elicits the willingness to pay (WTP) for a hypothetical COVID-19 vaccine during the first wave of the pandemic, prior to an actual vaccine being available. Given that our estimates were elicited before any COVID-19 vaccines were approved for use, our estimates are shadow prices, and thus are of policy relevance in making estimates of vaccine valuation. We specifically estimate the WTP in four Western countries, namely the United States (US), the United Kingdom (UK), Spain and Italy. These four countries were selected because each experienced significant morbidity and mortality during the initial wave of the pandemic and hospital capacity crises in select geographies within each of these countries. Using a payment card method, we estimate a monetary equivalent value of a SARS-CoV-2 vaccine (compensating variation) independently of its efficacy and characteristics. Given that individuals suffer from embedding effects, elicitation of the WTP is unlikely to vary with vaccine characteristics (Jones-Lee et al., 1995). WTP estimates are important to guide vaccine pricing and reimbursement decisions in different countries and settings.

The next section reports how the study contributes to the related literature. Section 3 describes the study design and data, Section 4 specifies the empirical strategy followed, Section 5 reports the results, Section 6 provides robustness checks to the estimation, and a final section concludes.

2 | RELATED LITERATURE

2.1 | Vaccine hesitancy and mistrust

An important factor that impacts vaccine hesitancy is trust in medicine and healthcare providers (Thomson et al., 2016), which varies across socio-demographic groups and geographic locales. However, in measuring vaccine hesitancy, it is important to consider the heterogenous aspects of non-acceptability of vaccines in general (Peretti-Watel et al., 2015). For example, some individuals refuse vaccines because of their general (socially and politically motivated) mistrust of public health authorities or authorities in general.

An underlying driver of immunization uptake is concern about the value of vaccines (Gust et al., 2008) and particularly their side effects and safety profiles (Neumann-Böhme et al., 2020). Limited knowledge of what vaccines do, and opposition from trusted sources (e.g., family and friends) has been shown to play an important role in vaccination in some countries (Rainey et al., 2011). Trust in information from governments has been shown to be positively related to COVID-19 vaccine acceptance in a 19-country survey (Lazarus et al., 2020). Similarly, trust in key stakeholders such as the WHO and health care systems may be especially important. An environment of distrust in institutions and "experts" additionally can hamper the public acceptability of vaccines. Evidence suggests that trust in healthcare professionals plays a key role in vaccination attitudes (Benin et al., 2006). Indeed, trust plays a central role as knowledge about vaccines is generally limited both among individuals who get vaccinated and those who refuse them (Cooper et al., 2008).

2.2 | Vaccination intentions

A survey across 19 countries fielded in 2020 found that 71.5% of participants would be very or somewhat likely to receive a COVID-19 vaccine, with higher willingness to vaccinate in the Asian and middle-income countries sampled (Lazarus et al., 2020). Consistently, Neumann-Böhme et al. (2020) estimate that 73.9% of respondents from a number of European countries (Denmark, France, Germany, Italy, Portugal, the Netherlands, and the UK) stated that they would be willing to get vaccinated. Evidence from an Australian survey on attitudes about COVID-19 suggests that ~86% intended to get the vaccine, and almost half (44%) of those who indicated they would not get the vaccine, believed the threat of COVID-19 has been exaggerated (Dodd et al., 2020). Sherman et al. (2020) showed that in July 2020 ~64% of the UK population were willing to be vaccinated when a COVID-19 vaccine would be available. In addition, US survey data of 1000 adults in April 2020 found 57.6% intended to be vaccinated (Fisher et al., 2020).

2.3 | Willingness to pay estimate methods and findings

Previous research has estimated the WTP for a number of hypothetical vaccines (Bishai et al., 2004), mainly using contingent valuation surveys to estimate the willingness to pay for a hypothetical vaccine to prevent HIV infection in Uganda. However, the emergence of the global COVID-19 pandemic has put the estimation of the WTP for a COVID-19 vaccine as a core policy priority. WTP is central to understanding consumer preferences even when a good is purchased by a third party such as health insurer or health system, since the demand cannot be accurately estimated. More specifically, studies typically estimate an individual's maximum WTP.

The measurement of WTP for a global public good across several countries requires using a specific elicitation instrument. Stated preference techniques such as contingent valuation use surveys to elicit preferences and reveal individuals' WTP values for either non-market resources or goods that have not been valued by the market such as vaccines, which have large externalities and are most often provided or subsidized by governments. These methods have an advantage as they measure "existence or passive values", namely a vaccine can improve welfare even for unvaccinated individuals.

Contingent valuation is a common technique used in the absence of market data (Carson & Hanemann, 2006). However, contingent valuation estimates are highly context dependent. That is, the values estimated are contingent on various aspects of the valuation scenario presented to respondents. Typically, WTP elicitation formats often use some form of a (single or double bounded) discrete choice approach and bidding game simulations. These approaches are unlikely to produce precise estimates as individuals are subject to "yea saying" (respondents tend to respond with a "yes" to a hypothetical offer which overestimates WTP values (see Blamey et al., 1999), starting point bias (the higher the initial offer, the higher the WTP estimates), and hold a set of inconsistent and strong assumptions about underlying preferences required for such approaches (Carson & Hanemann, 2006). This is especially important when there is wide heterogeneity in opinions about the value of a COVID-19 vaccine as some individuals are potentially vaccine hesitant. Harapan et al. (2020) use a contingent valuation survey with a simple dichotomous valuation format to estimate the willingness to pay for a COVID-19 vaccine in Indonesia.

An alternative methodology proposed in the context of value uncertainty is the payment card (PC) method where respondents are presented a range of bids and asked to circle the value representing their maximum WTP (Mitchell & Carson, 1989). The true value is expected to lie in the lower and higher interval if such a value exists. Individuals are expected to consider a range of values in which their WTP would lie, so there are limited strategic responses, and thus individuals are more likely to state the true WTP value (Ready et al., 2001). PC methods are not absent of biases such as potential framing effects of WTP values and, more generally, biases from PC design (Cameron & Huppert, 1989; Mitchell & Carson, 1989). However, a way to mitigate such effects is the use of a random payment card as this reduces midpoint and range bias (Shackley & Dixon, 2014), yet bias still remains unless analysis restricts response options to what respondents are "definitely sure" they are willing to pay. Given this background, PC methods have been advocated in health care decision making (Donaldson et al., 1997) as research in health care does not find evidence of the above mentioned design biases when using PCs (Ryan et al., 2004). Finally, to avoid mid-point biases one can employ interval regression methods and use a wider range of values. Following previous work, we do not adopt an increasing PC format but offer increasing ranges of values in boxes to tick (Smith, 2006). PC formats do not typically include an open ended question, as values are already elicited in a range from question format.

Existing studies estimating the willingness to pay for COVID-19 vaccines are limited in scope and follow a referendum format to elicit WTP estimates. Evidence from a survey that did not attempt to formally estimate the willingness to pay for a vaccine found that 50% of US adults would pay US $50 for the vaccine while 25% would pay $75 (Crane et al., 2020). Using a referendum format in Indonesia, which is sensitive to "yea saying", the estimated value was US $57.20 (Harapan et al., 2020). However, to our knowledge no other previous study has elicited a WTP value for the COVID-19 vaccine in the US. Another study used a double bounded referendum format in Chile, and estimates varied between US $232–52 Cerda and García (2021). Finally, a study in Malaysia using similar methods elicited a value of US $30.66 (Wong et al., 2020).

3 | DATA

3.1 | Study design and setting

From July 10–14, 2020, adults from Italy, Spain, the UK, and the US were recruited to participate in a web-based survey using existing Ipsos MORI online global omnibus panels. These panels employ quota sampling to create nationally representative samples for survey research. Specifically, Ipsos MORI uses quotas on age, gender, and geographic region and provides sample weights for analysis using these variables and others (e.g., social grade, household income, employment status). Italy, Spain, the UK, and the US were chosen because of high morbidity and mortality during the initial COVID-19 wave of 2020 and also experiencing a downward trend in case rates and mortality by the summer of 2020. Each country also experienced widespread community transmission, as well as concentrated outbreaks (e.g., Lombardy, Madrid, London, New York City) and associated capacity pressures on health care systems in these areas.

3.2 | Sample size and recruitment

Target sample sizes of $n = 1,000$ per country were selected to allow sample power for cross-country comparisons. In total, 4313 adults took part in the online survey, including 1051 adults from Italy, 1079 from Spain, 1098 from the UK, and 1085 from the US. All participants were recruited through an online survey panel with an electronic survey link sent to panel members via email or app who were aged 18 years or older. The survey was first developed in English and assessed COVID-19-related experiences, risk perceptions, behaviors, financial impacts, and vaccination intentions. Following initial survey development, the survey was translated into Spanish and Italian by Ipsos MORI survey translation team members and reviewed by our bilingual team members. An implied consent script was presented at the beginning of the survey to describe the study's purpose. Responses to all items were optional, and participants completed the survey in a self-administered format using the web-enabled device of their choosing (e.g., computer, smartphone). Recruitment continued until the target samples size for each country was reached. Enough potential participants were initially sent the survey to ensure that sampling quotas are met. If a quota had already been filled when a participant went to complete the survey, then they were no longer permitted to complete this particular survey. An additional sample might have also been invited to close out particular quotas. Non-responders were sent a single reminder to complete the survey but not multiple reminders. Individual sections of the questionnaire (which might include other clients' surveys) were not timed but based on the number of questions, however, IPSOS estimated an average duration of 6–7 min for this survey. Participants who were classified as speedsters (i.e., completing the survey 3+times faster than the median survey speed) or straightliners (i.e., straight-line response pattern on one or more grids and completion 2+times faster than the median) were excluded by IPSOS-MORI as part of their overall quality control process. The study protocol was reviewed and approved by the University of South Carolina Institutional Review Board.

3.3 | Measures

Data on participants' socio-demographic characteristics was supplied by Ipsos MORI and included age, gender, education, employment status, income, number of children and marital status. Income and education were collected using different scales in each country. We harmonized income values by using predictions from an interval regression, run separately in each country, with country-specific income classes as dependent variables and age, employment status, and region of residence as predictors. Then, in order to have comparable values, we multiplied income values for countries different from the US by the exchange rate and by the purchasing power parity (PPP) index. For education, we assigned to each respondent the number of years necessary to obtain the highest reported educational degree and then we categorized this variable in three classes identifying individuals with less than 8, or with 8–13, or with 14 or more years of education.

3.4 | COVID-19 experiences survey

The survey included a total of 54 items. Five items assessed general vaccination beliefs, two items assessed vaccination intentions (e.g., for COVID-19 and seasonal influenza), three items assessed personal experiences with COVID-19, six items assessed risk perceptions for COVID-19 and other health conditions, and four items assessed personal health status. An 8-item scale was used to assess participants' health behavior during the pandemic (e.g., sleep, alcohol use), and a 9-item scale was used to assess COVID-19-related mitigation behaviors (e.g., mask wearing, handwashing). Three items were developed to assess participants' perceptions of economic and public health “trade-offs” (e.g., perceived impacts of economic shutdowns), and an additional five items were used to assess trust in relevant institutions (e.g., local government, national healthcare system). Finally, one item assessed impacts of COVID-19 on participants' household finances and seven items assessed healthcare utilization (e.g., telehealth use, annual preventive visits).

3.5 | Willingness to pay measure

A final item on the COVID-19 experiences survey assessed participants' willingness to pay for a COVID-19 vaccination. Specifically, participants were asked to consider how much they would be willing to pay if there was a COVID-19 vaccine that was 100% safe and effective but was not paid for through their country's healthcare system or health insurance. Participants were provided with a range of payment options in their country's relevant currency (e.g., $1 − $10, $11 − $25, …, > $4, 000). Other response options included, “prefer not to say”, “I don't know”, and “would not pay for the vaccination”.[1] Since our main outcome variable (i.e., WTP) was recorded in intervals and local currencies, we decided to convert WTP values from the UK, Spain and Italy in US $ accounting for differences in PPP. We accomplished this by multiplying original WTP lower (upper) bounds by the exchange rate and by the PPP index. Values obtained with this procedure are then rescaled to match the nearest lower (upper) bound for WTP. Descriptive statistics for the variables of interest, PPP index and exchange rate considered are shown, by country, in Table A1.

4 | EMPIRICAL STRATEGY

We estimate the following interval regression (IR) model:

$$[WTP_l, WTP_u] = \alpha + X'\beta + \epsilon \tag{1}$$

WTP_l and WTP_u are the lower and upper bounds of WTP as elicited in Table A2. WTP is recorded as an interval variable with both left and right censoring. X is a matrix of control variables including the following dimensions: (i) basic controls described in Table A1; (ii) exposure to COVID-19 measured by a variable recording whether the respondent or one of her household members has had COVID-19, distinguishing between those who had symptoms but did not get tested and those with a positive test result; (iii) economic situation during lockdown, distinguishing between respondents who had improved or worsened household finances during lockdown; (iv) type of family, including variables measuring whether respondent is married and the number of kids ages 0–17 years; (v) level of trust in respondent's national government or in the WHO; (vi) an individual assessment of the preference toward a health-economy trade-off, defined on the basis of the following survey question: “If you were asked to advise the government on choosing between prioritizing immediate economic gains or immediate public health gains in your country, what would be your position be on a 0 to 100 scale now?”; (vii) country-specific fixed effects. For detailed information about our variables of interest see Table A1.

After estimating the model proposed in Equation (1), we can calculate average WTP and its standard deviation to test whether the average individual in the sample has a WTP that is different from zero. We elicit the WTP for the average person in our sample multiplying significant coefficients, estimated from Equation (1), by the average values of the corresponding observable covariates. In addition, we can use coefficients from Equation (1) to obtain average WTP values for individuals with characteristics that are different from the average person in the sample and test whether WTP values differ among the selected categories, or with respect to the average person. We test these assumptions using standard t-tests, assuming the usual confidence levels.

In addition to declaring a positive numeric value for WTP, respondents could also declare that they were either not prepared to pay for a COVID-19 vaccine, that they do not know, or that they preferred not to say how much they would be willing to pay for a COVID-19 vaccine. One potential concern is if individuals would use these responses as “way-out” to reduce the cognitive effort required to figure out a WTP value. However, the fact that individuals reported their attitudes to a vaccine and the simplicity of the PC made it easy to identify WTP. However, estimates could be influenced by sample selection if respondents self-select in eliciting WTP value, or in declaring a positive WTP value. Hence, estimating a simple Ordinary Least Squares (OLS) estimator to obtain the average WTP might lead to biased estimates if differences in the level of trust for authorities affect the probability of reporting a valid WTP. Correcting for such measurement error entails deciding how to handle non-responses and zeros. If non-response (zeros) are treated as missing, we risk overestimating the average WTP, because we would exclude respondents that intended to declare a WTP of zero. Yet, if zeros are truly valid answers, we risk underestimating the WTP if vaccine hesitant respondents represent a significant share of the sample. In order to shed light on this we estimate a probit model where the dependent variable is represent by the probability of: (i) not being prepared to pay, (ii) don't know how much, and (iii) preferring not to say how much respondent i would be willing to pay for a COVID-19 vaccine; X are the same observable covariates already described for Equation (1) and V is a matrix of observable covariates describing vaccination intentions.

We can estimate the magnitude of the bias deriving from self-selection using a two-step Heckman selection model:

$$d^* = \omega + Z'\rho + \varrho \tag{2}$$

$$d = \begin{cases} 1 & \text{if} \quad d^* > 0 \\ 0 & \text{if} \quad d^* \leq 0 \end{cases} \tag{3}$$

$$[WTP_l, WTP_u] = \begin{cases} \iota + X'\psi + \varepsilon & \text{if} \quad d^* > 0 \\ - \quad \text{if} \quad d^* \leq 0 \end{cases} \tag{4}$$

$[WTP_l, WTP_u]$ represent the lower and upper limits for the WTP in PPP and expressed in US$. In this model we assume that $\varrho \sim N(0, 1)$, $\varepsilon \sim N(0, \sigma^2)$ and $cor(\varrho, \varepsilon) = \rho$. Problems arise in estimating ψ when $\rho \neq 0$. This means that the error term in the outcome equation will not have a mean of zero and will be correlated with the explanatory variables, leading to inconsistent estimates. X is the matrix already discussed for Equation (1). $Z = X$, V includes also the control variables described in V (i.e., vaccination intentions). The Heckman model uses a two-step procedure, assuming that ϱ and ε are independent of the explanatory variables, estimating ρ from the selection equation by Maximum Likelihood Estimation (MLE), and computing the inverse Mills ratio $\hat{\lambda} = \frac{\phi(Z'\rho)}{\Phi(Z'\rho)}$ that is included as a regressor in the following equation:

$$[WTP_l, WTP_u] = \pi + X'\theta + \hat{\lambda} + \vartheta \tag{5}$$

The estimators from this two-step procedure are consistent and asymptotically normal. Hence, the Heckman model is identified even when the same independent variables appear in both the selection and the outcome equation due to non-linearity in the selection equation deriving from the inverse Mill's ratio, which may lead to imprecise estimates in the outcome equation. To address such concern, we need to find at least one independent variable that affects selection, but not the outcome. In our model we use a variable that takes a value of one if the respondent does not intend to receive the COVID-19 vaccine and 0 otherwise. This variable should have a clear influence on the selection equation but not on the WTP value. However, if individuals not willing to take the vaccine are also those that will not declare a WTP for a COVID-19 vaccine, identification would be impossible. For this reason we had an important clause in our WTP question, stating that the COVID-19 vaccine was: "100% safe and effective but was not paid for through (their) country's healthcare system or health insurance". This particular feature allows us to separate the behavior of respondents who are not willing to receive the COVID-19 vaccine because they are afraid of the possible adverse effects on health from the behavior of those who we define as protest respondents.

5 | RESULTS

5.1 | Sample selection

Table 1 shows the estimated odds-ratios from Equation (2), where the outcomes of interests are the probability to: not be prepared to pay for a COVID-19 vaccine (col. 1), don't know (col. 2), and prefer not to say (col. 3). Looking at the first column we can see that, many of the covariates included in the model are significantly different from 0. Not intending to receive a COVID-19 vaccine increases the probability of not being prepared to pay for the vaccine by 300%. Unemployed individuals are 20% more likely to not be prepared to pay for the COVID-19 vaccine. Respondents that directly experienced COVID-19, either by having suspected infection (i.e., showing symptoms of COVID-19) or having tested positive, are 20% less likely to not be prepared to pay for the COVID-19 vaccine. Experiencing an improvement in household finances during lockdown decreases the probability of not being prepared to pay for a COVID-19 vaccine by 20%. We observe similar results for respondents with 1 child and with 2 or more children younger than 17 years, for which the probability to not being prepared to pay for the COVID-19 vaccine decreases by 14% and 21%. We also document that trust in one's national government and in the WHO decreases the probability to not be prepared to pay for a COVID-19 vaccine by 22% and 23% respectively. Lastly, respondents from Spain and the US are less likely to not be prepared to pay for the COVID-19 vaccine. Looking at columns (2) and (3) (e.g., those measuring the association between observable characteristics and the probability to either respond "don't know" or "prefer not to say" how much they would be willing to pay for the COVID-19 vaccine) we identify no clear patterns from the analysis. Some of our coefficients are significant, but they do not seem to be consistent with a sample selection hypothesis.

From this analysis we can conclude that there is evidence of possible protest responses in our sample among those respondents declaring that they are not prepared to pay for the vaccine. That is, some respondents might not be willing to pay anything because they might refuse any vaccine, might be COVID-19 deniers, or might simply expect the government to pay for a COVID-19 vaccine. In particular, those that do not trust their national government or the WHO and those who are not willing to receive the COVID-19 vaccine are also those who are more likely to declare that they are not prepared to pay for the vaccine. Assigning a value equal to 0 to the WTP of these individuals would downward bias the average WTP and lead us to draw imprecise conclusions.

TABLE 1 Protest vote and sample selection.

	Not prepared to pay (1)	Don't know (2)	Prefer not say (3)
Not SARS-CoV-2 vaccine	3.0372***	0.8689	1.1682
	(0.193)	(0.074)	(0.152)
Male	0.9773	0.8573**	1.1887
	(0.059)	(0.058)	(0.135)
Age	1.0125	1.0134	1.0265
	(0.015)	(0.016)	(0.032)
Age^2	0.9999	0.9999	0.9997
	(0.000)	(0.000)	(0.000)
8–13 years of educations	1.0110	0.8489	0.9528
	(0.165)	(0.155)	(0.304)
≥14 years of education	0.8848	0.7007**	1.2007
	(0.146)	(0.126)	(0.362)
Employed part-time	1.1458	1.0890	0.9452
	(0.108)	(0.121)	(0.202)
Self employed	1.1125	0.8894	1.1436
	(0.121)	(0.116)	(0.225)
Retired	0.9658	0.8283	0.8202
	(0.131)	(0.127)	(0.303)
Unemployed	1.2165*	0.8917	0.8083
	(0.137)	(0.120)	(0.210)
Other condition	0.9940	1.1612	1.5336**
	(0.108)	(0.130)	(0.302)
Monthly income (PPP) in	1.0000	1.0000	0.9999**
	(0.000)	(0.000)	(0.000)
Had COVID-19: Thinks so	0.7862**	0.9905	0.9891
	(0.094)	(0.134)	(0.232)
Had COVID-19: Tested +	0.7689**	0.9436	1.5888*
	(0.074)	(0.157)	(0.382)
HH member had COVID-19: Thinks so	0.8882	1.0326	1.0606
	(0.138)	(0.167)	(0.309)
HH member had COVID-19: Tested +	0.9979	1.1646	1.3235
	(0.104)	(0.130)	(0.238)
HH finances during lockdown: Better	0.8100**	0.8543	1.0721
	(0.073)	(0.091)	(0.203)
HH finances during lockdown: Worse	0.9627	0.8640**	1.0902
	(0.061)	(0.063)	(0.142)
Married/couple	0.9978	0.8514**	1.1254
	(0.063)	(0.063)	(0.151)
1 kid	0.8538*	0.9296	0.8264
	(0.069)	(0.089)	(0.148)
2 or more kids	0.7921***	1.0147	0.8639
	(0.070)	(0.100)	(0.155)

(Continues)

TABLE 1 (Continued)

	Not prepared to pay (1)	Don't know (2)	Prefer not say (3)
Trust in National Gov.: Fair/great	0.7794***	1.0291	0.8929
	(0.047)	(0.075)	(0.113)
Trust in WHO: Fair/great	0.7738***	1.0076	0.9083
	(0.047)	(0.071)	(0.107)
Health/Economy trade-off	1.0006	0.9999	0.9975
	(0.001)	(0.001)	(0.002)
Spain	0.7156***	1.5771***	0.9768
	(0.062)	(0.145)	(0.141)
UK	1.0179	1.0375	0.7869
	(0.091)	(0.118)	(0.154)
US	0.7840**	1.5638***	0.7291
	(0.078)	(0.179)	(0.147)
Constant	0.4823*	0.2296***	0.1051***
	(0.186)	(0.101)	(0.089)
Observations	2890	3143	2938

Note: This Table shows the estimated odds-ratios from the probit model presented in Equation (2), where the outcomes of interests are the probability to: not be prepared to pay for a SARS-CoV-2 vaccine (col. 1), don't know (col. 2), and prefer not to say (col. 3) and control variables include the following dimensions: (i) basic controls; (ii) exposure to COVID-19 measured by a variable recording whether the respondent or one of her household members has had COVID-19; (iii) economic situation during lockdown, distinguishing between respondents who had improved or worsened household finances during lockdown; (iv) type of family, including variables measuring whether respondent is married and the number of kids ages 0–17 years; (v) level of trust in respondent's national government or in the WHO; (vi) an individual assessment of the preference toward a health-economy trade-off, defined on the basis of the following survey question: "If you were asked to advise the government on choosing between prioritizing immediate economic gains or immediate public health gains in your country, what would be your position be on a 0 to 100 scale now?"; (vii) vaccination intentions; and (viii) country-specific fixed effects.

Significant levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 2 displays a comparison of estimates from three strategies that we can adopt to control for sample selection. Column (1) shows IR estimates from Equation (1) when respondents who are not prepared to pay for a COVID-19 vaccine are all assigned a WTP equal to 0. This strategy depicts our most conservative approach and thus the estimated average WTP can be thought of as a lower bound of the "true value". Column (2) shows IR estimates from Equation (1) when respondents who are not prepared to pay for a COVID-19 vaccine are excluded from the analysis. In this case the estimated average WTP can be thought of as an upper bound of the true value. Columns (3) and (4) list estimates from the two-step Heckman model, related to the outcome - column (3) - and the selection - column (4) - equations. Table 3 shows predictions for the average WTP obtained according to the three different strategies adopted. First, looking at column (3) we document that the inverse Mills ratio is significantly different from zero, implying the presence of sample selection and thus suggesting that the adoption of the Heckman specification is our preferred choice. As indicated by the selection equation, respondents who are not willing to take the COVID-19 vaccine are 66% less likely to be prepared to pay for the vaccine. Estimated coefficients are generally very close among the three proposed strategies, but lead to significantly different WTP values. Table 3 reveals that under the first, and more stringent strategy, the average WTP is equal to US $106.8 one we adjust by PPP, whereas under the second, more lenient strategy, the average WTP is equal to US $172.0 once adjusted by PPP. These two values are statistically different from each other, as highlighted in Table A6, at the 1% confidence level. Finally, the average WTP obtained from the Heckman specification lies between these two values and is equal to US $143.4 adjusted by PPP. Given the presence of sample selection and that the estimated average WTP values are sensitive to the strategy adopted, we thus decided to use the estimates resulting from the Heckman specification as our preferred specification.

Lastly, we perform a series of robustness checks to account for the effect of protest responses. Accordingly, we can transform the average WTP estimated from the Heckman model into local currencies by multiplying by the PPP and the exchange rate between US$, € and £. We estimate that the WTP of US $143.4 adjusted by PPP corresponds to €81.80 in Italy, €82.88 (Spain), and £69.81.

TABLE 2 WTP (PPP) in US $—sample selection.

			Heckman	
	Missing	Zeros	Outcome	Selection
	(1)	(2)	(3)	(4)
Mills ratio			−71.1670***	
			(17.410)	
No SARS-CoV-2 vaccine				0.3301***
				(0.021)
Male	13.5927	18.5029	10.2719	1.0220
	(12.036)	(19.260)	(12.576)	(0.061)
Age	−9.3095***	−11.1750***	−9.6517***	0.9875
	(2.776)	(4.220)	(2.852)	(0.014)
Age^2	0.0853***	0.0940**	0.0901***	1.0001
	(0.031)	(0.047)	(0.032)	(0.000)
8–13 years of educations	39.8808***	67.0486***	41.9025***	0.9888
	(13.485)	(22.026)	(14.420)	(0.163)
≥14 years of education	61.1581***	94.2990***	57.6236***	1.1291
	(12.260)	(19.750)	(12.630)	(0.186)
Employed part-time	−44.1358**	−53.6316*	−39.2359**	0.8721
	(17.850)	(32.058)	(18.700)	(0.083)
Self employed	−42.8130***	−57.7092***	−36.2683***	0.8975
	(12.882)	(21.419)	(13.201)	(0.096)
Retired	−13.8255	−21.2278	−17.9582	1.0348
	(21.309)	(33.502)	(22.350)	(0.142)
Unemployed	−13.9060	−11.8220	−6.5053	0.8226*
	(18.389)	(29.325)	(19.566)	(0.090)
Other condition	−55.6603***	−79.1669***	−56.1767***	1.0063
	(18.209)	(29.757)	(18.976)	(0.112)
Monthly income (PPP) in $	0.0130***	0.0185**	0.0125**	1.0000
	(0.005)	(0.008)	(0.005)	(0.000)
Had COVID-19: Thinks so	12.0306	−7.2927	6.5942	1.2708**
	(26.447)	(38.109)	(28.275)	(0.144)
Had COVID-19: Tested +	139.3119***	218.0202***	114.7906***	1.3011*
	(39.942)	(66.373)	(39.587)	(0.206)
HH member had COVID-19: Thinks so	12.9168	−13.1049	10.7621	1.1211
	(34.743)	(44.379)	(36.418)	(0.168)
HH member had COVID-19: Tested +	15.0328	28.8417	9.7975	1.0038
	(18.461)	(33.593)	(19.200)	(0.104)
HH finances during lockdown: Better	22.6626	21.1861	14.5790	1.2330**
	(21.191)	(33.504)	(21.731)	(0.115)
HH finances during lockdown: Worse	−23.7284**	−37.9352**	−25.0556**	1.0403
	(11.662)	(18.237)	(12.242)	(0.066)
Married/couple	24.5964**	38.0329**	27.2767**	1.0020
	(11.324)	(18.806)	(11.590)	(0.065)

(Continues)

TABLE 2 (Continued)

	Missing	Zeros	Heckman Outcome	Heckman Selection
	(1)	(2)	(3)	(4)
1 kid	46.0351***	64.4804**	49.8174***	1.1711*
	(16.287)	(26.442)	(17.219)	(0.095)
2 or more kids	54.8653**	67.4616**	57.7985***	1.2598**
	(21.471)	(32.894)	(22.286)	(0.117)
Trust in National Gov.: Fair/great	42.0409***	51.8223***	28.7867**	1.2827***
	(11.471)	(18.112)	(12.357)	(0.078)
Trust in WHO: Fair/great	21.4334**	6.0560	6.8768	1.2939***
	(10.006)	(17.316)	(12.199)	(0.078)
Health/Economy trade-off	0.4787**	0.8927***	0.4589**	0.9994
	(0.199)	(0.333)	(0.211)	(0.001)
Spain	2.7853	−21.7972	−15.0111	1.3960***
	(14.483)	(23.824)	(16.143)	(0.120)
UK	33.8144**	52.3366*	32.4307*	0.9807
	(16.622)	(29.107)	(17.224)	(0.084)
US	−49.9097***	−87.9547***	−57.2576***	1.2726**
	(15.842)	(27.488)	(17.043)	(0.123)
Constant	155.2224**	209.6739**	214.7640***	2.0871*
	(70.517)	(105.247)	(74.199)	(0.791)
Observations	3040	2355	2879	2879

Note: This Table shows a comparison of three strategies that we can adopt to control for sample selection. Column (1) shows IR estimates from Equation (1) when respondents who are not prepared to pay for a SARS-CoV-2 vaccine are all assigned a WTP equal to 0. Column (2) shows IR estimates from Equation (1) when respondents who are not prepared to pay for a SARS-CoV-2 vaccine are excluded from the analysis. Columns (3) and (4) list estimates from the two-step Heckman model, related to the outcome—column (3)—and the selection—column (4)—equations. Control variables include the following dimensions: (i) basic controls; (ii) exposure to COVID-19 measured by a variable recording whether the respondent or one of her household members has had COVID-19; (iii) economic situation during lockdown, distinguishing between respondents who had improved or worsened household finances during lockdown; (iv) type of family, including variables measuring whether respondent is married and the number of kids ages 0–17 years; (v) level of trust in respondent's national government or in the WHO; (vi) an individual assessment of the preference toward a health-economy trade-off, defined on the basis of the following survey question: "If you were asked to advise the government on choosing between prioritizing immediate economic gains or immediate public health gains in your country, what would be your position be on a 0 to 100 scale now?"; (vii) vaccination intentions; and (viii) country-specific fixed effects.

Significant levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 3 Average WTP (PPP) in US $—sample selection.

	Missing	Zeros	Heckman
	(1)	(2)	(3)
Average	106.8***	172***	143.4***
Standard deviation	(10.10)	(16.67)	(14.69)
t-stat	10.58	10.32	9.765

Note: This Table shows predictions for the average WTP obtained multiplying significant coefficients estimated from Equation (1) by the average values of the corresponding observable covariates considering the following strategies: IR estimates when respondents who are not prepared to pay for a SARS-CoV-2 vaccine are all assigned a WTP equal to 0 (column [1]). IR estimates when respondents who are not prepared to pay for a SARS-CoV-2 vaccine are excluded from the analysis (column [2]). Estimates from the two-step Heckman model (column [3]). WTP in column (1) is obtained using information from Table 2 and Table A1 using the following formula: 155.2224 + 9.3095*43.97 + 0.0853*2152.264 + 39.8808*0.3387 + 61.1581*0.6229–44.1358*0.1179–42.8130*0.0772–55.6603*0.1028 + 0.0130*4986.87 + 139.3-119*0.0394–23.7284*0.4594 + 24.5964*0.6032 + 46.0351*0.1948 + 54.8653*0.1558 + 42.0409*0.4304 + 21.4334*0.58 + 0.4787*53.2 + + 33.8144*0.2155–49.9097*0.2714.

Significant levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

5.2 | Baseline estimates

Table 4 displays the main results from our preferred specification. Columns (1–6) list the coefficients estimated from the Heckman model described in Equations (2)–(4), when different set of covariates, already described in the empirical strategy of the paper, are included stepwise. This is to ensure that estimates from our preferred specification (column 6) are not affected by the presence of high levels of correlation among covariates. By comparing coefficients across specifications it is apparent that estimates are robust, that is estimates are reasonably stable. The inverse Mills ratio is always significantly different from 0, which means that sample selection represents a serious concern that we should correct in order to retrieve reliable and unbiased estimates. Column 6 suggests that the WTP estimates vary with age in a nonlinear u-shaped relation (e.g., the effect first decreases and then increases again after a certain threshold). We calculate that, according to our estimated parameters, the age at which WTP is the lowest is that of a 53 year old respondent. Respondents with 8–13 years of education and less than 14 years of education reveal a WTP of $41.90 and $57.62 higher, respectively, compared to respondents with 5–8 years of education. Results on education are in line with Crane et al. (2020). Respondents employed part-time, self-employed, or in other conditions[2] state a WTP of $39.23, $36.26 and $56.17 lower than those employed full-time. We found no significant differences in WTP levels of retired or unemployed respondents compared to respondents employed full-time. As expected, vaccines are a normal good, as an additional $100 of monthly income increases WTP by $1.25. Testing positive for COVID-19 exerts a large and positive impact on WTP, with infection increasing WTP by $114.79 compared to those who were not infected by COVID-19. Respondents who experienced a negative shock in their household finances also state a WTP of $25.05 lower than respondents whose household finances remained stable during lockdown. Similarly, respondents who are married, or that have children ages 0–17 years have WTP of $27.27, $49.81 and $57.79, higher than single or childless respondents, respectively. Consistently with the literature, respondents that trust their national government a fair amount or a great deal have WTP of $28.78 higher than respondents who do not trust their national government. As expected, respondents that prioritize health over the economy state a higher WTP. In particular, a 1 scale-point increase in the health economy trade-off is associated with a $0.45 increase in their WTP. Lastly, we find that respondents from the UK state an additional WTP of $32.43, relative to Italian respondents, whereas respondents from the US have WTP of $57.25 lower than Italian ones. We found no significant differences between respondents from Spain and Italy. The estimated average WTP is equal to $143.4 and is highly significant (t-stat = 9.76).

5.3 | WTP predictions conditional on observable characteristics

As expected, WTP estimates were not homogenous, hence in this section we have used the estimated coefficients from Table 4 to obtain predictions for the WTP of individuals with different socio-demographic characteristics. We present these results both graphically in Figure 1 and analytically in Table A6. Panel (a) of Figure 1 displays the predicted WTP for the average respondents and for respondents aged 18, 53 and 75 years, respectively. Estimates from Table A6 suggests that 18-year-old respondents state a WTP of $229.3, whereas 53- and 75-year-old respondents state a WTP of $115.4 and $156.8, respectively. As documented both from Figure 1 and as depicted in the *t*-test performed in Table 1, 18-year-old respondents' WTP is significantly different to the average WTP (column 4) and than that of both 53 and 75-years old respondents. Indeed, panel (b) in Figure 1 shows the estimated WTP by level of education, again looking at Table A6 we can see that respondents with 5–8 years of education have a WTP of $93.34, whereas respondents with 8–13 years and more than 14 years have a WTP of $135.2 and $151, respectively. The latter WTP is significantly different from that of the reference category (e.g., respondents with 5–8 years of education). Next, panel (c) displays WTP predictions by employment status. We do not find evidence of significant differences in this respect. Looking at Table A6 we can see that WTP varies between $101.2 for respondents in other employment conditions and $157.3 for respondents employed full-time. Interestingly, unemployed individuals state a WTP of $150.8, which is very similar to that of respondents employed full-time. This result can be explained by the fact that unemployed respondents have high returns from an effective vaccine, since it would allow them to have a higher probability of a return to everyday life and their finding employment. Panel (d) of Figure 1 shows the WTP for respondents with monthly income in US $ adjusted by PPP at the 10-th and 90-th percentiles of the distribution. High-income respondents state a WTP of $175.8, whereas low-income ones state a WTP of $119.4 (see Table A6). Panel (e) of Figure 1 shows the WTP for respondents who were infected or presumed to be infected by COVID-19 with respect to those who did not have COVID-19. The former group has a WTP of $253.7, that is almost twice that of the latter group revealing that direct exposure to COVID-19 is associated with the highest WTP among people in the sample. WTP of respondents who tested positive for COVID-19 is significantly different with respect to the average WTP (column 4) and with respect to WTP of individuals who did not have COVID-19. This result is expected as these respondents have experienced direct, negative impacts of COVID-19 including potential health-related challenges, costs

TABLE 4 WTP (PPP) in US $.

	Basic (1)	Exposure (2)	Economy (3)	Family (4)	Trust (5)	Trade-off (6)
Mills	−115.5964***	−107.2435***	−103.7811***	−92.3016***	−71.4502***	−71.1670***
	(13.898)	(13.224)	(13.327)	(12.745)	(17.370)	(17.410)
Male	12.0083	11.1777	10.8151	10.7571	9.3183	10.2719
	(12.624)	(12.568)	(12.656)	(12.622)	(12.660)	(12.576)
Age	−6.6858***	−5.8465**	−5.8613**	−9.8334***	−9.6597***	−9.6517***
	(2.591)	(2.584)	(2.580)	(2.865)	(2.850)	(2.852)
Age^2	0.0535*	0.0462	0.0463	0.0922***	0.0905***	0.0901***
	(0.029)	(0.029)	(0.029)	(0.032)	(0.032)	(0.032)
8–13 years of educations	45.1552***	44.2937***	41.8027***	46.2913***	42.7333***	41.9025***
	(14.098)	(13.950)	(13.613)	(14.386)	(14.424)	(14.420)
≥14 years of education	56.8008***	57.9387***	54.9996***	59.7640***	58.3432***	57.6236***
	(12.045)	(11.571)	(11.685)	(12.566)	(12.510)	(12.630)
Employed part-time	−44.7025**	−43.2728**	−41.2225**	−36.6258*	−38.9662**	−39.2359**
	(19.111)	(18.959)	(18.925)	(18.714)	(18.674)	(18.700)
Self employed	−45.9318***	−45.8108***	−41.1262***	−35.0435***	−36.3409***	−36.2683***
	(13.542)	(13.704)	(13.385)	(13.220)	(13.188)	(13.201)
Retired	−18.7973	−17.1352	−19.3135	−17.8090	−19.2294	−17.9582
	(22.582)	(22.642)	(22.541)	(22.490)	(22.359)	(22.350)
Unemployed	−27.1466	−25.0114	−23.0974	−3.4809	−6.2608	−6.5053
	(19.688)	(19.717)	(19.456)	(19.415)	(19.478)	(19.566)
Other condition	−66.0565***	−59.7590***	−58.7203***	−54.4614***	−56.0835***	−56.1767***
	(19.518)	(19.562)	(19.361)	(18.974)	(18.981)	(18.976)
Monthly income (PPP) in US $	0.0137***	0.0129**	0.0128**	0.0128**	0.0126**	0.0125**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Had COVID-19: Thinks so		11.9174	10.4930	7.0545	7.5892	6.5942
		(29.066)	(28.907)	(28.320)	(28.358)	(28.275)
Had COVID-19: Tested +		129.4963***	129.0016***	114.8640***	115.1969***	114.7906***
		(40.899)	(40.386)	(39.876)	(39.672)	(39.587)
HH member had COVID-19: Thinks so		6.2038	8.5900	9.1119	10.6879	10.7621
		(35.950)	(36.260)	(36.299)	(36.348)	(36.418)
HH member had COVID-19: Tested +		10.9308	10.1687	8.2162	9.3774	9.7975
		(19.170)	(19.036)	(19.102)	(19.140)	(19.200)
HH finances during lockdown: Better			20.5458	15.0537	15.8406	14.5790
			(22.163)	(21.856)	(21.979)	(21.731)
HH finances during lockdown: Worse			−19.7353	−26.5398**	−24.4779**	−25.0556**
			(12.029)	(12.149)	(12.204)	(12.242)
Married/couple				29.6603**	27.8806**	27.2767**
				(11.623)	(11.649)	(11.590)
1 kid				49.9682***	50.5266***	49.8174***
				(17.160)	(17.322)	(17.219)
2 or more kids				59.6131***	59.1631***	57.7985***
				(22.107)	(22.124)	(22.286)
Trust in National Gov.: Fair/great					28.8286**	28.7867**
					(12.387)	(12.357)

TABLE 4 (Continued)

	Basic (1)	Exposure (2)	Economy (3)	Family (4)	Trust (5)	Trade-off (6)
Trust in WHO: Fair/great					7.4907	6.8768
					(12.265)	(12.199)
Health/Economy trade-off						0.4589**
						(0.211)
Spain	−17.1283	−19.3614	−18.6284	−18.3057	−12.2666	−15.0111
	(15.563)	(15.702)	(15.914)	(15.662)	(16.436)	(16.143)
UK	30.9814*	27.5845	24.7217	29.0394	31.0564*	32.4307*
	(17.618)	(17.452)	(17.513)	(17.763)	(17.308)	(17.224)
US	−66.4414***	−66.4746***	−68.4171***	−64.8923***	−56.9171***	−57.2576***
	(15.989)	(15.935)	(16.206)	(16.395)	(17.147)	(17.043)
Constant	254.9621***	226.9314***	236.2154***	264.8795***	236.5669***	214.7640***
	(68.509)	(69.508)	(68.279)	(69.579)	(71.133)	(74.199)
Observations	2879	2879	2879	2879	2879	2879
Average WTP	165.4	160.5	156.5	152.8	143.4	143.4
Standard deviation	13.18	12.71	12.82	12.63	14.68	14.69
t statistic	12.54	12.63	12.21	12.10	9.768	9.765

Note: This Table shows the main results from our preferred specification. Columns (1–6) list coefficients estimated from the Heckman model described in Equations (2)–(4), when different set of covariates, already described in the empirical strategy of the paper, are included stepwise. Column (1) includes only basic controls. Column (2) controls for whether respondents or their household members either experienced symptoms or tested positive for COVID-19. Column (3) controls for variations (either positive or negative) in household finances during lockdown. Column (4) takes into account whether respondents are married or have kids with age between 0 and 2. Column (5) controls for the level of trust, we define two variables taking value one if respondents trusts a fair/great deal and 0 if she trusts not very much/at all, in National Government and the WHO. Lastly, column (6) adds a variable revealing respondents' preferences toward prioritizing health or the economy, measured on a scale between 0 (prioritize the economy) and 100 (prioritize health).

Significant levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

associated with illness and/or hospitalization, lost income, job losses, and household-related challenges. Panel (h) of Figure 1 shows the WTP according to marital status, and shows that married respondents state a WTP of $154.2 whereas unmarried respondents state a WTP of $127. Panel (h) of Figure 1 shows the WTP according to the number of kids ages 0–17 years. Childless respondents state a WTP of $124.7 compared to respondents with 1, or with 2 or more kids ages 0–17 years that state a WTP equal to $174.5 and $182.5, respectively. Panels (i) and (j) of Figure 1 show the WTP according to level of trust in the national government and the WHO, respectively. Respondents with trust levels in the national government and the WHO equal to fair/great deal state a WTP of $159.8 and $146.3, respectively, whereas respondents that do not trust their national government or the WHO state a WTP of $131.0 and $139.4, respectively. Panel (k) of Figure 1 shows the WTP according to the index measuring preferences toward the health economy trade-off. Respondents who prioritize health state a WTP equal to $164.9 and those who prioritize the economy state a WTP equal to $119. Lastly, Panel (l) of Figure 1 shows the WTP according to the respondents' country of origin. Respondents from Italy and Spain state the same WTP of $152, whereas respondents from the UK state a WTP of $184.4 and those from the US of $94.72.

5.4 | Heterogeneous effects

In this section we investigate the presence of possible heterogeneous effects among the variables considered in our main model. We performed this analysis considering interactions among basic covariates and country of origin, and all other covariates presented in Equations (2)–(4). We show results graphically in Figure 2 considering only variables with significant interactions. Looking at trust in the national government we estimate that respondents with a fair/great degree of trust and between 30 and 40 years of age state an additional WTP of $67.77 (s.e. = 39.88) with respect to respondents in other age groups. In contrast, unemployed respondents that trust the national government state a WTP of $47.86 (s.e. = 22.91) lower than employed respondents. Finally, respondents who trust the national government in the US state a WTP of $59.05 (s.e. = 29.10) higher with respect

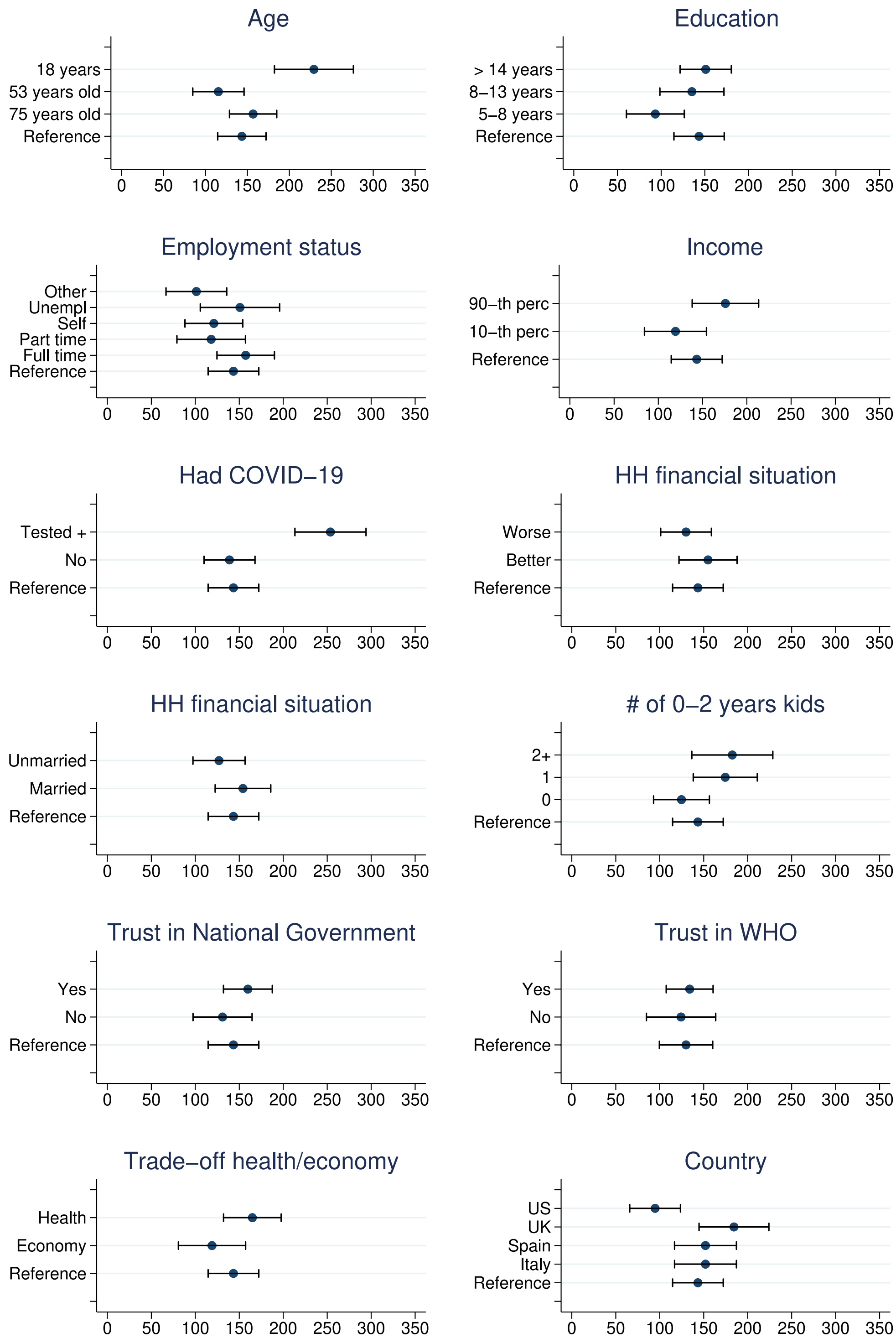

FIGURE 1 Average willingness to pay (WTP) (PPP) in US $, conditional on sample characteristics. This Figure shows predictions for the WTP of individuals with different socio-demographic characteristics. We obtained predictions through linear combination of significant coefficients from Table 4. Points represent the average prediction, whereas the horizontal bars show the 95% confidence interval.

to their counterparts in Italy, Spain and in the UK. Focusing on trust in the WHO, we find that respondents between 50 and 60 years of age state a WTP of \$53.64 (s.e. = 30.12) lower than those in other age groups. In addition, respondents in the UK and in the US who trust the WHO have a WTP of \$80.24 (s.e. = 33.61) and of \$42.09 (s.e. = 23.32) higher, respectively than Italian and Spanish respondents who also trust the WHO. Lastly, considering interactions among basic covariates and exposure to COVID-19 we document that respondents who were infected by COVID-19 and aged between 40 and 50 years and between

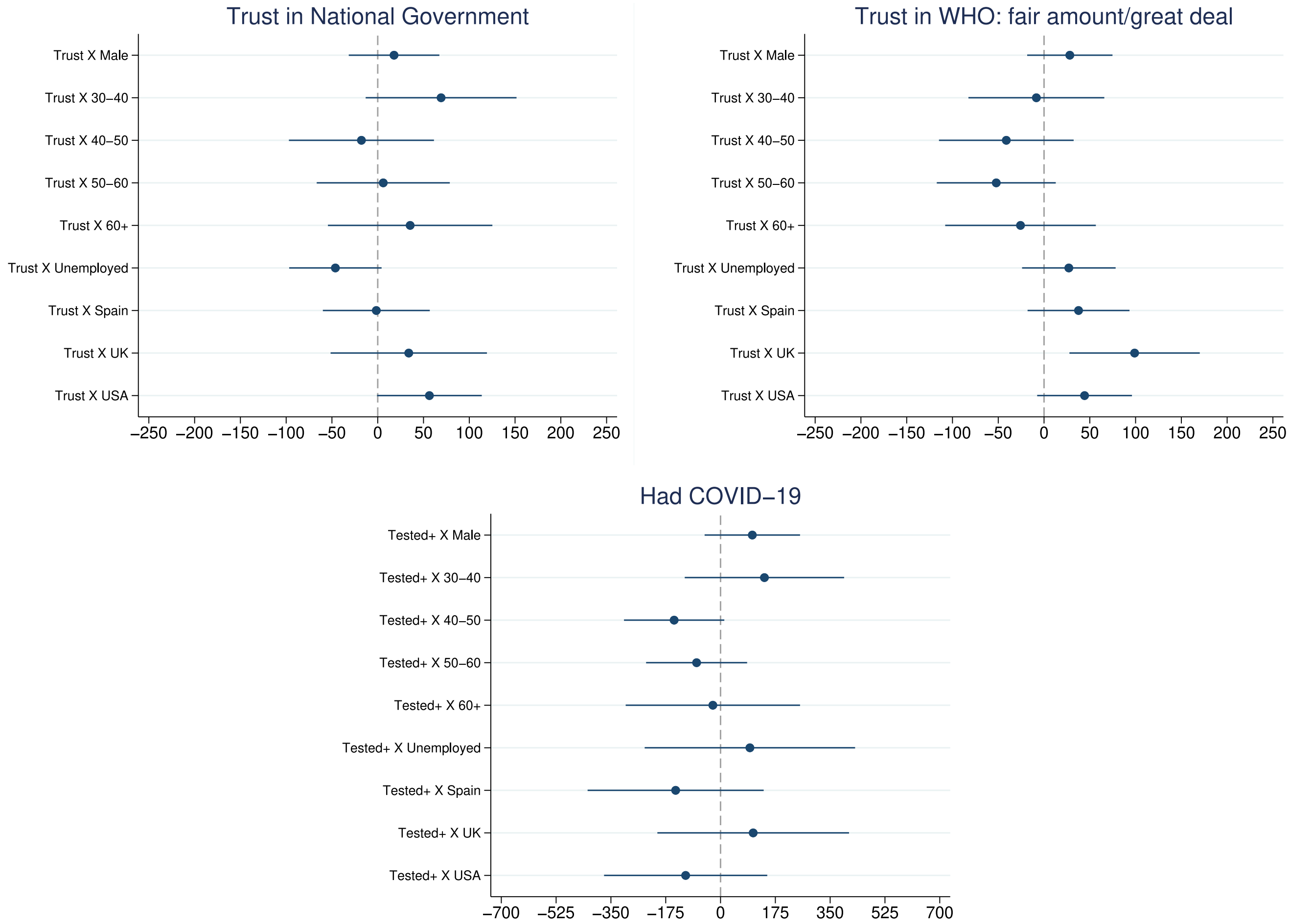

FIGURE 2 Willingness to pay (WTP) (PPP) in US $, heterogeneous effects for respondents who trust National Government and WHO, and who tested positive for COVID-19. This Figure shows heterogeneous effects among the variables considered in our main model, obtained by performing interactions among basic covariates and country of origin, and all other covariates presented in Equations (2)–(4). We report only significant interactions, that is, using trust in national government and in the WHO, or exposure to COVID-19. Points represent the average value, whereas the horizontal bars show the 95% confidence interval.

50 and 60 years state a WTP of \$193.94 (s.e. = 80.31) and \$135.80 (s.e. = 79.94) lower with respect to respondents in other age groups.

6 | ROBUSTNESS

In this section we propose additional analyses to check the robustness of our main estimates. First, we test the sensitivity of our results to the inclusion of regional dummies and regional control variables. Second, we calculate the average WTP using an inverse probability weight (IPW) estimator, as an alternative method to account for selection. Third, we present estimates considering WTP values in local currencies. Table A3, columns (1–3), shows how estimates change when using the Heckman model specification. Equations (2)–(4), includes regional control variables measuring the stringency index calculated by Thomas et al. (2020), the number of days since the last peak, and the number of cases per 1000 population,[3] or alternatively, regional fixed effects. Column (1) shows our main estimates, controlling for country dummies, as a comparison, column (2) adds regional dummies, and column (3) accounts for the regional covariates discussed above. The estimated coefficients are robust as they do not change significantly across specifications, and always remain within the confidence interval of our main estimates.

In the same Table, in column (4), we show the estimates obtained using an alternative specification to account for selection. Under this strategy, following Abadie (2005), we weighted estimates by the inverse propensity score of observing a positive WTP. Columns (5–6) show IPW estimates when we included regional control variables and regional dummies. Irrespective of the strategy used, or of the control variables included, results do not significantly change with respect to our benchmark specification. Table A4 shows the average WTP obtained as a linear combination of significant coefficients estimated in previous models. Including regional dummies or regional control variables (columns 1–3) does not significantly alter our estimated results.

Moreover, Table A5 displays the WTP estimates measured in local currencies. Comparing the full model estimates (column 6) and our main estimates, with WTP in US$ adjusted by PPP (Table 4), we observe that, as expected, almost always the same variables are significant. The inverse Mills ratio is significantly different from 0, meaning that selection continues to play an important influence. The magnitude of the estimated coefficients is suggestive of differences in the estimated linear combinations used to obtain average WTP values, that are now lower than before. However, this was an expected result since the exchange rate and PPP between € or £ and US $ are higher than 1, as shown in Table A1.

Finally, Table A7 reports the estimates when the outcome is measured as the logarithm of the WTP in PPP. Coefficients are expressed as semi-elasticities and can be interpreted as the percentage change in the WTP that corresponds to a unitary variation in the covariates. Results from this analysis are in line with those listed in Table 4, and in particular we can notice that the same covariates are significant.

7 | DISCUSSION AND CONCLUSION

This paper has examined the social value (shadow price, estimates as the WTP) of a COVID-19 vaccine before it was announced and launched. This is important given the positive externalities such a vaccine on population health, society and the economy. Social values are retrieved by estimating the WTP for a hypothetical COVID-19 vaccine in the US, the UK, Spain and Italy during the first wave of the pandemic when vaccines were in development but not yet approved for use nor subsidized.

Our estimates suggest that as expected, the shadow price, or the social value of such a vaccine exceeds its market value. WTP estimates are elicited using a payment card method to avoid "yea saying" biases, and we study the effect of protest responses, sample selection bias, as well as the influence of trust in government and exposure to COVID-19 (exposure to risk) on estimates of WTP. We find the average value of a hypothetical vaccine to be in the range of 100–200 US dollars once adjusted by purchasing power (PPP) in a sample of four Western countries. Our findings reveal no variation in WTP estimates between Spain and Italy but suggest higher values in the UK, alongside lower values in the US compared to the other countries. More specifically, indicate that the lower WTP in the US might have resulted from respondents' mistrust in the national government, since respondents who trust the US government stated a WTP equal to respondents in other countries.

These findings are important for policy makers in understanding the societal value of the COVID-19 vaccine without being influenced by the actual market price (unknown at the time of the survey), and negotiations between governments and manufactures.

We document that the social value of a COVID-19 vaccine is considerably larger than the actual price of any COVID-19 vaccine commercialised later, which indicates that the COVID-19 vaccine encompassed a significant welfare improvement compared to a scenario of no vaccine available.

This study has three main limitations that are discussed below. First, our sample was collected from an online panel and thus is limited by the nature of the respondents in the IPSOS/MORI Online Global Omnibus Panel. The panel uses quota sampling based on age, gender and geographic region to improve representativeness of the sample. Given this quota sampling to provide representativeness, the sample size for each country in our sample (ranging from $n = 1098$ in the UK to $n = 1085$ in the US) and the number of demographic details supplied by IPSOS/MORI to use as controls in our analysis, this study is able to offer robust WTP estimates.

Second, we ask participants to state the maximum WTP for a vaccine that was hypothetically presented as 100% safe and effective. At the time of the survey, no vaccine for COVID-19 was available, and acceptability of vaccines is complex and affected by individual perceptions about their potential effectiveness and side-effects. However, we believe that the inclusion of information about respondents' risk experience (whether someone had COVID or thinks they did) can mitigate this bias capturing differences in safety perceptions across individuals.

Finally, estimates from contingent valuation studies are context dependent and in the case of COVID-19, there may also have been contextual effects due to structural differences in health care system delivery between the four countries as well as differences in the specific policy responses to the pandemic. However, this problem is attenuated by the inclusion of country and region-specific fixed effects that are able to account for such differences. In addition, the inclusion of information in our models about the trade-off between policies that focus on health and the economy also capture such differences in the contextual effects of variations in policy approaches.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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] A copy of the of the WTP question and the Payment card as shown to the participants included in the online Appendix A1.

[2] Full-time parent, homemaker, military, retired, student/pupil.

[3] We obtained this data from Guidotti and Ardia (2020). The number of days since the last peak is calculated as the number of days between the date corresponding to the maximum number of cases registered in each region since the 1st of January 2020 and the interview date.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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