Health Policy and Technology 15 (2026) 101156

Contents lists available at ScienceDirect

Health Policy and Technology

journal homepage: www.elsevier.com/locate/hlpt

Vaccination preferences and predictors of vaccine hesitancy in Brazil: A discrete choice experiment

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ARTICLE INFO

Keywords:
Immunisation
Vaccine
Hesitancy
DCE
Brazil
COVID-19

ABSTRACT

Objective: This study investigates the extent to which individual characteristics and preferences towards vaccine attributes and societal restrictions influence vaccination behaviour in a representative Brazilian population.
Method: We conducted a discrete choice experiment (DCE) involving 3,001 Brazilian respondents from July to September 2022 through an online panel. The DCE involved five vaccine features and two social restriction features. Participants were presented to a sequence of binary choices of hypothetical vaccination programs, with an option to opt-out. We performed multiple regression models to investigate the predictors of vaccination and opt-out decisions. We also performed a latent class logit model to estimate trade-offs between vaccination attributes and societal restrictions across groups.
Results: Our regression results identified that gender, religiosity, income, political orientation and trust in public health institutions were important predictors of vaccination decisions in Brazil. Our latent class models indicated significant heterogeneity and detected four main classes: (i) left-leaning, pro restrictions, who showed strong preferences for vaccine features such as its effectiveness (62.4%); (ii) left-leaning, pro mandates, who showed strong support for societal restrictions (19.5%); (iii) centrists, pragmatics, who were opposed to restrictions but supportive of vaccine features (11.4%); (iv) right-leaning, vaccine refusers, who showed a willingness to opt-out from vaccination programmes and did not show any preferences for vaccine features (6.7%).
Conclusions: Our findings suggest that the Brazilian population had overall high willingness to accept vaccines and displayed high trust in public health authorities. Nonetheless, the presence of a non-negligible proportion of cautious and hesitant groups may prevent the effectiveness of vaccination campaigns in the future.
Lay summary: This study investigated the factors that influence people's decisions to get vaccinated in Brazil. We asked 3,001 participants to choose between different vaccination programs with various features, including vaccine effectiveness and the presence of social restrictions. We found that factors such as gender, income, religion, political views, and trust in public health institutions affected people's vaccination decisions. The study also identified four groups: one strongly supports vaccines and their characteristics, one supports both vaccines and social restrictions, another prefers vaccines but dislikes restrictions, and a fourth is more hesitant-refuser about vaccines and more likely to opt out of vaccination. Overall, most Brazilians showed high trust in vaccines and public health advice. However, a small but significant group remains hesitant and refusing, which could pose challenges for future vaccination efforts and public health policies. Understanding these groups can help design better strategies to improve vaccination rates and protect public health.

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https://doi.org/10.1016/j.hlpt.2026.101156

Available online 16 January 2026

Introduction

In 2019, the World Health Organisation (WHO) identified vaccine hesitancy as one of the top ten threats to global health [1], and in response to the COVID-19 pandemic, launched the Immunisation Agenda 2023 [2] to promote equitable vaccine access and uptake worldwide. Having achieved substantial improvements in childhood and maternal health through over five decades of expanded primary care and vaccination coverage [3,4], those 'hard-won gains' are now being tested, as illustrated by COVID-19 vaccine hesitancy and lower coverage of routine vaccination due to COVID-19 disruption [5]. Vaccine hesitancy, defined as concerns and doubts towards vaccination [6], exists on a spectrum and is influenced by a complex interplay of individual, contextual, and vaccine-specific factors [7,8]. Despite these factors, the continued development of vaccines targeting diseases such as malaria, tuberculosis, and HIV/AIDS [9] underscores the urgent need to better understand vaccine hesitancy.

Historically, Brazil's history on vaccination coverage and public health campaigns has been a role model to the Global South countries. The national health systems designed to deliver primary health services at local level, led to high levels of vaccination coverage.

Examining the literature on vaccine behaviours and factors associated with vaccine hesitancy in Brazil, it becomes evident that the complex interplay of individual attributes (economic, social, religious and gender-related) and geographical inequities in access to healthcare services constrained vaccine adherence [10–12]. The role of healthcare providers in overcoming information asymmetry and providing information about vaccine safety [13], as well as considering tailored information for male partners who influence vaccine adherence in their family has been also discussed in the literature [13]. There is a lack of research on the public preferences for vaccine characteristics and non-pharmaceutical interventions. Only one study could be found reporting on the perceptions about the short vaccine research and development process and its relation to vaccine safety and distrust [14].

Given the rapid changes in the vaccination discourse in Brazil with a significant role of political polarisation, social media and misinformation and a decline in the historical high immunisation coverage post-COVID-19, a Discrete Choice Experiment (DCE) becomes a useful tool to understand what attributes drive vaccine decision making, as well as segmenting population groups with distinct preferences.

This study aims to understand COVID-19 public preferences for pharmaceutical (vaccine characteristics) and non-pharmaceutical interventions (government mandates) concomitantly, as well as to examine the predictors of vaccination decision among the representative population surveyed in Brazil. This is the first discrete choice experiment (DCE) focused on COVID-19 in Brazil, combining data on government-led policy restrictions and public preferences for COVID-19 vaccines, with sociodemographic data, moral attitudes, risk and time preferences, and political opinions [15]. The database provides insights into the behavioural response and main predictors of vaccine hesitancy and refusal in Brazil. The literature review on the history of vaccination policies and hesitancy since the 19th century, alongside recent vaccination policies and hesitancy during COVID-19, provides a comprehensive historical background that will support our analysis on preferences for vaccination.

The original contribution of this manuscript is the combination of a unique database on public preferences toward vaccination and non-pharmaceutical intervention, as well as a review of secondary sources, both in Portuguese and English, of the history of vaccination and hesitancy in Brazil.

The rest of the manuscript is structured as follows. Section 2 provides a short story of the vaccination policies in Brazil from the 1850s until the onset of COVID-19. Section 3 describes succinctly the vaccination polices and hesitancy during COVID-19. Section 4 focuses on the methodology, describing the DCE design, recruitment and sample, as well as the econometric analysis. Section 5 discussed the findings, followed by Section 6 with the discussion of results, implications for policy and practice and conclusion.

History of vaccination policies and hesitancy

We provide a short story of the vaccination policies in Brazil from the early 19th century until 2019. Our revision of the literature will focus on government vaccination policies, significant disease outbreaks, and the creation of health institutions overseeing health and vaccination. The analysis of the government policies will also be complemented by how the Brazilian population reacted to them. To do so, we will uncover the literature on vaccine acceptance, hesitancy and refusal in the period under analysis. The section concludes with the description of recent vaccine coverage rates just before the onset of the COVID-19 pandemic.

XIX to 1960s

From the 19th century to the 1930s, Brazil's vaccination policy centred on smallpox due to its severity. The monarchy established institutions like the Vaccination Board for the Court (1811), the Imperial Vaccine Institute (1846), making smallpox vaccination mandatory in 1832 [16,17]. Under the First Republic (1889–1930), compulsory vaccination and quarantines were enforced, sparking public resistance, notably the 1904 "Vaccine Revolt" in Rio de Janeiro [18–20]. Physician Oswaldo Cruz led campaigns against smallpox, yellow fever, and plague, founding the Federal Serum Therapy Institute (1900), now Instituto Butantan. Despite some success in controlling smallpox by 1906, challenges persisted, including Brazil's decentralised health system, geographic barriers, and logistical issues with vaccine administration [18,21]. The 1918 Spanish flu exposed further weaknesses, with mortality peaking at 1,100 deaths per 100,000 in January 1919 [22].

1930s-1960s

Between the 1930s and 1960s, Brazil expanded public health through national programmes and international partnerships. The Ministry of Health was created in 1930, followed by disease-specific services in 1941 focusing on malaria, leprosy, tuberculosis, and rural endemic diseases [13]. Brazil collaborated with the World Health Organisation (WHO) and the Pan American Health Organisation (PAHO) to eradicate smallpox, malaria, and polio [23]. The 1966 National Plan for Smallpox Eradication emphasised community engagement, achieving eradication by 1973. Bilateral health diplomacy, especially with the US, provided financial support for malaria control [18,23].

1970s-2000s

In the late 20th century, Brazil underwent significant transformations in its public health services, marked by the creation of the National Immunisation Program (PNI) in 1973 and the National System of Epidemiological Surveillance in 1975 [24]. These initiatives aimed to eradicate infectious diseases such as smallpox (1973), polio (1994), and rubella (1996), and to establish a comprehensive National Immunisation Schedule by 1977 [24]. Despite initial challenges—including inconsistent municipal demographic data and limited local engagement—the expansion of preventative services gained momentum [25], particularly in response to the military dictatorship (1964-1985) and the global influence of the 1978 Alma-Ata Conference. The 1988 Constitution enshrined health as a universal right and state responsibility (article 196) [26], laying the foundation for the Unified Health System (SUS) in 1990, which prioritised universality, equity, decentralisation, and participatory governance [24,26].

A pivotal development within SUS was the 1994 launch of the Family Health Strategy (ESF), designed to deliver primary care through multidisciplinary teams and community health workers [24]. By 2019, ESF

had registered 62.6% of the Brazilian population—approximately 131 million people—with the highest coverage in the Northeast and South regions, particularly benefiting socioeconomically disadvantaged and rural populations [27,28].

2000 to 2019

Building on the positive achievements in the late 1990s, the 2000s were characterised by a significant expansion and introduction of new vaccines, free of charge and for all, funded through general taxation. Starting with the most vulnerable population and progressively expanding to the whole population (e.g. Hepatitis B, Influenza, HPV vaccine and meningococcal C), the progressive introduction of new vaccines in the National Immunisation Schedule from 2000 to 2019 is summarised in Appendix 1.

Examining the literature on hesitancy, a study by França et al. conducted a household survey in 2017-18 and reported high levels of vaccine trust (94.5%), defined as trust in the government and included in the National Immunisation Program. Further, 96.7% expressed intention to vaccinate (96.7%). The study identified health services barriers as the main factors contributing to vaccine hesitancy [12]. Brown and colleagues (2018) revealed a vaccine hesitancy rate of 16.5%, primarily attributed to lack of confidence (41.4%), doubts about vaccine efficacy and safety (25.5%), and concerns over adverse events (23.6%) [10]. In these studies, lower vaccine confidence was disproportionately reported among mothers with low educational levels, parents of children, and families with lower income, underscoring socioeconomic disparities in vaccine attitudes [10,12].

2019-present

Analysis of Brazil's Ministry of Health Immunisation dashboard [29] reveals a gradual decline in vaccination coverage rates since 2017, with notable variation across vaccine types—such as Meningococcus C, Hepatitis B, Penta, Pneumococcal, and BCG—and geographic regions, particularly the North and Northeast, which exhibit the lowest coverage levels (Appendix 2). Concurrently, data from the WHO Immunisation Data Portal indicate a resurgence of certain vaccine-preventable diseases over the past five years [30] (Appendix 3).

These trends unfold within a broader context of Brazil's historical commitment to public health and immunisation, juxtaposed against persistent structural challenges. Despite the country's internationally recognised achievements in vaccine development, production, and universal health coverage through the Unified Health System (SUS), ongoing issues such as geographic disparities, a decentralised federal health system, limited infrastructure and workforce, and pronounced economic inequalities continue to hinder progress. Moreover, systemic weaknesses in immunisation services [12] and rising vaccine hesitancy risk [10] undermining the substantial public health gains Brazil has historically achieved.

Vaccination policies and hesitancy during COVID-19

Prior to the COVID-19 pandemic, Brazil faced significant systemic challenges in both its healthcare infrastructure and economy, with over 213 million residents - 17 million of whom lived in densely populated slums lacking basic sanitation [31,32]. This context was compounded by high unemployment, a large informal labour sector, chronic underfunding, medical staff shortages, and the influence of economic austerity and far-right political shifts [33,34]. In our previous research, we identified three phases in Brazil's pandemic policy response [21,35] (Fig. 1). The initial phase (February 2020 to January 2021), characterised by the absence of vaccines, relied on non-pharmaceutical interventions (NPIs) such as social distancing, school closures, and event bans, which were implemented inconsistently across states and lacked coordination between federal and state government levels [36,37]. The Oxford COVID-19 Government Response Tracker revealed significant variation in policy stringency [38], with states like Rondônia enforcing strict measures early, while others, such as Mato Grosso do Sul, imposed minimal restrictions. The federal government's failure to coordinate efforts, its dissemination of misinformation, and its minimisation of the virus's severity further hindered a unified national response [39–41].

Phase two of Brazil's COVID-19 response was marked by the initiation of the national vaccination campaign on 17 January 2021, coinciding with the third wave of infections driven by the Delta variant, which resulted in the highest global mortality rate at the time - 14 deaths

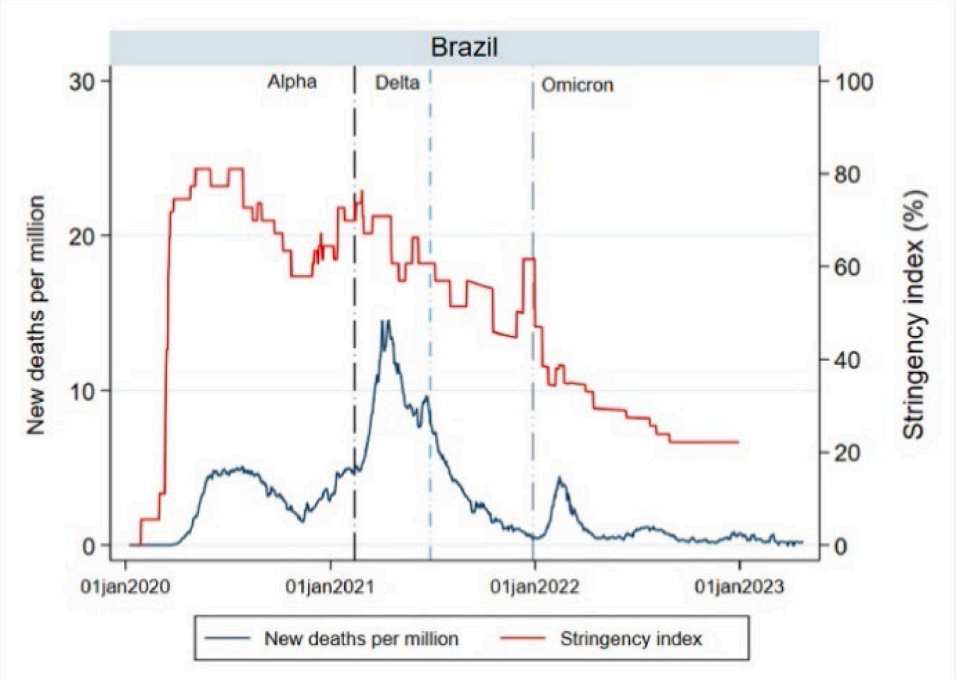

Fig. 1. Brazil: COVID-19 deaths per million and stringency index 2020–2023.

per million on 1 April 2021 [42]. The government, echoing its historical stance on vaccination, declared COVID-19 vaccination compulsory under Decree 13.979/2020 [43], emphasising collective responsibility. Implementation of the National Operation Plan for Vaccination was delegated to municipalities, supported by state governments. Priority groups included healthcare workers, elderly care staff, individuals aged 90 and above, indigenous populations, and institutionalised individuals [44,45].

Brazil leveraged its established role in global vaccine research and manufacturing through public-private partnerships to ensure vaccine access and distribution across its vast territory [21]. Despite initial delays and misinformation propagated by the former President Bolsonaro [46,47], the country achieved high vaccine uptake - 80.2% for the first dose, 72% for the second, and 28.5% for boosters by January 2022 [48]. However, coverage varied geographically, influenced by vaccine hesitancy in Bolsonaro-supporting municipalities [47] and limited access in socioeconomically disadvantaged areas [49].

The third phase came into effect in early 2022. With the vaccination roll-out well underway, and a reduction in the number of cases and deaths for COVID-19, in March 2022, the federal government declared COVID-19 as endemic, and the termination of the national public health emergency and its related exceptions [50]. This phase was characterised by minimal or no NPI, with a continuation of high uptake of vaccines and boosters.

Brazil's long-lasting trust in healthcare authorities and adherence to vaccination, alongside its community and multidisciplinary primary care network, had a protective effect towards adherence to vaccination, despite the high death toll, health inequities towards vulnerable groups and Bolsonaro's scientific denial of the pandemic and vaccine efficacy.

The absence of DCE studies on public preferences for vaccine characteristics and non-pharmaceutical interventions in Brazil during COVID-19 and in its aftermath, support the originality and significant contribution of this study. In this paper, we employed a DCE to uncover vaccine preferences and their drivers using a representative Brazilian population during the COVID-19 pandemic.

Materials and methods

Discrete choice experiment

To understand preferences for vaccination, we selected the attributes and levels following best practices indicated in the literature [51]. First, we conducted a literature review in Scopus to identify attributes used in previous vaccination preference studies. Second, we ranked these attributes using an expert scorecard completed by 26 experts working in the health policy and health economics domains. Finally, we validated the highest-scoring attributes and their associated visual icons through think-aloud interviews with 13 additional health systems and vaccination strategy experts. Detailed methodology is provided in Antonini et al. [8,15], with DCE design specifications in Appendix 4. Our DCE included seven attributes encompassing vaccine characteristics and societal restriction measures (Table 1). Attributes were presented using icon arrays, ratios, and percentages to ease comprehension [8,52] Respondents received detailed attribute descriptions and practice questions before choice tasks.

We generated an unlabelled DCE with two alternative vaccination programs and a follow-up question where respondents could confirm their choice or opt out of vaccination entirely. The opt-out reveals the extent to which participants are hesitant to (or willing to refuse) the vaccine, and will be used in the results section as a key proxy for vaccine hesitancy and refusal.

An example of the choice task is presented in Fig. 2. A D-efficient design focused on main effects only, incorporating non-zero priors based on expected preference directions, was employed to generate 36 choice tasks. These were divided into 3 blocks so that each respondent had to face 12 tasks. The design was optimised for the estimation of a multinomial logit (MNL) model and created using NGENE software [53].

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

The order of the 12 tasks within each block was randomised for each participant to minimize potential ordering effects [54]. We imposed a dominance constraint in the experimental design to prevent the co-occurrence of 90% vaccine effectiveness with full societal restrictions (i.e., lockdown), as this combination was deemed unrealistic given that most countries relaxed lockdown measures for vaccinated populations during COVID-19, based on confidence in vaccine effectiveness.

Recruitment and sample

We recruited a demographically representative sample (n=3,001) of Brazilian respondents between July 1, 2022, and September 20, 2022, as a part of the larger VaxPref study [15]. Participants were recruited through online panels by the market research company DemetraOpinioni, ensuring representation across age groups, gender, and geographical distribution of Brazilian states. To determine the minimum sample size (approximately 250 individuals), we applied the parametric formula[1] developed by Louviere et al. [55]. Given our objective to explore preference heterogeneity, we increased the sample size to 3,001 within available budget constraints to maximize statistical power and information content. Age and gender quotas were interlocking, while regional/state quotas were applied independently. Quota sampling was

[1] The parametric approach suggests that the sample size required for the main effects depends on the number of choice sets per respondent, the true population proportion, the one minus true population proportion, the inverse cumulative Normal distribution function, the allowed deviation from the true population proportion, and the significance level.

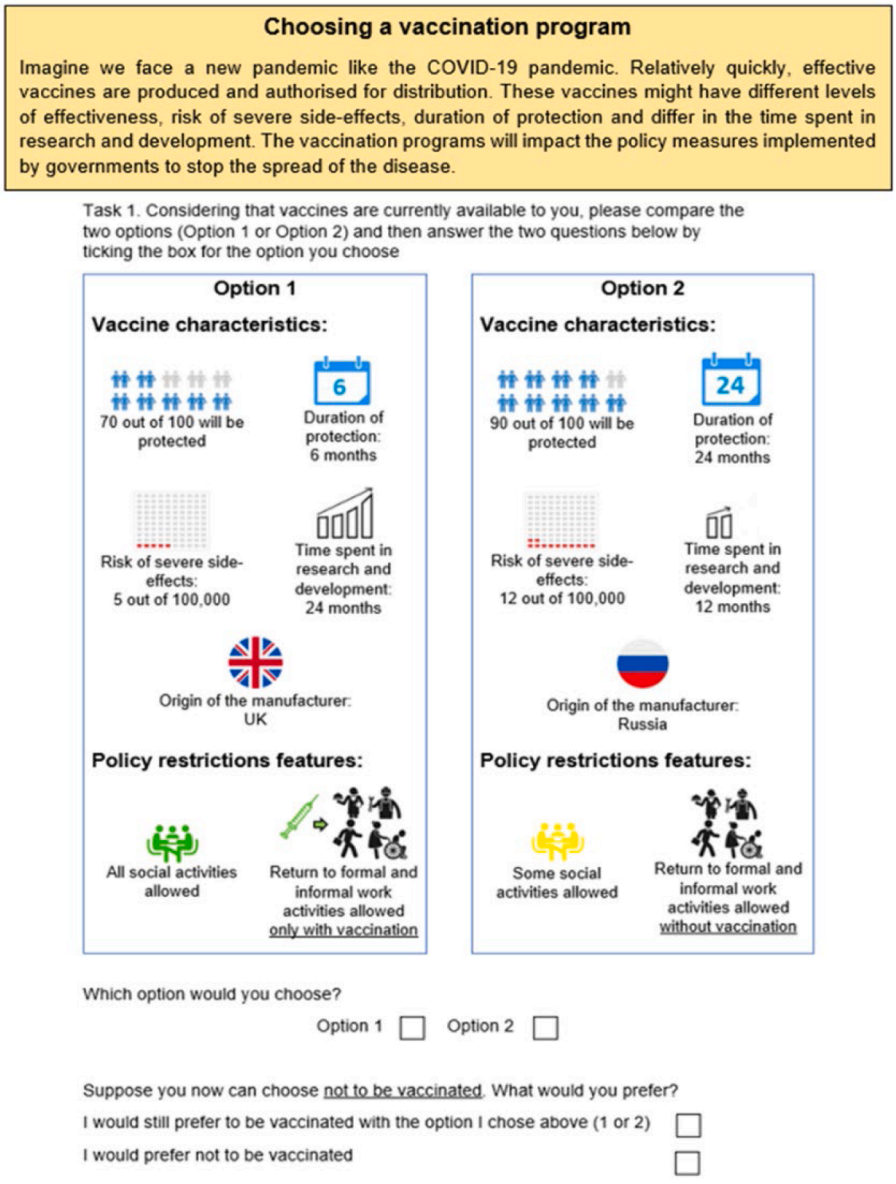

Fig. 2. Example of the choice task.

based on Brazilian official demographic statistics (see Appendix 4 for detailed sources). The survey was administered via the market research company's online platform.

Prior to quota completion, we identified and excluded speeders (i.e., respondents who completed the survey in less than 40% of the median completion time) and replaced them with new respondents meeting the quota criteria. Data quality was assessed through multiple mechanisms, including cross-validation of demographic information and profiling data to identify potentially fraudulent responses. For detailed information about data quality assurance and the collection process, see [8,15].

Econometric analysis

Logit and ordered logit analysis of vaccine acceptance

Our analysis investigates preferences and trade-offs regarding vaccine attributes and societal restrictions in future pandemic scenarios, identifying how these preferences vary across subgroups within the Brazilian sample. To identify relevant subgroups for inclusion in the DCE analysis, we first conducted two regressions examining revealed and stated vaccination behaviours.

The first model uses a logit specification with COVID-19 vaccination status as the dependent variable, incorporating demographic and attitudinal covariates relevant to vaccination decisions in the Brazilian context. Demographic covariates included age and its squared term (to control for non-linear effects), gender, highest educational attainment, high income status (>200% of median household income), religiosity (evangelical Christians versus other denominations), and residence in Southern/Southeastern states. Attitudinal covariates comprised trust in public health authorities and political orientation. Trust was measured through agreement with the statement "I trust public health authorities for pandemic management" (coded as 1 for responses from 'Slightly agree' to 'Strongly agree' and 0 otherwise). Political orientation used a -5 to +5 left-right scale, creating a binary leftist variable (1 for positions -5 to -1, 0 otherwise). This variable is particularly relevant given former President Bolsonaro's politicization of vaccination during COVID-19 [21,46,56].

To validate these findings and address limited variation in COVID-19 vaccination status (96% of participants reported full vaccination), we estimated an ordered probit model using the number of opt-out choices

in the DCE as the dependent variable, following Hess et al. and Attema et al. [57,58]. The ordered probit specification appropriately accounts for the ordinal nature of this dependent variable, which ranged from 0 to 12 opt-out choices across the choice tasks.

Conditional logit model and latent class model of vaccination program preferences

We analysed DCE choice data using random utility maximisation [59], which assumes that respondents choose the alternatives that maximise their utility.

We first used conditional logit models to estimate attribute effects on respondents' utility and verify that coefficient signs aligned with expectations. However, conditional logit assumes preference homogeneity across all respondents. To account for preference heterogeneity, we employed latent class (LC) models segmenting individuals into discrete classes with homogeneous within-class preferences [57]. Optimal class numbers balanced statistical efficiency (Bayesian Information Criterion [BIC], and Akaike Information Criterion [AIC]), parsimony, and interpretability [57]. The probability of class membership depends on individual and attitudinal characteristics. Based on the logistic and ordered probit regression results, we included the same demographic and attitudinal covariates with two exceptions. First, we excluded the squared age term given its minimal economic and statistical significance. Second, we added COVID-19 vaccination status (≥2 doses) amongst the attitudinal variables given its relevance for predicting future vaccination behaviours [8].

To address potential scale heterogeneity between classes [60], we calculated Marginal Rates of Substitution (MRS) using the risk of severe side effects as the denominator. Using the risk of severe side effects is advantageous as it provides a natural scale for trade-offs, expressed as additional cases per 100,000 people, facilitating intuitive interpretation and cross-attribute comparisons. We tested linearity and proportionality of risk level coefficients (5,12, 20 per 100,000), failing to reject the null hypothesis ($\chi^2 = 3.71$, $p = 0.16$). Overall, the MRS provides a scale-free measure of the additional risk of severe-side effects per 100,000 people that individuals are willing to accept for improvements in other vaccine or social restriction attributes, relative to baseline.

Results

Descriptive statistics

Table 2 presents the descriptive statistics for the surveyed representative Brazilian population. Respondents were 51.7% female, 45.8% held a bachelor's degree or higher, and 15% were evangelical Christians. Nearly half of the sample (48.6%) were considered high income, while a majority (56.5%) resided in the South and Southeast regions of Brazil. The average age was 42.2 years, with participants ranging from 18 to 84 years old.

Ninety-six percent of respondents reported being fully vaccinated. A high trust in public health authorities was observed, with a mean of 4.45 on a 6-point scale and 81.5% agreeing or strongly agreeing with those authorities. Politically, 27.9% of the sample identified as leftist, and the average political orientation leaned slightly right of centre (mean = 0.96 on a scale from -5 to 5) (Table 2).

Table 2
Descriptive statistics.

Variables	N	Mean / Proportion	SD	Min	Max
Female (%)	3,001	51.7%	0.50	0	1
Bachelor's degree (%)	3,001	45.8%	0.50	0	1
Evangelical Christian (%)	3,001	15.0%	0.36	0	1
High income (%)	2,913	48.6%	0.50	0	1
South or Southeast (%)	3,001	56.5%	0.50	0	1
Age (mean)	3,001	42.21	15.34	18	84
Fully vaccinated (%)	3,001	96.0%	0.19	0	1
Trust in public health authorities (mean)	3,001	4.45	1.35	1	6
High trust in public health authorities (%)	3,001	81.5%	0.39	0	1
Leftist (%)	3,001	27.9%	0.45	0	1
Political orientation (mean)	3,001	0.99	2.94	-5	5

Notes: The income category reports n=88 missing values, reflecting individuals who answered 'prefer not to answer' to the question about their family income.

Predictors of vaccination decisions

To better understand the predictors of vaccination decisions, we ran a logistic regression. Gender emerged as a key factor, with females significantly more likely to be vaccinated ($b = 0.314$, $p < 0.001$). Higher-income individuals were also marginally more likely to be vaccinated ($b = 0.191$, $p < 0.01$), whereas evangelical Christians were significantly less likely to be so ($b = -0.244$, $p < 0.05$). Political orientation played a critical role, with individuals positioned further to the left being more likely to be vaccinated ($b = 0.691$, $p < 0.001$). Trust in public health authorities showed a positive association with vaccination uptake ($b = 0.333$, $p < 0.001$). Having a bachelor's degree, and age and regional factors did not significantly influence vaccination decisions.

To validate these findings and address the limited variation in vaccination status within the sample (as 96% of the participants reported being fully vaccinated), an ordered probit model was estimated using the number of times respondents opted out of vaccination in the DCE as the dependent variable. Consistent with the probit results (and with the expected opposite signs), being female ($b = -0.143$, $p<0.001$), left-leaning ($b = -0.389$, $p<0.001$) and of higher-income ($b = -0.067$, $p<0.001$) significantly decreased the likelihood of opting out, indicating a higher propensity to accept vaccination scenarios. Being evangelical Christian, in turn, increased the likelihood of opting out ($b = 0.238$, $p<0.001$). Importantly, trust in public health authorities continued to play a decisive role, strongly reducing the likelihood of opting out ($b = -0.257$, $p < 0.001$). Despite not being significant in the ordered probit regressions, having a bachelors' degree ($b = -0.125$, $p < 0.001$) and living in South and Southeast regions ($b = 0.015$, $p < 0.10$) were associated with opt-out vaccination decisions (Table 3).

Taken together, these consistent findings across models suggest that

Table 3
Regression results: Logit Model for COVID-19 vaccination status and ordered Probit Model for opt-out vaccination preferences.

	Fully vaccinated	Opt-out of vaccination (DCE)
Age	-0.006	-0.003
	(0.020)	(0.002)
Age * Age	-0.000	-0.000**
	(0.000)	(0.000)
Female	0.314***	-0.143***
	(0.098)	(0.008)
Has bachelor's degree	0.115	-0.125***
	(0.109)	(0.009)
Leftist	0.691***	-0.389***
	(0.154)	(0.010)
Evangelical Christian	-0.244**	0.238***
	(0.118)	(0.011)
High-income	0.191*	-0.067***
	(0.112)	(0.010)
Trust public authorities	0.333***	-0.257***
	(0.031)	(0.003)
Lives in South and Southeast regions	-0.017	0.015*
	(0.098)	(0.009)
Observations	2,909	104,724

Standard errors in parentheses
***p<0.01, **p<0.05, *p<0.1

gender, religiosity, and income, but especially political ideology and trust in public health institutions are important predictors of vaccination decisions.

Model results

The initial conditional logit model results (presented in Appendix 4 Table A3) confirmed that utility coefficients exhibited the expected signs, validating the theoretical foundation of our model specification. Notably, time for market approval did not achieve statistical significance at the 5% level, suggesting limited influence on vaccination preferences in our sample.

The latent class model revealed four distinct preference patterns regarding vaccination decisions in Brazil, based on the Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), and the interpretability of the results. Model validity was confirmed by the expected signs of coefficients across key vaccine attributes, such as effectiveness, duration of protection, and origin of the vaccine manufacturer. Crucially, the opt-out coefficient varied considerably across classes, reflecting differing preferences for vaccine hesitancy and refusal.

The four latent classes were labelled, based on respondents' preference structures and sociodemographic profiles, as: *Left-Leaning Pro-Mandates* (62.4% of the sample), *Left-Leaning Pro Restrictions* (19.5%), *Cautiously Pragmatic Centrists* (11.4%), and *Right-Leaning Vaccine Refusers* (6.7%).

Sociodemographic profiles are displayed in Table 4, with the reference category being the *Right-leaning vaccine refuser* group. Compared to this group, all other groups tend to be younger and more left-leaning. They also tend to have higher levels of trust in public health authorities and be fully vaccinated. Crucially, compared to centrists, both leftist groups show a significantly higher leaning to the left, they tend to be more vaccinated, and display higher levels of trust in public authorities.

Table 5 presents the estimated preference parameters across latent classes, and Fig. 3 reports the MRS, which allows for comparisons across

Table 4
Sociodemographic profiles across classes.

	Left-leaning, pro-mandates	Left-leaning, pro-restrictions	Centrists, (Cautiously) Pragmatists
Age	-0.017***	-0.016**	-0.028***
	(0.006)	(0.007)	(0.007)
Female	0.176	-0.008	-0.150
	(0.182)	(0.199)	(0.207)
Bachelor's degree	0.176	0.018	-0.126
	(0.203)	(0.222)	(0.235)
High Income	0.012	0.016	-0.260
	(0.208)	(0.227)	(0.240)
Trust in public health authorities	1.745***	1.717***	0.955***
	(0.187)	(0.218)	(0.214)
Leftist	1.476***	1.447***	1.028***
	(0.300)	(0.313)	(0.325)
Evangelical Christian	-0.262	-0.348	0.137
	(0.229)	(0.259)	(0.254)
Fully vaccinated	3.809***	3.178***	1.854***
	(0.361)	(0.436)	(0.298)
South or Southeast	-0.016	-0.052	0.018
	(0.185)	(0.202)	(0.209)
Constant	-2.016***	-2.373***	-0.290
	(0.462)	(0.536)	(0.420)
Observations	104,724	104,724	104,724
Number of groups	34,908	34,908	34,908
Log Likelihood	-24078	-24078	-24078
AIC	48360	48360	48360

Standard errors in parentheses. Reference category is Right-Leaning, Vaccine Refusers group.
*** p<0.01, ** p<0.05, * p<0.1

Table 5
Estimated preference parameters from the latent class model.

	Left-leaning, pro-mandates	Left-leaning, pro-restrictions	Centrists, (Cautiously) Pragmatists	Right-Leaning, Vaccine Refusers
Vaccine effectiveness (ref. 40%)				
60%	0.275***	1.092***	0.343***	0.010
	(0.031)	(0.104)	(0.080)	(0.422)
70%	0.421***	1.628***	0.572***	0.291
	(0.028)	(0.148)	(0.071)	(0.376)
90%	0.658***	2.723***	0.705***	0.294
	(0.038)	(0.206)	(0.087)	(0.483)
Duration of protection (ref. 3 months)				
6 months	0.181***	0.239***	0.241***	0.085
	(0.030)	(0.082)	(0.079)	(0.433)
12 months	0.312***	0.174**	0.346***	-0.045
	(0.026)	(0.087)	(0.068)	(0.409)
24 months	0.356***	-0.014	0.317***	0.653
	(0.029)	(0.081)	(0.075)	(0.408)
Time of vaccine approval (ref. 6 months)				
12 months	-0.049**	0.326***	0.036	0.506
	(0.022)	(0.084)	(0.061)	(0.406)
24 months	-0.000	0.806***	0.117*	0.379
	(0.027)	(0.130)	(0.067)	(0.470)
Vaccine origin (ref. China)				
European Union	0.030	1.006***	0.560***	0.218
	(0.036)	(0.162)	(0.089)	(0.547)
Russia	-0.031	-0.207	0.136	-0.132
	(0.034)	(0.142)	(0.090)	(0.607)
United Kingdom	0.122***	0.933***	0.491***	0.094
	(0.035)	(0.165)	(0.090)	(0.541)
United States	0.028	1.941***	0.759***	0.472
	(0.035)	(0.241)	(0.088)	(0.581)
Stringency of social restrictions (ref. No social activities allowed)				
Some social activities allowed	0.418***	0.290***	0.330***	-0.126
	(0.026)	(0.078)	(0.069)	(0.435)
All social activities allowed	0.731***	-0.602***	0.401***	0.713**
	(0.032)	(0.090)	(0.069)	(0.356)
Mandates (no mandate to return to work)				
Mandates to return to work	0.475***	-0.338***	0.020	-0.119
	(0.020)	(0.074)	(0.047)	(0.288)
Risk of severe side effects (out of 100,000)	-0.025***	-0.044***	-0.039***	-0.049**
	(0.002)	(0.005)	(0.004)	(0.024)
Opt-out	-3.219***	-2.625***	1.057***	4.739***
	(0.123)	(0.319)	(0.130)	(0.720)
Observations	104,724	104,724	104,724	104,724
Number of groups	34,908	34,908	34,908	34,908
Log Likelihood	-24078	-24078	-24078	-24078
AIC	48360	48360	48360	48360

Attribute reference levels in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Standard errors in parentheses

Fig. 3. Marginal rates of substitution. Panel A: vaccine attributes, social restrictions, and mandates. Panel B: Opt-out.

the classes.

Left-leaning, pro-mandates (class 1; 62.4%)

Respondents in this class are left leaning, more likely to be vaccinated, and exhibit high levels of trust in public health authorities. The lowest and negative, large, and significant opt-out coefficient (MRS = -126.56, $p<0.001$) indicates a low likelihood of vaccine refusal. This group displays positive preferences for vaccine characteristics such as high vaccine effectiveness, and longer protection. They also displayed a higher preference for vaccines when social restrictions are lifted. Further, the distinctive factor of this group is their significant and positive support for vaccine mandates (MRS = 18.69, $p < 0.001$).

Left-leaning, pro-restrictions (class 2; 19.5%)

Members of this group are similar to the first group and tend to be left leaning, more likely to be vaccinated, and exhibit high levels of trust in public health authorities. This group attributes strong preferences for vaccine features and has the highest MRS for vaccine effectiveness and

protection duration. This group also show greater support for vaccine manufacturers of the US, the UK, and the EU, relative to China and Russia. This group also showed a negative and large opt-out coefficient (MRS = -59.44, p<0.001), a notable difference compared to the first group. Crucially, this group differs from the first such that it is against the lifting of social restrictions. In sum, this class prefers to maintain some levels of social restrictions, without imposing a mandate.

Centrists, (cautiously) pragmatists (class 3; 11.4%)

This group consists largely of individuals that politically lean more towards the centre. They trust in public health officials and have vaccination uptake to a lower extent than left-leaning groups, but to a greater extent than the right-leaning group. This group values higher vaccine effectiveness and longer protection duration but shows resistance to mandates. In line with the previous group, this class also show greater support for vaccine manufacturers of the US, the UK, and the EU. In sum, this group is responsive to vaccine attributes but displays more neutral attitudes toward mandates. The opt-out coefficient is positive (MRS = 26.82, p < 0.001), but its lower magnitude (compared to Class 4) suggests that this group is not fundamentally opposed to vaccination but remains cautious and deliberative in their choices.

Right-leaning, vaccine refusers (class 4; 6.7%)

This group is distinct in both vaccine and social preferences. Compared to other classes, members are older and more politically right-leaning. They express the lowest levels of trust in public health institutions, tend to be less vaccinated, and demonstrate the strongest preference for opting out of vaccination (MRS = 97.35, p = 0.049), indicating strong hesitancy or outright vaccine refusal. Further, members of this group show little to no preference for improvements in vaccine attributes, as displayed in Fig. 3, Panel A.

In sum, this group shows little responsiveness to vaccine attributes and a strong preference for the absence of social restrictions and opting out, indicating general resistance to vaccination and government restrictions.

Discussion and concluding remarks

Our analysis investigates public preferences for pharmaceutical and non-pharmaceutical interventions, and trade-offs regarding vaccine attributes and societal restrictions during COVID-19, identifying how these preferences vary across subgroups within the Brazilian sample.

Our descriptive results show that trust in public health institutions remained high in Brazil: 81.5% of the participants trusted or fully trusted them, with the 6-point scale reaching an average of 4.45. This figure is consistent with previous research showing high trust among the Brazilian population [61] and underscores the important role of public trust in shaping health behaviours.

Our review and findings also highlighted five key predictors of vaccination status: political orientation, trust, religiosity, gender and income. Political polarisation is now viewed as a crucial determinant of health [62,63]. Early studies during the COVID-19 pandemic in Brazil showed diverging risk perceptions between conservatives and liberals [64], with important consequences in risk perceptions between these groups [64]. Furst and colleagues showed that despite notable disparities in vaccination adherence during the early stages of the rollout, the gap between conservatives and non-conservatives narrowed significantly over time (from 20.71% in 2020 to 4.25% in 2022) [56]. This convergence was primarily driven by a markedly faster increase in vaccine uptake among those who were initially the most sceptical [56].

The three-class groups exhibit high levels of trust in the public health authorities, and preference for high vaccine effectiveness and longer protection. In 2021, when the COVID-19 vaccine roll-out started, several studies reported a non-negligible vaccination hesitancy, not only toward children (13.3%) [65], but also adults (10.5% and 12.8%, respectively) [11,66]. However, as the vaccination roll-out progressed into 2022, the vaccine hesitancy gap reduced significantly. Lazarus et al. study reported a decrease in vaccine hesitancy between 2020/2021 and 2022, from 12.8% to 3.6%, respectively, which aligns with 4% of our study [66].

In regards to the vaccine refusers, the right-leaning political orientation and convergence with evangelical Christian religiosity validates some findings from other COVID-19 studies [67,68]. The attribute of gender (female) and high income has been corroborated in other studies [10,12] associated with high vaccination adherence. Our analysis demonstrates that Brazil's historical vaccination track might have contributed to high vaccination adherence, however the political polarisation and demographic attributes were presented as a new phenomenon, that was dynamic and changing overtime [66,56], and that must be considered in future vaccination campaigns.

Our review and DCE findings provide a significant contribution to understand individual attributes, public preferences and trade-off on pharmaceutical and non-pharmaceutical interventions, in the roll-out of the existing immunisation program. In light of future health crises due to infectious disease pandemics or others, policymakers and public health authorities must review health communication strategies towards vaccine-hesitant and refuser groups, as well as strengthen some of the eroded public trust due to COVID-19 events.

Our study has several limitations. First, while our sample is demographically representative of Brazil's age, gender, and geographical distribution, respondents have higher education and income than the general population, potentially limiting generalizability to lower-income groups and those with limited internet access. Second, our main-effects-only design cannot exclude significant attribute interactions. Third, attitudinal variables (political orientation, trust in authorities) used proxy indicators that may introduce measurement error due to varied Likert scale interpretation. Finally, data collection at COVID-19's end may have influenced current vaccination preferences.

Our findings can also offer actionable insights for the design and evaluation of technology-driven public health policies. First, leveraging digital platforms and social media to amplify messages from trusted and potentially politically neutral voices, such as community leaders and health professionals, can help mitigate political resistance and foster trust in vaccination campaigns. Recent evidence of behavioural claims suggests that interventions directed at identifying credible and trusted sources to share public health messages can increase adherence to behavioural interventions that can ultimately lead to better health outcomes [69]. Second, developing algorithms that ensure health information is presented in politically neutral formats may further enhance message receptivity across ideological divides. Third, implementing dynamic preference tracking systems, such as annual vaccine sentiment monitors at the state level, can enable policymakers to detect shifts in public attitudes and adapt strategies accordingly. These technology-enabled approaches can support more responsive, inclusive, and trust-centred public health interventions in Brazil and beyond.

Ethical approval

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

Funding

ARS acknowledges research grant from Vice Chancellor's 2022 Seed Funding Round - Murdoch University, Australia. The sponsor was not involved in the study design, data analysis and writing of the article. The information and views set out in the article are those of the authors.

CRediT authorship contribution statement

Ana Rita Sequeira: Conceptualization, Investigation, Formal analysis, Visualization, Funding acquisition, Writing – original draft, Writing – review & editing. **Marcello Antonini:** Conceptualization, Investigation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Bernardo Andretti:** Investigation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

All authors declare no conflict or competing interests.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.hlpt.2026.101156.

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