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Are we ready for the next pandemic? Public preferences and trade-offs between vaccine characteristics and societal restrictions across 21 countries

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ABSTRACT

In vaccination decisions, individuals must weigh the benefits against the risks of remaining unvaccinated and potentially facing social restrictions. Previous studies have focused on individual preferences for vaccine characteristics and societal restrictions separately. This study aims to quantify public preferences and the potential trade-offs between vaccine characteristics and societal restrictions, including lockdowns and vaccine mandates, in the context of a future pandemic. We conducted a discrete choice experiment (DCE) involving 47,114 respondents from 21 countries between July 2022 and June 2023 through an online panel. Participants were presented with choices between two hypothetical vaccination programs and an option to opt-out. A latent class logit model was used to estimate trade-offs among attributes. Despite some level of preference heterogeneity across countries and respondents' profiles, we consistently identified three classes of respondents: vaccine refusers, vaccine-hesitant, and pro-vaccine individuals. Vaccine attributes were generally deemed more important than societal restriction attributes. We detected strong preferences for the highest levels of vaccine effectiveness and for domestically produced vaccines across most countries. Being fully vaccinated against COVID-19 was the strongest predictor of pro-vaccine class preferences. Women and younger people were more likely to be vaccine refusers compared to men and older individuals. In some countries, vaccine hesitancy and refusal were linked to lower socioeconomic status, whereas in others, individuals with higher education and higher income were more likely to exhibit hesitancy. Our findings emphasize the need for tailored vaccination programs that consider local contexts and demographics. Building trust in national regulatory authorities and international organizations

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through targeted communication, along with investing in domestic production facilities, can improve vaccine uptake and enhance public health responses in the future.

1. Introduction

The likelihood of pandemic-causing infections, such as the SARS-CoV-2 (COVID-19) and influenza, is expected to intensify in the near future due to increased global travel, urbanization, and exploitation of the natural environment (Madhav et al., 2017; Vos et al., 2020). Combined with the threat of Antimicrobial Resistance (OECD, 2023), which may limit countries' ability to manage certain pathogens, a thorough analysis of national strategies to address the outbreak of infectious diseases is timely.

Vaccination is the most cost-effective tool against viral and bacterial infections (Kim et al., 2022; Luyten and Beutels, 2016; Ozawa et al., 2012). Effective vaccines can help policymakers reconcile the trade-off between societal objectives and individual freedom when responding to an outbreak. Indeed, high vaccination coverage enables governments to lift social restrictions and reopen economies simultaneously. However, populations do not automatically accept available vaccines. Uptake depends on factors including social or economic incentives, misinformation, or entrenched political or religious beliefs (Dubé et al., 2021; Yaqub et al., 2014). Similarly, vaccination attitudes and preferences are highly influenced by the design and implementation of vaccination campaigns, as well as broader relationships involving public institutions and health entities (Attwell et al., 2022a; Collis et al., 2022).

In the context of a novel pandemic with available vaccines, governments should define the optimal mix of pharmaceutical and non-pharmaceutical interventions (NPIs) that maximize vaccine uptake and population health, whilst minimizing the trade-offs on individual freedom and the spillover effects of the pandemic. Incorporating individual preferences into the design of vaccination policies can help maximize compliance (Hess et al., 2022). Indeed, vaccine-hesitant individuals, defined as those with reservations and concerns regarding vaccinations (Dubé et al., 2021), may accept vaccination if certain conditions are met, such as high effectiveness, lower risk of side effects, and the possibility of resuming day-to-day activities (Dubé et al., 2021).

During the COVID-19 pandemic, social restrictions including lockdowns, limitations on gatherings, social distancing, and/or vaccination mandates were initially implemented to reduce viral transmission in numerous countries, and subsequently to provide incentives for immunization. However, if they are not supported by the population, such measures can be counterproductive and – in the case of vaccination – worsen acceptance rates (Bardosh et al., 2022). Additionally, restrictions or mandates may undermine trust in public authorities, scientific institutions, and regulatory bodies, exacerbating social tensions and reinforcing the vaccine-refusing segments of the population (Phelan et al., 2020). Furthermore, whilst vaccine requirements increased uptake during the pandemic in several countries (Karaivanov et al., 2022; Mills and Ruttenauer, 2022; Oliu-Barton et al., 2022), the extent, speed, and duration of this effect remains unpredictable.

Traditional surveys and opinion trackers are the most used techniques for understanding public opinion. However, they are limited in their ability to integrate and measure the relative role that vaccine attributes and policy restriction features play in shaping individuals' preferences and attitudes (Hess et al., 2022). In contrast, preference elicitation techniques such as discrete choice experiments (DCEs) are commonly used to measure the relative importance of various characteristics or attributes of a treatment and assess the trade-offs between these attributes (Lancsar and Louviere, 2008; Ryan et al., 2008).

Previous DCE literature investigating preferences related to the COVID-19 pandemic predominantly focused on non-pharmaceutical preventive measures (lockdowns), policies related to the lifting/relaxation of restrictions and exit strategies, and vaccine characteristics (see Haghani et al. for a full review(2022)). These interrelated dimensions were typically examined in isolation, overlooking their reciprocal effects on individuals' behaviors. For instance, individuals may be more incentivized to get vaccinated if doing so exempts them from social restrictions. Incorporating these trade-offs is therefore crucial when designing future vaccination policies. Only Bughin et al.(2023) explored the trade-offs between pharmaceutical and NPIs during COVID-19 through a conjoint analysis; they found that an effective vaccine might offset the cost of prolonged social restrictions in Germany. However, their findings are limited in their applicability to countries with diverse cultural, economic, human capital, vaccine investment, and healthcare contexts.

Few cross-country investigations were conducted (Hess et al., 2022; Liu et al., 2021; Tervonen et al., 2021); a common limitation in the existing DCE literature investigating vaccination preferences (Bergen et al., 2023). Cross-country analyses offer a comprehensive view of preferences for vaccination and policy restrictions, which may differ among individuals within and across countries. We address this gap by involving 21 countries from six different continents.

Lastly, few studies have explored preferences for a *future* pandemic. Lancsar et al. (2023) quantified how much the tax-paying public is willing to sacrifice in GDP per death avoided in the next pandemic. Loria-Rebolledo et al. (2022) focused on preferences for lockdowns, while Chorus(2020) estimated monetary values in terms of the value of life. Prior to the COVID-19 pandemic, Determann et al. (2016) investigated how disease and vaccination characteristics determine preferences for new pandemic vaccinations. Our study contributes to this forward-looking literature, exploring and quantifying the trade-offs and dilemmas faced by policymakers to inform responses to future pandemics. We offer new insights into the dynamic interplay between vaccine characteristics, NPIs, and the modification of NPI strategies simultaneously.

We conducted an online DCE involving 47,114 respondents from 21 countries, between July 2022 and June 2023, to measure individuals' preferences for, and trade-offs between, the attributes and characteristics of a hypothetical vaccine and societal restrictions for a future pandemic. Specifically, we aimed to: (a) elicit preferences of the general population concerning hypothetical vaccination programs, quantifying the trade-offs individuals make between vaccine attributes and societal restrictions and (b) explore how these preferences varied based on key sociodemographic factors such as age, educational level, income, location of residence, and having children. Broad international sampling allowed us to compare across countries with different demographic and socioeconomic profiles for both aims.

2. Methods

2.1. Recruitment and sample

Between July 1, 2022, and June 30, 2023, we recruited a representative sample of participants (n = 47,114) aged over 18 living in Australia, Brazil, Chile, Croatia, France, Israel, Italy, Latvia, Lithuania, Norway, Russia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Turkey, the United Kingdom, and the United States. Countries were chosen to provide variation on the overall impact of COVID-19, including epidemiological outcomes and policy responses as well as different cultural, socioeconomic and demographic backgrounds to maximize the generalizability of the multicountry comparison. An additional criterion for country inclusion was the inclusion of researchers in our team who are familiar with the country context, the language, and the COVID-19 experience in each country, or our access to such individuals through our networks.

Participants were recruited through online panels by the market research company, DemetraOpinioni, ensuring representation across age groups, genders, and geographical distribution within each country. Age and gender quotas were interlocking, whereas the region/state quota was independent. Quota sampling was based on official statistics from each country (see Appendix for source details). The survey was hosted on the market research company platform.

Multiple mechanisms were used to avoid poor-quality or fraudulent responses, including leveraging demographic information and profiling data to identify fraudulent anomalies, such as spikes in users with similar characteristics, IP ranges, or completion time intervals. DemetraOpinioni conducted additional checks by cross-referencing IP addresses, biographical data, and UserAgent information to identify any duplicates that may have evaded the panel's initial controls. Lastly, before the finalization of the quotas, speeders were identified and replaced with new respondents. We defined speeders as those individuals below 40% of the median time taken to complete the survey in each country. To further assess the quality of our data, we investigated the extent of flatlining (or straightlining) in the first choice option (i.e., Option 1 versus Option 2) across the 12 choice task. Flatlining refers to respondents consistently choosing alternatives positioned in the same location within choice tasks (e.g., always selecting the option on the left), regardless of the attribute levels presented (Johnson et al., 2019; Veldwijk et al., 2023).

Various approaches have been suggested to calculate the sample size in the literature (de Bekker-Grob et al., 2015). For our study, we used a formula developed by Louviere et al. (2000) to determine the minimum required sample size, which was approximately 250 respondents. This baseline ensures sufficient statistical power for basic choice model estimation. To address our objective of exploring preference heterogeneity and running advanced models, we then expanded the sample to maximize study power (de Figueiredo et al., 2020). Specifically, to account for varying population sizes across countries while maintaining feasibility, we implemented a tiered approach: for countries with populations over 15 million, we included at least 3000 respondents; for those between 5.6 million and 15 million, the sample size was 1500 respondents; and for countries with populations under 5 million, we included 1000 respondents. These tiers were chosen to balance statistical power with diminishing returns on increased sample sizes. The larger samples in more populous countries allow for more nuanced subgroup analyses.

This study received ethical approval from the Human Care and Ethics Committee of the University of Newcastle (Approval No. H-2021-0363).

2.2. Survey

Participants completed an online survey that asked about vaccination status, experience with COVID-19, beliefs about vaccination, and demographic details. The questionnaire was originally developed in English (for Australia, the UK, and the US) and in Italian (for Italy) by MA, MG, CB, and FP. The questionnaire was then translated into other languages by professional translators and cross-validated by authors fluent in both English and the respective local languages (CB, DB, SBG, AK, MH, LM, FP, TPH, ARS, AT, RP, JKW). Content was adjusted minimally to account for variations in population, healthcare systems, economy, and cultural characteristics, as well as to comply with data protection regulations. Additional information regarding the full database, *VaxPref* database, which we fully employed except for excluding data for India due to a different design, can be found elsewhere (Antonini et al., 2024).

2.3. Discrete choice experiment

DCEs present participants with a series of hypothetical alternatives that resemble real-life scenarios and ask them to select their preferred option. DCE technique has its theoretical roots in Lancaster's theory of value and consumer theory (Lancaster, 1966). It assumes that goods or services (in our case, vaccination programs) can be described by attributes and the levels of these attributes.

Our DCE included seven characteristics describing different vaccination programs, including the characteristics of the vaccine itself and features related to societal restrictions measures (see Table 1). The attributes and levels were selected following best practices indicated in the literature (Reed Johnson et al., 2013) using a rigorous top-down approach (see Appendix for detailed overview). Respondents were guided through the experiments with a description of the attributes included and their associated levels, and through warm-up questions. Attributes were presented using icon arrays/visuals, ratios, and percentages to ease comprehension. The visual aids were developed through an iterative process involving multiple rounds of discussion among the researchers. Base icons were selected from Microsoft Office Stock Images and Wikimedia Commons, then customized.

There is an ongoing debate in the DCE literature regarding the use of visual aids. While graphics can enhance understanding (Mühlbacher et al., 2024), they can also introduce challenges such as information overload (Vass et al., 2019) or distraction (Marshall et al., 2024; Veldwijk et al., 2015), and bias as respondents may simply count the figures presented in the visual aids, creating linear assumption between levels. We used a combination of icon arrays and numerical percentages, to encourage respondents to consider both and avoid linearity assumptions. Further, the icons were refined based on feedback gathered through think-aloud interviews with 13 experts, along with pilot studies involving non-experts, to ensure they were clear and accessible to the public. Colors were selected to enhance both clarity and ease of understanding. To depict social restrictions, we employed a traffic light

Table 1
Attributes and levels included in the discrete choice experiment.

Attribute	Definition	Levels
Vaccine features		
Vaccine effectiveness	Preventing laboratory-confirmed severe illness (i.e., deaths, hospitalizations) among people without evidence of previous infection	40 out of 100 (40%), 60 out of 100 (60%), 70 out of 100 (70%), 90 out of 100 (90%),
Risk of severe-side effects	Probability of getting severe side-effects that require urgent hospitalization after the vaccination (e.g., thrombosis/ blood clots, heart attack)	1 out of 100,000, 5 out of 100,000, 12 out of 100,000, 20 out of 100,000,
Duration of protection	Length of time before a new vaccination is required to boost the initial immune protection	3, 6, 12, 24 months
Time between the first clinical trial and market approval	Length of time between the first clinical trial of the vaccine(s) to market approval	6, 12, 24 months
The origin of the manufacturer	Location in which the vaccine manufacturing company has its headquarters	China, European Union, United Kingdom, USA, Russia
Social restrictions features		
Stringency of social restrictions	Stringency of the social activities ban (how restricted are social activities)	No social activities allowed, Some social activities allowed, All social activities allowed
Vaccine mandate	Vaccine mandate to return to usual work activities (formal or informal)	Return to formal or informal work activities not allowed without the vaccine, Return to formal or informal work activities allowed without the vaccine

system (red, yellow or green). Red was also used to represent the risk of severe side effects, aligning with social norms equating red with danger or warning. Blue was chosen for vaccine effectiveness to clearly distinguish it from other attributes. Blue is often associated with trust and reliability in color psychology, and this choice aligns with previous literature in health communication (Daziano and Budziński, 2023). Based on the pilot study results, we made final adjustments to ensure optimal clarity and ease of understanding.

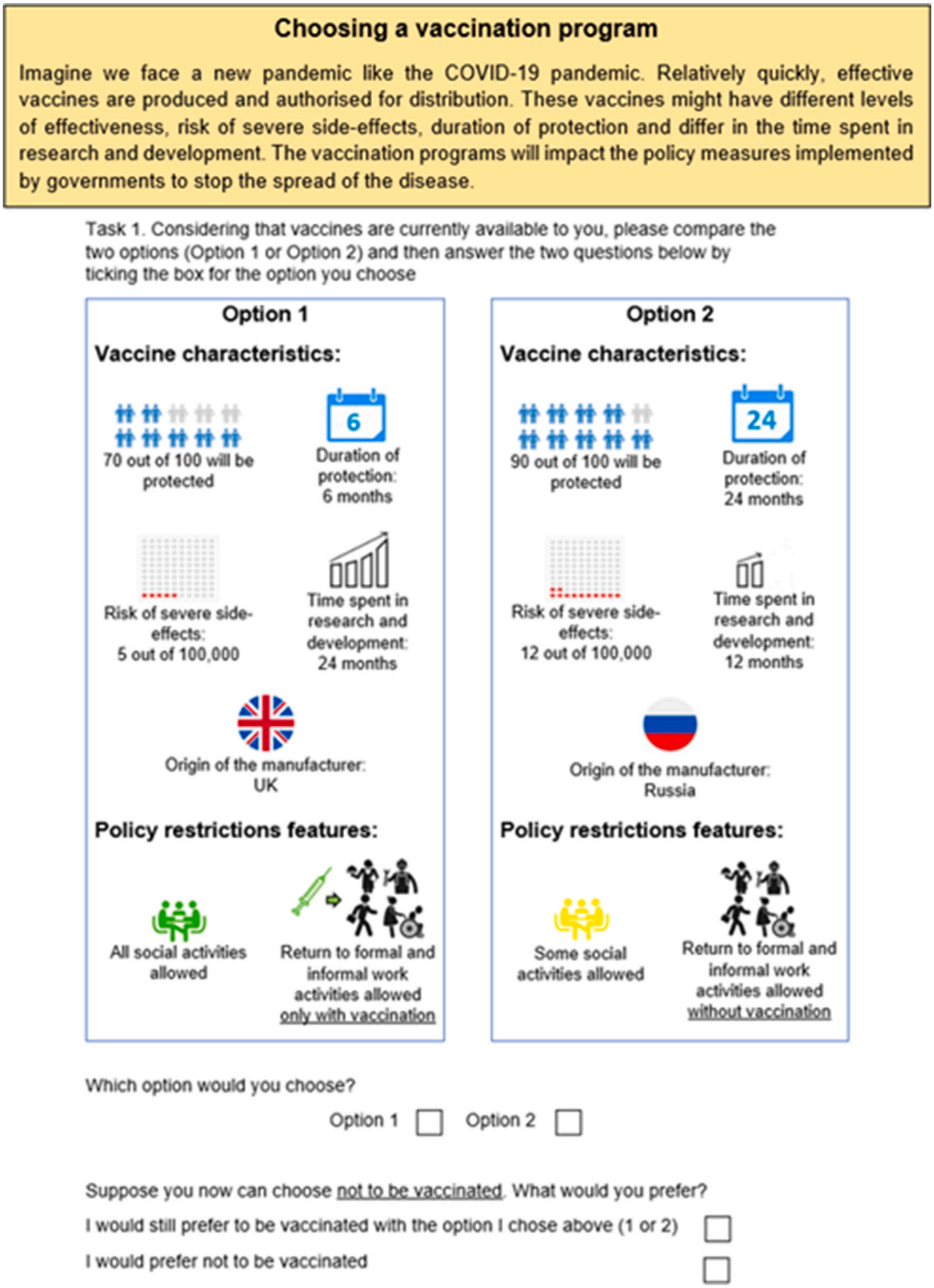

Fig. 1. Choice context and choice task example.

Attributes and levels were combined into pairwise choice tasks using a D-efficient design focused on main effects only, with non-zero informative priors to reflect the directionality of levels. We did not include informative priors for the origin of the manufacturer attribute given the different populations surveyed, who are expected to display contrasting preferences for this specific attribute. This resulted in 36 choice tasks. To minimize cognitive burden, these 36 tasks were blocked into three versions. We specified the 3 blocks into the design. The design was optimized for the estimation of a multinomial logit (MNL) model and was created using NGENE software (ChoiceMetrics, 2018). The experimental design aims to create a subset of all possible choice tasks that minimizes the determinant of the variance-covariance matrix for a given number of choice tasks. The model was specified to allow the characteristics' levels to be included in an MNL model as dummy variables. A set of three candidate designs were created using a modified Fedorov algorithm combined with a swapping algorithm (Miller and Nguyen, 1994). The best design was then selected based on the lowest D-error, minimum overlap between levels of attributes in a task, better level balance, and lowest Pearson correlations between characteristics (Rose and Bliemer, 2009).

The order of the 12 tasks was randomized for each participant to minimize ordering effects (Genie et al., 2023; Ryan et al., 2018). We also imposed a constraint in the experimental design to avoid the co-existence of a 90% vaccine effectiveness and the presence of full restrictions (i.e., lockdown), since most countries abandoned lockdown measures for the vaccinated population during COVID-19, relying on the effectiveness of the vaccines. We expect a similar strategy to be adopted in the future.

Respondents were initially presented with a description of the attributes and their corresponding levels. Then, an example choice task was provided, with a description of the tasks. The choice tasks consisted of two unlabeled alternatives, denoted as Option 1 and Option 2 (Fig. 1). Following the rationale proposed by Veldwijk et al. (2014), a dual response design (Brazell et al., 2006; Rose and Hess, 2009) was implemented to improve data quality, with respondents first asked to indicate their preferred option: "W*hich option would you choose*?" (Option 1 versus Option 2). Following this choice, respondents were then asked to choose between the chosen vaccination program and an opt-out (non-vaccination) option: "*Suppose you now can choose not to be vaccinated. Which option would you choose?"* (I would still prefer to be vaccinated with the option I chose above (1 or 2) versus I would prefer not to be vaccinated).

2.4. Econometric analysis

Responses to DCE tasks are often modelled within a random utility maximization framework (McFadden and Zarembka, 1974). This assumes that respondents choose the option that maximizes their utility. The utility (U) of the vaccination alternative *(j)* faced by individual *(n)* in choice task *(t)* depends on a systematic component (V) and an unobservable stochastic component (ε):

$$U_{ntj} = V_{ntj} + \varepsilon_{ntj} \quad (1)$$

To analyze the choice data from the DCE, we first conducted the Swait and Louviere test to determine whether pooling all the data for analysis was appropriate. The test for preference differences, allowing the scale to vary across countries, produced a Likelihood Ratio Test statistic = 44316.38, df = 359, p-value = 0.000. As such, we rejected pooling across countries. As a next step, we ran conditional logit models. The conditional logit model presents certain limitations, notably its inability to capture preference heterogeneity. To address this, we used latent class (LC) models (Hess, 2014). The choice probability that a respondent n of class q chooses alternative i from a particular set J, comprising j alternatives, is expressed as:

$$P_{n|q} = \prod_t \frac{\exp\left(\sum_k \beta_{qk} X_{ntik}\right)}{\sum_{j=1}^{J} \exp\left(\sum_k \beta_{qk} X_{ntjk}\right)} \quad q = 1, \ldots, Q \quad (2)$$

where β_{qk} are the average preferences for attribute k in latent class q associated with the vector of explanatory variables X_{ntik}, t corresponds to the choice tasks, n to the respondents, k to the attributes, j to the choice options, and i denotes the chosen option. $P_{n|q}$ is the probability of all the choices made by individual n conditional on being in class q.

The underlying theory of the LC suggests that respondents' choice behavior and preferences are allocated into a set of Q latent classes. Preferences within each class are assumed to be homogenous but allowed to differ across classes. The LC estimates Equation (2) for Q classes and predicts the probability H_{qn} of respondent n being in class q. Then, the probability of individual n belonging to class q, H_{qn}, is given as:

$$H_{qn} = \frac{\exp\left(\sum_s \alpha_{qs} Z_{ns}\right)}{\sum_q \exp\left(\sum_s \alpha_{qs} Z_{ns}\right)} \quad (3)$$

where s denotes the personal characteristics (e.g., age, gender, income, etc.), Z_{ns} is the value of the sth characteristic for respondent n. α_{qs} capture the effects of the personal characteristics on the class membership.

The unconditional probability of the choices made by individual n, P_n, is given as:

$$P_n = \sum_q H_{qn} P_{n|q} \quad (4)$$

We allocated individuals across classes by combining Bayes theorem with the maximum probability allocation rule (Greene and Hensher, 2003); the class share represents the proportion/percentage of respondents belonging to each class.

$$\widehat{H}_{q|n} = \frac{\widehat{P}_{n|q} \widehat{H}_{qn}}{\sum_q \widehat{P}_{n|q} \widehat{H}_{qn}} \quad (5)$$

Explanatory variables of class membership and preference parameters of respondents in each class are estimated jointly. We included the following covariates of class membership based on previous literature:

Age reflects respondents' age at the time of data collection. Older individuals are more likely to experience the adverse effects of a novel pathogen compared to younger ones, as clearly demonstrated with COVID-19 (Harris, 2023). Moreover, older adults were prioritized in the COVID-19 vaccination campaigns due to their higher risk of hospitalization if infected. Building on previous findings, we hypothesize that older individuals are more likely to be pro-vaccine (support vaccinations) compared to younger respondents (Hess et al., 2022; Lazarus et al., 2023; Schwarzinger et al., 2021).

Gender is represented by a dummy variable equal to 1 for respondents who self-identify as female. Studies have shown that, on average, females are more risk-averse than males (Byrnes et al., 1999; Harris and Jenkins, 2006). This tendency extends to vaccination decisions, with women being more hesitant compared to their male counterparts (Bish et al., 2011; Morillon and Poder, 2022; Toshkov, 2023). In the context of COVID-19, only one study reported opposite findings (Lazarus et al., 2021). Accordingly, we hypothesize that females are more likely than males or individuals of other genders to be vaccine-hesitant and/or anti-vaccine.

Education is a dummy variable equal to 1 if respondents held (at least) a bachelor's degree. Evidence suggests the existence of a social gradient in vaccine hesitancy, with less-educated individuals more likely to be unvaccinated (Borga et al., 2022; Craig, 2021; Hess et al., 2022; J. V. Lazarus et al., 2023; Mouter et al., 2022). Recently, Bergen et al. (2023) provided additional granularity to the association between the two dimensions among unvaccinated people using data from 90 countries. They found that vaccine *hesitancy* was higher among those with lower education, while vaccine *refusal* was higher among those with higher education, especially in high-income countries. Accordingly, we hypothesize that people with higher education will be more likely to be pro-vaccine compared to those with lower educational levels, but in some countries, this relationship might be reversed.

Income is a dummy variable equal to 1 if the respondent was categorized as high income. To facilitate comparisons across countries we used the OECD classification (OECD, 2019). High-income individuals reported a household income twice the household median income in their country. The effect of income on vaccination decisions is expected to follow a pattern similar to education (Bergen et al., 2023; Motta, 2021). Accordingly, we hypothesize that higher-earning respondents are more likely to support vaccinations compared to low-income respondents. However, the literature provides mixed evidence, with either no statistically significant differences across income groups, or with higher earning individuals less likely to vaccinate in some countries (Endrich et al., 2009; Lazarus et al., 2023). These contradictory findings, present also for other vaccines (Tur-Sinai et al., 2019), may reflect the fact that high-income earners can work remotely in highly skilled jobs, or possess the means to isolate more effectively from others.

Residence location is a dummy variable equal to 1 if the respondent resides in an area with more than 50,000 inhabitants. Viral infections spread more easily in areas with higher density and mobility (Balcan and Vespignani, 2011; Belik et al., 2011; Hazarie et al., 2021). Therefore, the perceived risk of the virus is expected to be relatively lower in semi-urban and rural areas than in urban agglomerations. Previous evidence reported larger influenza vaccination rates in larger cities compared to smaller towns (Endrich et al., 2009). Accordingly, we hypothesize that people in urban areas are more likely to support vaccinations compared to those living in semi-urban or rural areas.

Children is a dummy variable equal to 1 if the respondent has any children. Parental vaccination decisions for their children have been widely researched, with previous studies revealing that parents are more cautious about vaccinating children than themselves (Szilagyi et al., 2021; Teasdale et al., 2021). Non-vaccinating parents also perceive that they experience stigma (Carpiano and Fitz, 2017; Wiley et al., 2021). Such extrinsic motivation might push parents towards vaccination compared to childless people. Therefore, we hypothesize that respondents with children will be more likely to support vaccinations.

Fully vaccinated against COVID-19 is a dummy variable equal to 1 if the respondent was fully vaccinated (at least 2 doses) against COVID-19 at the time of data collection. Previous vaccination behaviors have been reported to explain current vaccination behaviors (Endrich et al., 2009). Accordingly, we expect that people who are vaccinated against COVID-19 will be more likely to support vaccination (Bish et al., 2011).

The optimal number of latent classes is a trade-off between explanatory power, the number of additional parameters, and ease of interpretation (Hess, 2014). The statistical criteria and the significance of the parameter estimates also need to be tempered by the analyst's own judgement of the suitability of the model (Scarpa and Thiene, 2005). We estimated latent class models for each country and the final selection of the optimal number of classes was based on multiple criteria, including the log-likelihood function, BIC and AIC statistics, parsimony, and plausibility of results (Zhou et al., 2018).

A potential limitation when interpreting differences across countries and classes is the statistical confounding between preference and scale heterogeneity (Vass et al., 2018). To address this, we calculated the Marginal Rate of Substitution (MRS), using the risk of severe side effects as the denominator. This approach specifically measures respondents' willingness to accept increased risk for improvements in attribute levels compared to their baseline. By doing so, we obtain a scale-free measure of the additional risk out of 100,000 people that individuals are willing to accept in exchange for improvements in other vaccine or social restriction attributes. This calculation requires the risk attribute to exhibit linearity across its levels. We applied a Chi-squared test to verify this assumption for each country, finding that most countries met the linearity requirement (results of the linearity tests are available from the corresponding author upon reasonable request). The MRS is given by:

$$MRS_{k|q} = -\frac{\beta_{qk}}{\beta_{qrisk}} \tag{6}$$

Where β_{qk} is the preference weight for attribute k in class q, and β_{qrisk} is the preference weight for the risk attribute in the same class.

Lastly, as our objective is to provide policy insights for increasing vaccine uptake in the event of a new pandemic, we investigated the percentage change in uptake probabilities compared to the opt-out option. The base vaccine program was characterized by a risk of severe side effects of 20 out of 100,000, with all other attributes set to their reference levels. We then iteratively improved each attribute to its maximum level and measured the predicted change in uptake. This approach allows us to quantify the effect of each attribute on vaccine uptake and assess the relative importance of each in enhancing uptake (Lancsar et al., 2007)(see the Appendix for the method). An advantage of calculating the predicted probabilities, alongside the MRS, is that we can also assess the relative importance of the risk attribute. Furthermore, since our analysis uses models with main effects only, MRS would yield the same ranking of relative attribute impacts as the size and significance of the raw attribute coefficients. All statistical analyses were performed in Stata version 18.

To facilitate the presentation of our results and their implications for policymakers, we grouped countries based on the stringency of government policies enacted during the COVID-19 pandemic. We considered the median value of the OxCGRT stringency index for each country between January 2020 and December 2022 (Hale et al., 2021). The stringency index ranges between 1 and 100. A higher score indicates a stricter response (i.e. 100 = strictest response). We defined 4 groups as follows (see Fig. 2):

- Low stringency (<40): Croatia, Sweden, Lithuania, Turkey, Norway, Slovakia.
- Med-low stringency (<45): Russia, Latvia, Slovenia, UK, Spain, France.
- Med-high stringency (<50): South Africa, South Korea, Singapore, Israel.
- High stringency (50+): USA, Australia, Brazil, Italy, Chile.

3. Results

3.1. Descriptive statistics

We report descriptive statistics for our sample and the variables selected for class membership in Table 2. Notably, the share of people with (at least) a bachelor's degree ranged from 23% (France) to 71% (South Korea). The share of high-income respondents is also heterogeneous, with the largest share in South Africa (64% of the sample). We observed a relatively large share of outright vaccine refusers (i.e., the share of individuals who stated they were not vaccinated against COVID-19 and not willing to get vaccinated in the future) in lower stringency categories, particularly from Eastern European countries, with the South African and the US respondents being an exception among the countries in more stringent groups. This is in line with previous findings (Hess et al., 2022).

The analysis of the extent of flatlining in our data (see Table 2 and OSM3 for a detailed overview) revealed that 4.1% of the pooled sample consistently chose "Option 1" (3.4%, n = 1,430) or "Option 2" (1.1%, n = 519) across all choice tasks. This behavior was most prevalent among respondents from Turkey and the US, with 6–7% of each country's sample exhibiting this pattern, while Italian and Swedish respondents reported the lowest occurrence at 2%. Moreover, approximately 19% (n = 8,768) of the pooled sample consistently opted out by always choosing

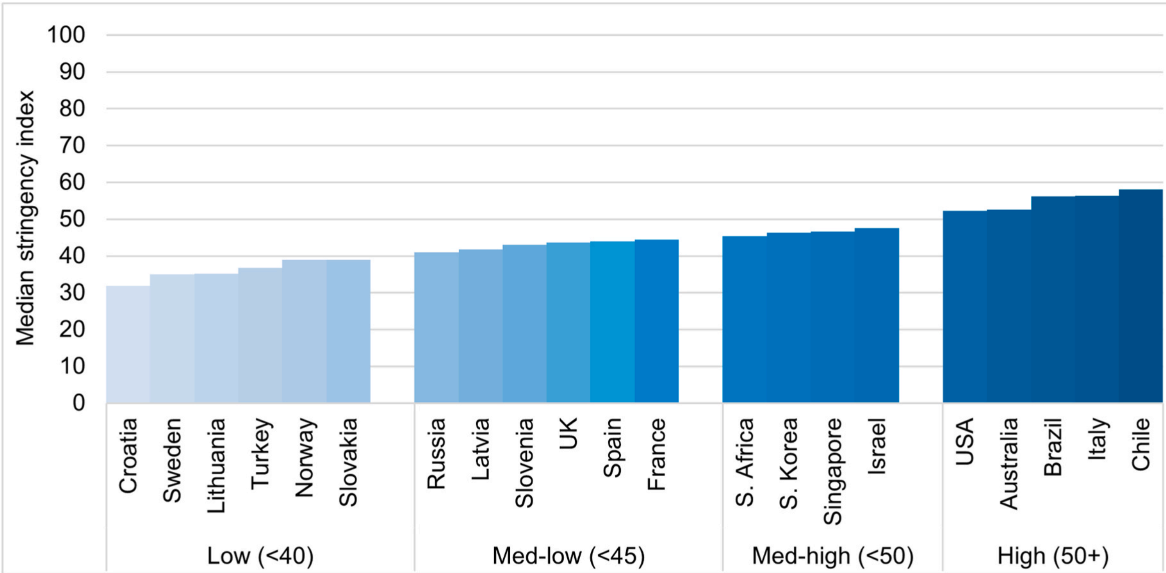

Fig. 2. Categorization of the countries included in the experiment by the median OxCGRT stringency index between January 2020 and December 2022.

Table 2
Descriptive statistics.

Country	Respondents (N)	Median Age[a]	Female (%)	Bachelor and over (%)	High income[b] (%)	Urban area (>50k inhabitants) (%)	Children (%)	Outright refusers[c] (%)	Flatlining (%)
Low stringency									
Croatia	1062	49	51.1	45.0	18.7	41.0	63.4	20.6	4.2
Sweden	1503	49	49.9	50.5	18.5	44.2	63.8	7.7	2.5
Lithuania	1010	48	54.1	67.6	8.0	43.5	67.8	16.5	5.1
Turkey	3086	41	50.4	64.4	48.3	81.0	70.6	8.3	6.8
Norway	1033	46	49.8	51.7	5.6	39.2	66.5	5.0	2.8
Slovakia	1009	46	51.1	32.3	22.0	27.8	67.0	20.4	4.1
Med-low stringency									
Russia	3010	46	54.5	63.8	22.1	79.6	76.2	21.9	3.0
Latvia	1109	47	54.4	34.5	20.3	32.6	71.0	18.0	4.9
Slovenia	1061	47	50.1	45.0	27.1	23.0	69.3	21.8	4.2
United Kingdom	3115	47	51.2	34.6	9.6	30.2	62.8	7.4	3.9
Spain	3266	47	50.9	43.0	6.3	54.5	67.2	4.6	3.3
France	3165	48	52.2	23.1	17.2	24.2	67.6	9.3	5.8
Med-high stringency									
South Africa	3002	36	51.9	41.9	63.6	56.9	72.0	15.1	3.3
South Korea	3000	49	50.0	70.9	32.5	77.7	65.4	3.8	3.4
Singapore	1002	47	51.7	51.4	15.0	42.9	58.6	1.2	4.3
Israel	1513	40	50.2	52.3	12.3	47.3	63.1	5.6	3.0
High stringency									
United States	3158	45	51.4	48.2	12.3	37.4	64.4	14.7	6.8
Australia	3004	45	51.0	39.9	20.2	51.9	67.0	5.5	4.5
Brazil	3001	40	51.8	45.8	48.6	66.8	71.2	1.7	4.6
Italy	3001	51	51.7	36.4	18.6	42.9	61.0	4.6	2.5
Chile	3004	40	51.0	73.2	54.8	61.3	71.2	2.2	2.8
Total	47,114	45	51.4	48.5	24.8	51.5	67.5	9.2	4.1

Notes.
[a] In Singapore the adult age is at 21 years old.
[b] To facilitate comparisons across countries we followed the OECD income classes classification (OECD, 2019), which divide the population in income classes as follow: Lower-income class refers to households with income below 75% of the median national income; middle-income class refers to households with income between 75% and 200% of the median national income; upper-income class refers to households with income above 200% of the median national income.
[c] Unvaccinated individuals against COVID-19 at the time of data collection who reported no intentions to vaccinate in the future.

"No vaccine."

3.2. Model results

The initial MNL results (presented in the Appendix) show that the utility coefficients have the expected signs, confirming the theoretical validity of the model. However, we observe some disordering within the levels of the Time from first clinical trial to market approval attribute in the Australian and Russian data, where respondents report a negative utility for the 12-month level compared to the 6-month reference ($p < 0.05$), but a positive utility for the 24-month level, though this is only statistically significant at the 90% confidence level for the Australian data. For this attribute, we also note that South Korean respondents, on average, dislike longer waiting times for vaccine authorization. While this observation contradicts our assumption, it is interesting as it reveals that respondents in these two countries seem to be more impatient compared to those from other countries. Overall, respondents placed significantly more weight on the vaccine characteristics than on the social restriction features. Indeed, the origin of the manufacturer emerged as the most important attribute across all countries. Most European countries showed strong preferences for a vaccine manufactured in the European Union compared to one manufactured in China. Similarly, Russian respondents expressed a strong preference for a Russian vaccine ($b = 0.54$, $p < 0.01$) and negative preferences for vaccines manufactured in Western countries compared to one made in China. Interestingly, participants were generally indifferent toward the presence of vaccine mandates, with weak statistical significance or relatively small magnitude compared to the other attributes.

For the sake of brevity, the LC results are presented in OSM 1: the left-hand Tables reports the estimates in preference space, while the right-hand side Table reports the MRS coefficients in willingness to accept risk. The lower part of the left-hand Tables indicates the effect of covariates on class membership. We also report the average class probabilities.

Based on BIC and AIC statistics, parsimony, and the plausibility of results, we identified three latent classes for most countries ($n = 15$). We identified two classes for five countries (Croatia, Israel, Norway, Singapore, and Slovenia) and four classes for Russia. The key differences among the classes within each country were the magnitude of the opt-out coefficient (i.e., the marginal utility of not choosing any vaccine) and whether respondents were trading off the attributes included in the choice tasks. Based on these preferences regarding a potential future vaccination program, estimated through the LC models, we labeled the classes as “Pro-vaccine”, “Hesitant”, and “Vaccine refusers/fearers”. These results align with the notion of vaccination behaviors and vaccine hesitancy as a spectrum, ranging from strongly pro-vaccine individuals to refusers. Between these extremes lies a group of hesitant individuals who are uncertain about vaccination due to concerns about vaccine characteristics (e.g., manufacturers, duration of protection, risk of side effects) and whose decisions may also be influenced by opposition to government impositions (e.g., vaccination mandates or social restrictions).

For countries where we identified only two classes, we followed the same classification. We were able to clearly identify the pro-vaccine class (i.e., negative and statistically significant opt-out coefficient). For labeling the other class as either "Hesitant" or "Vaccine refuser", we first looked at the magnitude and significance of the opt-out coefficient and then examined whether respondents traded off the attributes. If the class revealed only statistically significant preferences for opting out, we labeled it “Vaccine Refuser”. If they also considered improvements in other attributes, we labeled them “Hesitant”, in line with the assumption that hesitant individuals are willing to get the vaccine if specific conditions are met.

It is important to note that the number of classes identified reflects the preference patterns in *our* data. While we might anticipate distinct pro-vaccine, hesitant, and refuser groups in the broader population, our data may not reveal clear and meaningful distinctions in preferences. For example, hesitant and refuser respondents might exhibit similar choice patterns, resulting in only two groups instead of three. Furthermore, allocation to each class is probabilistic; thus, even if a respondent aligns more closely with one class, they still have a chance of belonging to another.

The characteristics of the various classes are reported as follows:

Pro-vaccine: This category includes respondents who reported a negative preference for the opt-out option, with the magnitude of the opt-out coefficient relatively higher than other coefficients. The willingness to accept risk for the opt-out option ranged from −4.99 out of 100,000 in Croatia to −159 out of 100,000 in Turkey ($p < 0.01$).

Hesitant: This category includes respondents who assigned a positive and relatively higher weight to the opt-out option compared to other attributes, but relatively smaller compared to the vaccine refuser class in the country. The opt-out coefficient expressed in willingness to accept risk ranged from 7 out of 100,000 in Chile ($p < 0.01$) to 78 out of 100,000 in Israel ($p < 0.01$). In this class, respondents made trade-offs among various attributes, suggesting they were generally inclined to get the vaccine only if specific attribute levels were present in the vaccination scenario. Across all countries, respondents favored improved vaccine features and reduced social restrictions compared to baseline levels. Across all countries, the highest willingness to accept risk was placed on the manufacturer’s origin. This trend was common across all countries, even those not belonging to one of the specified areas (i.e., Australia, Brazil, Chile, Israel, Singapore, South Korea). The only exception was South African respondents, who valued the absence of social restrictions and improved vaccine effectiveness more than the manufacturer’s origin. It is worth noting that we do not include the second class from Croatia and Slovakia as "Hesitant," as they aligned more closely with our overarching definition of the "Vaccine refuser" class, based on the relatively large opt-out coefficient and lack of trade-offs among attributes.

Vaccine refusers/fearers: This category includes respondents who assigned a positive and significantly higher weight to the opt-out option compared to other attributes and tended not to report statistically significant preferences for vaccination program attributes. For simplicity, we refer to this class as "refusers." The willingness to accept risk coefficient of the opt-out parameter ranged from 56 out of 100,000 in Italy ($p < 0.01$) to 175 out of 100,000 in Croatia ($p < 0.05$). Large preferences for the opt-out option revealed that this class grouped preferences of respondents who were either against vaccination or afraid of the vaccine. Vaccine opposition was found in the Australian, Chilean, Croatian, French, Slovenian, Spanish, UK, and US data, where only the opt-out or the absence of social restrictions (compared to lockdown) coefficients were statistically significant. For the remaining countries, participants in this class only favored the vaccination option compared to the opt-out with the maximum level of vaccine effectiveness and the avoidance of the full lockdown scenario. Lastly, we include in this category the third class identified from the Russian sample, which we can further characterize as *nationalist* vaccine refuser/fearer. This group revealed a tendency to choose the opt-out option and to prefer the maximum level of vaccine effectiveness compared to the baseline, as well as a Russian-manufactured vaccine compared to a Chinese one.

Table 3 reports the average class probabilities for each country obtained LC model. On average, we observed a higher probability of having refuser or hesitant class preferences in countries with lower stringency measures. This trend is primarily driven by the significantly lower probabilities reported in Eastern European countries, with the two Baltic countries, Latvia and Lithuania, reporting the lowest probability for respondents to report pro-vaccine preferences (31% and 38%, respectively). Conversely, the largest probabilities of belonging to the pro-vaccine class are reported for Singaporean (75%) and Norwegian (73%) respondents across the countries with two classes, and Brazilian (82%) Chilean (74%) and Spanish (66%) respondents across the countries with three classes.

When examining characteristics that predict class membership and the changes in uptake predicted probabilities by varying the attribute levels, we focus on the hesitant class, as policymakers should target this cohort to increase vaccination coverage in the event of a future pandemic (see OSM 1 for the full results).

3.2.1. Hesitant preferences class membership

Starting with the class membership (Table 4), an important caveat to this analysis is that we can only compare relative differences across individual parameter estimates because we cannot disentangle taste and scale differences (Vass et al., 2018). Accordingly, the following interpretations are made through this lens.

Table 3
Average class probabilities (%).

Low stringency	Refuser	Hesitant	Pro-vaccine	Med-low stringency	Nationalist Refuser	Refuser	Hesitant	Pro-vaccine
Croatia	43.5	–	56.5	Russia	7.6	38.7	13.5	40.1
Sweden	12.3	39.3	48.4	Latvia	–	50.3	18.7	31.0
Lithuania	44.1	18.2	37.6	Slovenia	–	38.5	18.7	42.8
Turkey	21.2	21.3	57.5	United Kingdom	–	13.8	22.8	63.8
Norway	–	26.7	73.3	Spain	–	14.0	19.5	66.5
Slovakia	35.9	18.6	45.9	France	–	26.5	24.1	49.4
Med-high stringency				**High stringency**				
South Africa	27.0	18.3	54.7	United States	–	20.8	20.7	58.5
South Korea	15.3	31.1	53.5	Australia	–	12.5	20.7	66.8
Singapore	–	24.7	75.3	Brazil	–	6.9	11.4	81.7
Israel	–	29.3	70.7	Italy	–	16.8	22.1	61.1
				Chile	–	13.4	12.8	73.8

Table 4
Class membership for the hesitant class.

Hesitant class	Age	Female	Bachelor	High income	Urban	Children	Vaccinated
Low stringency							
Croatia±	–	**-**	–	–	–	–	–
Sweden (ref: pro vaccine)	**−0.83*****	−0.15	−0.15	0.1	−0.15	**0.26****	**−0.98*****
	(0.13)	(0.12)	(0.12)	(0.16)	(0.12)	(0.13)	(0.26)
Lithuania (ref: pro vaccine)	−0.18	0.00	0.22	−0.10	−0.08	−0.07	**−1.34*****
	(0.20)	(0.19)	(0.22)	(0.38)	(0.19)	(0.20)	(0.46)
Turkey (ref: pro vaccine)	**−0.39*****	**−0.32*****	0.16	−0.04	**−0.32****	**−0.46*****	**−1.72*****
	(0.11)	(0.1)	(0.11)	(0.1)	(0.13)	(0.11)	(0.23)
Norway (ref: pro vax)	−0.14	0.01	0.05	0.16	−0.12	−0.14	**−2.73*****
	(0.17)	(0.17)	(0.16)	(0.36)	(0.17)	(0.18)	(0.30)
Slovakia (ref: pro vaccine)	**−1.08*****	**−0.63*****	−0.05	0.03	0.24	−0.40*	**2.40*****
	(0.25)	(0.22)	(0.24)	(0.28)	(0.24)	(0.24)	(0.24)
Med-low stringency							
Russia (ref: pro vaccine)	**−0.59*****	**0.42*****	0.20	**−0.43*****	−0.09	**−0.56*****	**−1.01*****
	(0.13)	(0.13)	(0.14)	(0.16)	(0.15)	(0.14)	(0.13)
Latvia (ref: pro vaccine)	**−0.74*****	−0.05	0.19	0.24	0.20	**−0.49****	**−0.83*****
	(0.20)	(0.19)	(0.20)	(0.23)	(0.19)	(0.21)	(0.34)
Slovenia ±	–	–	–	–	–	–	–
United Kingdom (ref: pro vaccine)	**−0.81*****	−0.13	−0.14	0.06	−0.04	−0.08	**−1.73*****
	(0.10)	(0.10)	(0.10)	(0.16)	(0.11)	(0.10)	(0.24)
Spain (ref: pro vaccine)	**−0.35*****	−0.17*	0.12	0.27	−0.03	**−0.25****	**−1.81*****
	(0.10)	(0.10)	(0.10)	(0.19)	(0.10)	(0.10)	(0.32)
France (ref: pro vaccine)	**−0.60*****	−0.02	0.17	−0.00	0.10	−0.10	**−1.45*****
	(0.09)	(0.09)	(0.11)	(0.12)	(0.11)	(0.10)	(0.24)
Med-high stringency							
South Africa (ref: pro vax)	**−0.48*****	−0.04	**0.35*****	−0.17	−0.12	**−0.43*****	**−1.32*****
	(0.13)	(0.11)	(0.11)	(0.12)	(0.11)	(0.12)	(0.13)
South Korea (ref: pro vax)	**−0.73*****	0.16*	−0.02	−0.02	−0.02	0.00	**−1.45*****
	(0.10)	(0.09)	(0.10)	(0.13)	(0.11)	(0.10)	(0.22)
Singapore (ref: pro vax)	0.09	**0.20****	−0.10	**−0.38*****	**0.26****	−0.19*	**−2.15*****
	(0.09)	(0.09)	(0.09)	(0.11)	(0.11)	(0.10)	(0.09)
Israel (ref: pro vax)	**0.39****	**−0.49*****	0.16	−0.06	0.09	−0.17	**2.82*****
	(0.18)	(0.16)	(0.16)	(0.21)	(0.16)	(0.18)	(0.18)
High stringency							
United States (ref: pro vaccine)	**−0.55*****	0.01	−0.16	**−0.46*****	**−0.39*****	0.07	**−1.08*****
	(0.10)	(0.10)	(0.11)	(0.17)	(0.11)	(0.10)	(0.15)
Australia (ref: pro vaccine)	**−0.30*****	−0.07	0.11	0.15	−0.02	**−0.25****	**−1.04*****
	(0.10)	(0.10)	(0.11)	(0.13)	(0.10)	(0.10)	(0.25)
Brazil (ref: pro vaccine)	**−0.30****	**−0.33****	−0.24*	**−0.32****	−0.20	−0.03	**−2.01*****
	(0.14)	(0.13)	(0.14)	(0.15)	(0.14)	(0.14)	(0.36)
Italy (ref: pro vaccine)	**−0.38*****	0.06	**0.21****	−0.14	0.08	0.07	**−2.00*****
	(0.11)	(0.10)	(0.10)	(0.13)	(0.10)	(0.11)	(0.59)
Chile (ref: pro vaccine)	**−1.01*****	−0.15	0.03	−0.17	0.13	−0.20	**−1.76*****
	(0.15)	(0.12)	(0.14)	(0.13)	(0.13)	(0.13)	(0.43)

Note: ± In the Croatian and Slovenian sample we only identified the pro vaccine and refuser classes. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Standard errors in parenthesis.

Our analysis revealed that being fully vaccinated against COVID-19 at the time of data collection was the most significant individual characteristic associated with class membership, showing statistical significance across all countries. Being fully vaccinated against COVID-19 was more likely to predict pro-vaccine class preferences ($p < 0.01$). Similarly, older respondents were more likely to report pro-vaccine class preferences compared to young respondents across most countries, aligning with our hypothesis that respondents more at risk are also more likely to accept the vaccine, regardless of the restrictions in place.

Gender, educational level, income and living in an urban area provided mixed findings on the probability of belonging to the hesitant class compared to the pro-vaccine class. However, we observed statistically significant effects only in a few countries. Lastly, having children was not found to be a strong predictor for characterizing hesitant class preferences across countries. However, some country-specific variations were observed. Turkish, Russian, Latvian, South African, and Australian parents reported a smaller probability of belonging to the hesitant class ($p < 0.05$), potentially revealing a tendency of parents to avoid risk with their health given their duty of care ($p < 0.05$). Swedish respondents with children were the only ones reporting the opposite findings ($p < 0.05$), possibly revealing higher concerns about vaccination because of their duty of care.

3.2.2. Predicted vaccine uptake and percentage changes in predicted uptake probabilities

We focused on the predicted uptake probabilities focusing on the hesitant class preferences to provide policy insights for future vaccination programs strategies and to explore the relative importance of the various attributes. We excluded respondents from Croatia and Slovenia from this analysis as we did not identify hesitant classes there according to our classification.

Our base case is the choice between the opt-out and a vaccination program characterized by attributes at their baseline levels, except for the risk of severe side effects which we assumed to be at its highest level (i.e., 20 out of 100,000). Fig. 3 reports the predicted uptake assuming hesitant class preferences. Respondents from the US (22%), Turkey (20%), and South Africa (15%) were relatively more likely to accept the baseline vaccination option compared to the opt-out option. Conversely, Lithuanian, Israeli, Italian, Norwegian, and Singaporean respondents all report a very low probability of uptake (<5%).

In Fig. 4, we report the percentage changes in predicted probabilities by improving one attribute to its maximum level at a time. For simplicity, we excluded the coefficients for the time to market approval, the UK manufacturer, and the imposition of mandate due to their small magnitude.

While we observed heterogeneity across countries, some clear patterns emerged: improving the effectiveness of the vaccine, reducing the risk of severe side effects, and administering a vaccine from a Western manufacturer (compared to a Chinese one) increased the predicted uptake of the vaccine. Based on these results, we can infer that these three attributes were the most important for respondents within the hesitant class. Interestingly, moving from full social restrictions to no restrictions, without improving the features of the vaccine, produced a relatively low increase in the predicted probability for uptake (generally below 5%). Overall, these results suggest that the hesitant population places greater importance on the characteristics of the vaccine rather than the societal restrictions they face when deciding whether to get vaccinated.

4. Discussion

This paper examined preferences for hypothetical vaccination programs in a future pandemic, surveying respondents from 21 countries across six continents. The primary aim was to consider the challenges confronted by policymakers in shaping effective vaccination campaigns and provide forward-looking insights to inform strategies for future pandemics. Using an online DCE, we elicited public preferences for vaccination programs, quantified the trade-offs individuals make between vaccine attributes and societal restrictions, and explored how these preferences and trade-offs varied across key sociodemographic factors.

Our study employed the largest sample size to date for a DCE in this field. This included diverse institutional and geopolitical dimensions spanning political systems, economic profiles, and healthcare systems. This diversity helps to ensure the broad applicability of our findings, providing a valuable resource for both current and future vaccination policies. Furthermore, unlike previous research, our study simultaneously explored trade-offs between vaccine characteristics and social restrictions, a crucial aspect for designing effective pandemic policies. The timing of the data collection – post widespread COVID-19 vaccination – allowed respondents to make informed choices based on both the descriptions of attributes included in the experiment and their personal experience.

4.1. Beyond a binary classification of vaccine attitudes

Our latent class analysis classified respondents into three or more distinct subgroups in most countries ($n = 16$) based on their attitudes to vaccination: vaccine refusers/fearers, vaccine hesitant, and pro-vaccine individuals. This classification is in line with previous DCE studies on vaccination preferences (Determann et al., 2016; Hess et al., 2022) and echoes classical work on vaccine hesitancy (Dubé et al., 2021; Morillon and Poder, 2022).

Vaccine refusal remains a key public health issue to tackle. Even in our hypothetical scenario, almost one fifth of our respondents (19% on average in the overall sample) opted out and preferred no vaccine program across all choice tasks. However, we were able to measure strong preferences for improved vaccine characteristics even in the refuser classes, potentially indicating that a portion of these respondents are not outright refusers but rather very fearful of vaccines and their consequences. This confirms the finding that only a very small minority are radically antivaccine (Dubé et al., 2021).

4.2. Vaccine features are prioritized over societal restrictions in decision making

Studies prior to the distribution of COVID-19 vaccines found that people might be willing to sacrifice some freedoms during a severe pandemic in exchange for the protection offered by social restrictions (Manipis et al., 2021). However, this study highlighted that vaccine characteristics are significantly more relevant than social restrictions in determining an individual's decision to vaccinate across countries and classes. Indeed, an effective vaccine might reduce the burden of long-term social restrictions on individuals (Bughin et al., 2023), allowing policymakers greater flexibility in easing social restrictions or managing pandemic-related social restriction measures. For instance, restrictions and vaccine requirements can be targeted at specific groups, such as the elderly or those more susceptible to contagion, aligning with

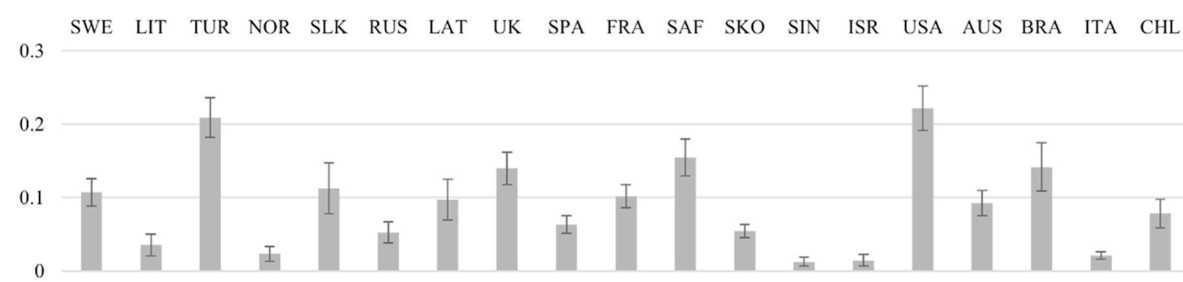

Fig. 3. Predicted vaccine uptake (%) with baseline vaccination program versus opt-out option (Hesitant class preferences).

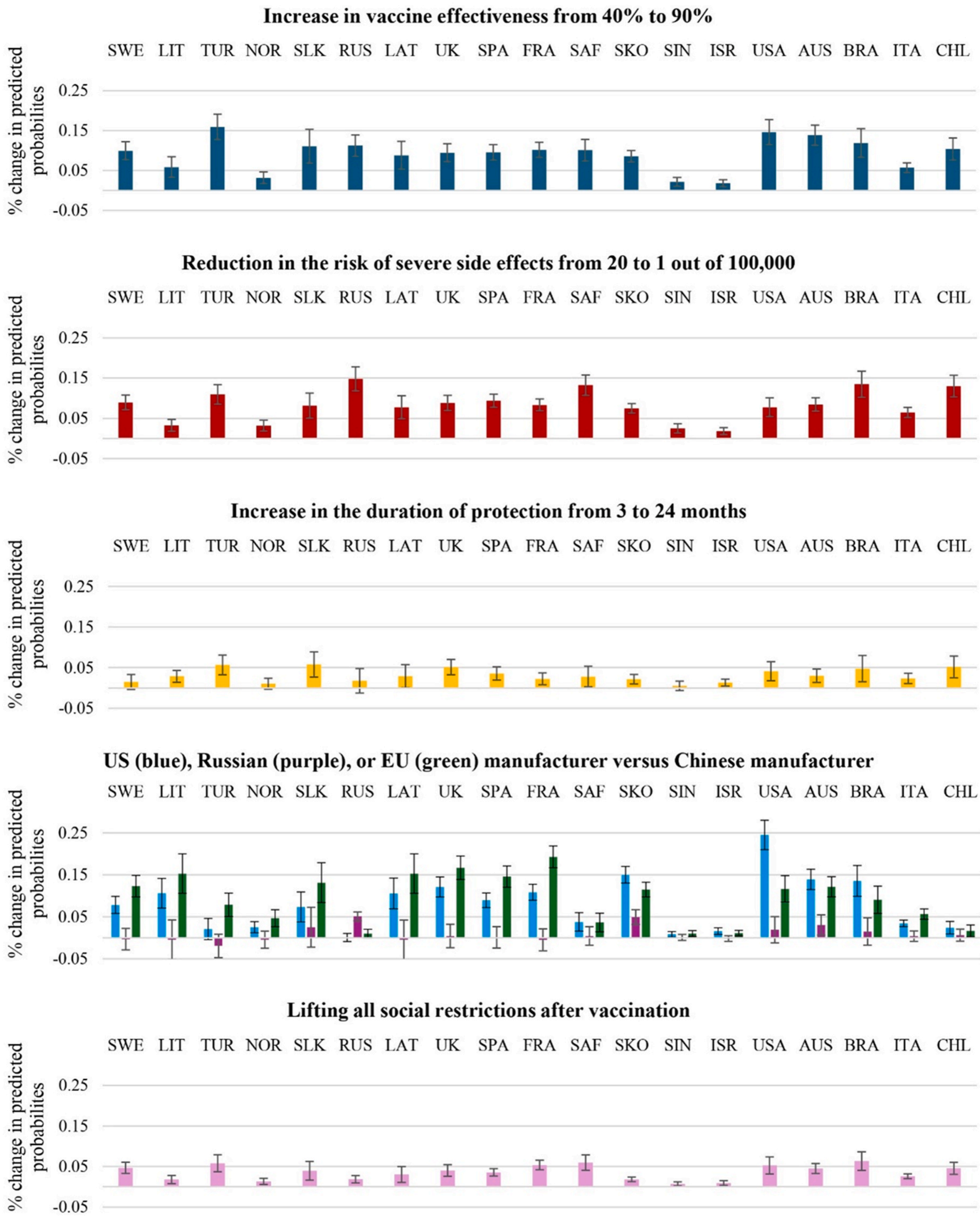

Fig. 4. Percentage changes in predicted vaccine uptake probabilities by improving one attribute from its baseline level to its maximum level at a time (Hesitant class preferences).
Notes: For simplicity, we excluded the coefficients for the time to market approval, the UK manufacturer, and the imposition of mandate due to their relatively small magnitude compared to the other attributes.

overarching policy goals like ensuring schooling or safeguarding key economic sectors (Manipis et al., 2021; Sicsic et al., 2023).

Although vaccine characteristics were more influential in decisions to vaccinate, an aversion to full-scale social restrictions, such as lockdowns, also significantly affected decision-making. Full lockdown scenarios were significantly associated with lower willingness to be vaccinated. However, there was little difference between preferences associated with either some levels of social restrictions or null social restrictions: decisions to vaccinate were relatively unaffected by social restrictions under either condition. This might suggest that respondents tend to perceive restrictions in binary terms (i.e., any restrictions vs no restrictions).

4.3. *Vaccine nationalism drives vaccine acceptance*

The strong emphasis on vaccine origin across all classes corroborates prior research on vaccine nationalism, the attachment of a 'national' character to vaccines (Vanderslott et al., 2021). For instance, respondents from the US, the UK, and all other European countries (e.g., Croatia, France, Italy, Latvia, Norway, Slovenia, Slovakia, Spain, Sweden) exhibited positive and relatively stronger preferences for locally produced vaccines over those from China. Australian respondents also showed stronger preferences for UK-produced vaccines compared to Chinese-produced ones. Exceptions were found in Chile, South Africa, where respondents placed the highest relative importance on the risk of severe side effects or vaccine effectiveness. This result might be attributed to lived experience: the vaccines available in these countries, primarily manufactured in China, were less effective than the mRNA vaccines produced in Western countries (Ndwandwe and Wiysonge, 2021). We expected respondents from countries with access to the most effective vaccines (i.e., mRNA vaccines) to be less sensitive to the origin of the manufacturer in a future pandemic compared to those with access to less effective vaccines and this was not borne out in our data.

Previous research presents mixed evidence regarding preferences for domestically manufactured vaccines across countries. In the US (Daziano and Budziński, 2023; Kreps et al., 2020; Motta, 2021), France (Schwarzinger et al., 2021), and Canada (Morillon and Poder, 2022), domestic vaccines were preferred compared to imported vaccines, in line with our findings. The opposite was observed in China (Dong et al., 2020) and Iran (Darrudi et al., 2022). Other studies found no effect of the vaccine origin from US and German respondents (Kobayashi et al., 2021). These national differences are likely to be shaped by various influences including vaccine developers and domestic factors, such as government support, local debates, regulatory responses, and media coverage.

Individual vaccine nationalism is not inherently negative. A preference for domestically manufactured vaccines reveals trust in national authorities, which policymakers can leverage to increase vaccine uptake. However, this lever is effective only if the country has the capacity to produce effective vaccines. Otherwise, as demonstrated by the Australian experience during COVID-19 (Gillespie et al., 2022), vaccine nationalism can become detrimental, slowing down vaccine uptake. To counteract vaccine nationalism, governments should strengthen international entities like the WHO, establish a robust multilateral response, and enhance public trust in regulatory authorities. Achieving this necessitates significant investments in campaigns promoting regulatory authorities, greater authority for supranational organizations, and political commitment to establishing new international regulatory bodies (Sachs et al., 2022).

4.4. Vaccination mandates are less influential than expected

Vaccine mandates prompt significant debate in the literature and the political arena (Attwell et al., 2022b; Omer et al., 2019). However, our study indicated that individuals placed relatively low importance on these measures compared to other attributes, especially in countries with low to medium stringency or other pandemic control measures. Some exceptions were noted across respondents in Brazil, Lithuania, and South Africa in the pro-vaccine classes, who reported a willingness to accept risk in line with the other attributes.

We found mixed outcomes comparing preferences across countries with established traditions of vaccine mandates against those without such practices. For example, the hesitant and the pro-vaccine classes from Spain, a nation without a tradition of mandates, expressed positive preferences (on average) for them. Conversely, France, Croatia, Latvia, and Slovenia, which have mandates for childhood immunizations, exhibited weak or no statistically significant preferences for mandates overall. The Italian sample, which experienced COVID-19 vaccine mandates to access public venues and return to work, reported positive preferences for them, both in the pro-vaccine and the hesitant classes. This support does not mean that policymakers should rely on coercive measures to drive vaccine uptake. Public education and vaccine accessibility remain crucial strategies (Dubé et al., 2021).

4.5. The importance of exploring preference heterogeneity

The variability observed in our estimated models across population subgroups underlines the importance of exploring preference heterogeneity. Support for policy options at the population level may differ significantly between countries, even if there is apparent support from the average decision-maker within each country.

We cannot completely disentangle preference from scale heterogeneity– and thus cannot be definitive in our conclusions – but our findings regarding the characteristics associated with vaccine refusal and hesitancy broadly align with those reported in previous literature (Gagneux-Brunon et al., 2023; Harapan et al., 2022; Hess et al., 2022; J. V. Lazarus et al., 2023), and our a-priori hypotheses.

Previous experience with vaccination significantly increases the likelihood of individuals receiving a vaccine in the future (Endrich et al., 2009). Therefore, it is essential for vaccination to become a habitual practice within the population, not just during exceptional times like future pandemics. Policymakers must guarantee easy and affordable access to vaccines, while also designing effective communication campaigns to raise awareness about the availability of vaccines and their positive impacts on public health.

Older individuals were more likely to belong to the pro-vaccine class, while female respondents were more likely to belong to the vaccine-refuser class compared to their male counterparts (Morillon and Poder, 2022). Women's higher hesitancy or aversion towards vaccines is established in the literature (Reich, 2016). More research focusing on women is needed to deeply understand the drivers and the behavioral insights associated with these findings. The key starting point for addressing this challenge is the need to incorporate a greater representation of women- and girls-led groups in vaccine program development and design (Nassiri-Ansari et al., 2022).

A socioeconomic gradient arose in vaccination attitudes, although this was not uniform: broadly, respondents with higher income and education were more likely to report pro-vaccine or at least hesitant class preferences. Reducing inequalities in vaccination outcomes remains a key issue for policymakers to resolve in future pandemic policies. Governments must consider lower-income earners' access to vaccinations and refine communication, outreach and education concerning the positive effect of vaccination for this group. This group may also be receptive to hearing about the potential of successful vaccination programs to allow them to escape social restrictions and resume normal life (Habersaat et al., 2020; Hudson and Montelpare, 2021).

4.6. The role of policy stringency and vaccine availability

Our analysis is not able to directly measure how the level of social restrictions experienced during COVID-19 might have affected respondents' preferences, but our categorization provides some insights that could be explored further in future research. For instance, we observed a significant difference in the proportion of pro-vaccine individuals between high- and low-stringency countries. Specifically, high- and medium-high stringency countries show a clear difference in class probabilities (at least 25% and 22%, respectively) compared to low-stringency countries, where the difference is less pronounced (e.g., only 1.4% in Russia or 6% in Lithuania). A possible explanation is that, in countries with higher levels of restrictions, respondents were often required to be fully vaccinated to re-engage in typical activities. Having experienced the positive effects of the vaccine in relieving restrictions may reduce doubts or fears about receiving a vaccine for a future disease. Furthermore, most countries with high stringency policies were also countries with lower-than average levels of hesitancy before COVID-19 (de Figueiredo et al., 2020). Low hesitancy might make the implementation of stringent measures less costly for policymakers.

The type of COVID-19 vaccines available in each country may also affect these preferences. Most of the countries in the high-stringency group had access to the more effective mRNA vaccines, whereas medium-low and low-stringency group countries had a more mixed distribution, especially at the beginning of the vaccination campaigns. For example, respondents in Croatia, Slovakia, Slovenia, Sweden, and Latvia had a higher share of AstraZeneca vaccines, which were less effective than the mRNA vaccines and less used after initial market authorization. In contrast, Russian respondents only had access to the Sputnik vaccine. This explanation also seems plausible when considering other medium-low to low-stringency countries, such as Norway, Spain, and France, which primarily had access to mRNA vaccines and reported class probability differences similar to those of the medium-high and high-stringency groups.

Future research should further investigate the role of stringency and proportion of different vaccine origins in the country in influencing the willingness to get vaccinated.

4.7. Limitations

Our study is not exempt from limitations. First, utilizing online platforms might have introduced selection bias in the sample, potentially excluding certain demographic groups. Although our sample was representative in terms of age, gender, and geographical distribution across countries, it was not fully representative of the underlying population. Specifically, we observed an upward bias in education levels across most countries, as well as some differences in income levels. This is likely due to the mode effect inherent in online surveys, which often exclude less educated and poorer individuals, especially those without internet access (Grewenig et al., 2023). Additionally, there is a tendency for more educated individuals to self-select into these surveys. Consequently, our findings should be validated with face-to-face surveys to mitigate these biases.

Second, lessons learned about preferences from this study may not be transferable to low-income countries. Our sample underrepresented countries from the Asian and African continents, in which online data collection is more challenging. Future research should focus on these countries and provide policy insights following previous research like the one conducted by Harapan et al.(2022).

Third, the heterogeneity in preferences could be influenced by varying pandemic conditions during the data collection period, which we cannot account for in our analysis. Fourth, while the inclusion of a large sample of countries using a standardized questionnaire is a key strength of this study, the volume of data may limit our ability to conduct in-depth analysis of certain findings. To address this potential limitation, we are conducting additional country-specific analyses to reinforce our findings.

Fifth, we specified a design focused on main effects only, in line with previous studies (Determann et al., 2016; Dong et al., 2020; Luyten et al., 2019). Although a D-efficient design allows for some limited correlation between the attributes (Szinay et al., 2021), we acknowledge that interaction effects among attributes may be present, and we encourage future research to design more complex experiments that account for these effects and compare the findings with ours.

Sixth, while we randomized the choice tasks across respondents to minimize the effects of choice set ordering, we did not randomize the attributes, because we sought to enhance comprehension and understanding for respondents, improve choice consistency (Heidenreich et al., 2021; Norman et al., 2016), and avoid nonintuitive attribute orderings (Kjær et al., 2006). Indeed, given the relatively large number of choice tasks (n = 12), using a fixed attribute order helped respondents identify the various attributes more easily when transitioning between tasks, as validated during think-aloud interviews. However, attribute ordering effects have been identified in the literature (Boxebeld, 2024), and we cannot fully exclude the possibility that such effects influenced our results. Further, the phrasing of attributes (i.e., positively versus negatively worded) may have influenced respondents' preferences. This is a critical issue in stated choice experiments (Kragt and Bennett, 2012), particularly concerning risk attributes(Veldwijk et al., 2016). We chose to phrase the risk attributes negatively, aligning with the common language used by the media, experts, policy documents, and the scientific literature from vaccine clinical trials, thereby enhancing the external validity of the study. Moreover, prospect theory suggests that individuals tend to be more sensitive to potential losses than equivalent gains (Kahneman and Tversky, 1979). In the context of vaccine decision-making, framing in terms of risk (potential loss) may more accurately capture the decision-making process of individuals considering vaccination.

Seventh, other models could have been run to investigate preference heterogeneity, including mixed multinomial or nested logit models. We chose LC models for two main reasons. First, based on literature, vaccine hesitancy is a spectrum with distinct groups (refusers, hesitant, accepters), making LC models more informative than alternatives like mixed logit models. Second, LC models showed better statistical performance, with superior fit indicators such as Log-likelihood, pseudo R^2, AIC, and BIC. Similarly, we could have simulated more complex scenarios to predict the percentage changes in predicted uptake or we could have selected different changes across levels (e.g., from 60% to 90% effectiveness). However, we opted for a simpler approach to focus on the relative importance of attributes and provide clear policy insights.

Lastly, despite grouping the countries by the median stringency level over the COVID-19 pandemic and observing a larger probability of belonging to the no-vaccine or the vaccine-hesitant classes in lower stringency countries, we were not able to draw causal conclusions. Future research should explore more in detail if there is a significant association between the level of the stringency applied by the government and vaccination behaviors.

5. Conclusion

An optimal combination of pharmaceuticals and NPIs is required to design vaccination policies that limit adverse outcomes in a future pandemic. Our study indicated that respondents generally preferred improvements in vaccine attributes over improvements in social restriction attributes. This highlights the need for a balanced approach that combines improved vaccine characteristics with the implementation of flexible social restriction measures. While vaccine mandates may enhance vaccination coverage in the short term, the primary challenge in preparing for future pandemics is likely to be addressing vaccine nationalism. Countries must either collaborate to establish international regulatory bodies to bolster trust in manufacturers universally or invest significantly in domestic production facilities to leverage this national sentiment for higher vaccination rates. These strategies must be supported by strong investments in public health infrastructure, education, and regulatory frameworks to improve vaccine acceptance and access.

CRediT authorship contribution statement

Marcello Antonini: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mesfin G. Genie:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Katie Attwell:** Writing – review & editing, Validation, Supervision. **Arthur E. Attema:** Writing – review & editing, Methodology. **Jeremy K. Ward:** Writing – review & editing, Validation. **Alessia Melegaro:** Writing – review & editing, Investigation, Funding acquisition. **Aleksandra Torbica:** Writing – review & editing, Investigation, Funding acquisition. **Brian Kelly:** Writing – review & editing, Supervision, Funding acquisition. **Chiara Berardi:** Writing – review & editing, Methodology, Conceptualization. **Ana Rita Sequeira:** Writing – review & editing, Investigation, Funding acquisition. **Neil McGregor:** Writing – review & editing, Investigation, Funding acquisition. **Adrian Kellner:** Writing – review & editing, Investigation, Funding acquisition.

Shuli Brammli-Greenberg: Writing – review & editing, Validation, Resources. **Madeleine Hinwood:** Writing – review & editing, Supervision, Resources. **Liubovė Murauskienė:** Writing – review & editing, Investigation, Funding acquisition. **Daiga Behmane:** Writing – review & editing, Investigation, Funding acquisition. **Zsolt J. Balogh:** Writing – review & editing, Supervision. **Terje P. Hagen:** Writing – review & editing, Resources, Investigation, Funding acquisition. **Francesco Paolucci:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization.

Ethical approval

This study received ethical approval from the Human Care and Ethics Committee of the University of Newcastle (Approval No. H-2021-0363).

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Declaration of competing interest

J.K.W. is a member of the Commission Technique des Vaccinations at the Haute Autorité de la Santé. The other authors have nothing to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2025.117687.

Data availability

Data will be made available on request.

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