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Inequality in COVID-19 vaccine acceptance and uptake: A repeated cross-sectional analysis of COVID vaccine acceptance and uptake in 13 countries

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ABSTRACT

Background COVID-19 vaccine hesitancy was a key barrier to ending the pandemic via mass immunisation.

Objectives Assess magnitudes and differences in socioeconomic inequality in stated COVID-19 vaccine acceptance (hesitancy) and uptake.

Methods Online surveys were conducted in 13 countries, collecting data from 15,337 and 18,189 respondents respectively. The investigation compares socioeconomic inequality in reported vaccine acceptance, measured in 2020–21 and subsequent uptake of vaccination in 2022. Inequalities are quantified using differences, ratios and the Erreygers adjusted concentration index. A regression decomposition approach is used to identify factors associated with inequality.

Results Mean uptake levels were 87 %, while acceptance was lower at 77 %. The difference between the richest and the poorest quintile was as large as 23 percentage points in acceptance and 30 p.p. in uptake, both observed in France. Acceptance and uptake were pro-rich (regressive) in most countries. Nine countries reported pro-rich inequality in acceptance, and eight in uptake. Uptake was significantly less regressive than acceptance in Australia, China, India, and USA. Australia and Colombia were the only countries where vaccination uptake was pro-poor (progressive). Age, marital status and political ideology were correlated with socioeconomic inequalities in several countries in both waves, while gender and education were associated with acceptance, and health levels with uptake.

Conclusion We found significant inequalities in vaccination acceptance and uptake across countries but inequality was generally lower in vaccine uptake than in acceptance. This suggests that inequalities can be reduced over time if adequate policies are in place to overcome hesitancy and reduce inequalities.

1. Background

The COVID-19 pandemic caused worldwide disruption, leading many governments to impose lockdown restrictions. Restrictions were intended to minimise Coronavirus infections and were seen as an immediate solution to reduce mortality and prevent overwhelming national health systems [1]. Mass immunisation was touted as a viable measure to allow a return to normality, provided sufficient vaccination rates could be achieved to reduce virus transmission [2]. Global vaccine shortages led to inequalities and inequities in vaccine procurement and activity, particularly for Global South countries [3,4]. Shortages were driven by hoarding, vaccine nationalism, and the enforcement of intellectual property rights which restricted vaccine production, amongst other factors [3–6]. While the importance of sufficiently high overall vaccination rates to reduce transmission was recognised, failure to achieve sufficient coverage in any population sub-group risked the

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emergence of vaccine-resistant escape variants of the Coronavirus [7–9]. An effective vaccine rollout depended on overcoming two challenges; first of global disparities in allocation caused by shortages, which garnered much attention, and then of local disparities in allocation, caused by hesitancy across diverse populations [10]. There is an extensive literature on the global allocation of COVID vaccines, but investigations have often overlooked the socioeconomic-related distributional inequality perspective, particularly at the national level. This paper seeks to fill this gap by analysing the distributional inequality of COVID-19 vaccine sentiment in 13 national contexts.

The COVID-19 Vaccine Preference and Opinion Survey (CANDOUR) collected online responses from adults in 14 countries in 2020/2021. A second wave of responses was collected in 16 countries in 2022. This study population focuses on the 13 countries sampled in both waves. The paper aims to quantitatively investigate socioeconomic inequality in prior acceptance and subsequent reported vaccination using the difference, ratio, and Erreygers adjusted concentration index in each of the countries studied. We analyse inequality in self-reported vaccine acceptance in 2020/2021 and self-reported vaccination status in 2022 to determine how hesitancy changed over the course of the pandemic. We further investigate possible sources of observed inequality using recentred influence function (RIF) regression decomposition methods. Finally, we compare covariate associations from the RIF regressions with inequality in acceptance prior to vaccine availability to associations with inequality in reported vaccine uptake.

2. Methods

2.1. Study design and population

This study was conducted using data from the first and second waves of the COVID-19 Vaccine Preference and Opinion Survey (CANDOUR) study. CANDOUR is an online, longitudinal, multi-country survey for adults aged 18 and over. All participants provided informed written consent before beginning the survey. Wave 1 data were collected from 14 countries between November 2020 and January 2021. Wave 2 data were collected in 16 countries between March and November 2022. We restricted analysis to the 13 countries surveyed in both waves to enable ex ante and ex post comparison, namely: Australia, Brazil, Canada, Chile, China, Colombia, France, India, Italy, Spain, Uganda, the United Kingdom (UK), and the United States of America (US). The sample population is 15,337 observations in wave 1, and 18,189 in wave 2. Quota sampling was employed to ensure representative samples across gender, age, education and geographic setting per country. Post-stratification weighting was adopted if imbalances remained. Despite these efforts, we could not achieve sample representativeness in Uganda or India. Participants with missing household income or vaccination data were excluded, resulting in effective sample sizes of 13,090 (85 %) in wave 1 and 16,161 (89 %) in wave 2. We employed a re-weighting process to maintain representative samples after exclusion, available in the supplementary materials (*S2 Table*). This study is reported per the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline (*S1 Table*).

2.2. Data collection

In wave 1, participants were asked their intended actions if an effective COVID-19 vaccine were to become available. Respondents could select the following options: definitely get it; probably get it; probably not get it; definitely not get it; do not know; prefer not to say. “Definitely get it” and “Probably get it” were coded as accepting. “Prefer not to say” was excluded. The remaining options, including “do not know” were coded as hesitant. In wave 2, participants were asked if they had received a COVID-19 vaccine. Respondents who had received at least a single shot of any COVID vaccine were deemed vaccinated. Respondents who had not been offered a vaccine, who were still waiting for a vaccination, or who had declined the vaccination were deemed non-vaccinated. Annual household income was self-reported in bands, which we equivalised using square root equivalisation [11]. We excluded respondents with missing vaccination or income data. Health levels were self-reported on a scale of 0–100, where 100 represents perfect health. Ideology was also self-reported, where a score of 10 represented the greatest possible affiliation with right-leaning political ideology; whereas a score of 0 was associated with left-leaning ideology. Education is coded from 1 to 4, where 4 represents completion of tertiary or university education; 3: completion of secondary education; 2: completion of primary, and 1: less than primary education completed.

2.3. Statistical analysis

We aim to determine if there is a difference in socioeconomic inequality between vaccination uptake and ex-ante vaccination intention (acceptance), and identify factors associated with inequality in each country. We use absolute differences and relative rate ratios in uptake and acceptance between the highest and lowest income quintiles in each country for an initial assessment of inequality. We then investigate across the full distribution using concentration indices, the bivariate extension of the Gini coefficient, which are employed frequently in health economics to measure the relationship between socioeconomic and health-related variables. The index estimates a measure of dispersion based on the covariance between two variables. Positive values represent a concentration of higher values of the health-related variable amongst higher income earners (regressive, if the health value is desirable, e.g., good health), while negative values represent a concentration of higher values of the health-related variable amongst lower income earners. A value of 0 indicates perfect equality. Greater absolute values indicate deviations to progressive inequality (−1) or regressive inequality (1). We compute concentration indices within each country for dichotomized vaccine acceptance and vaccination uptake variables in waves 1 and 2 respectively. We then compare and test the vaccine acceptance indices (2020/21) with the vaccine uptake indices in each country (2022). We assess covariate associations with inequality using the recentered influence function (RIF) regression decomposition approach. The RIF regression decomposition assesses the average influence of covariates on the bivariate distributional inequality index, rather than on the uptake or acceptance variables. The RIF approach estimates how the concentration index changes if an individual were removed from the calculation (the influence function). It assesses the average contribution of each covariate by removing individuals, and observing how their covariate values impact the index. Interpretation of the RIF decomposition is analogous to ordinary least squares (OLS) regression, where coefficients are the effect on the index if every individual moved 1 unit of the covariate. We consider age, health levels, presence of chronic diseases, gender, marital status, education, and political ideology in the decomposition.

In analysing the inequality in the dichotomized uptake and acceptance variables, we employ a binary specific method. The Wagstaff (quasi-relative) and Erreygers (quasi-absolute) adjusted concentration indices have both been developed to analyse binary variables [12]. Discrepancies in mean vaccination uptake levels (due to varying timelines of national vaccine rollout) can impact the magnitude of relative measures, particularly as means approach the bounds [10]. Harper et al. produce a succinct discussion on the implicit values of inequality measurement and the use of both absolute and relative measures [13]. The mirror property, which produces equal estimates for measures of health and ill-health (e.g., acceptance and hesitancy) in the same population is present in both the Wagstaff and Erreygers index. We report the Erreygers’ index in the main text, due to its ability to contend with estimates that have different underlying population means (e.g., national uptake and hesitancy). We report concentration indices and ranks for both methods in the supplementary materials (*S3 Table*), allowing us to compare indices that have relative and absolute properties, respectively

[12,14].

We decompose the Erreygers adjusted index to identify covariates associated with the observed inequality and its changes. Wagstaff, van Doorslaer, Watanabe, and Erreygers and Kessels have developed popular decomposition approaches [15–18]. However, the interpretation of these decompositions is not immediately clear [19]. The RIF approach addresses critiques raised by Fortin et al. and Erreygers and Kessels, and decomposes the index itself rather than the covariance-forming variables in a general decomposition approach for bivariate rank indices using an influence function [16,19,20]. We employ the RIF-regression decomposition, which has the benefit of producing partial effects on the index, linking to conventional evaluation literature. Interpretation is akin to OLS regression, with which most readers will be familiar [18,19]. The RIF decomposition produces easily interpreted results, with coefficients interpreted as the expected change in inequality associated with a 1-unit societal (e.g., all individuals in a country) shift in the covariate. These methods provide a perspective on the distributional landscape of COVID vaccination, thereby filling the gap this paper seeks to address.

Further discussion on methods is contained in Erreygers (2008) [14],

Table 1
Sample descriptive statistics for acceptance (2020/21) and uptake (2022).

Panel 1	Acceptance (%)	Age* (Years)	Health (%)	Chronic diseases (n)	Education level	Ideology *	Female (%)	Household size (n)	Married (%)	Household income ('000 s PPP $)
Overall – **2020/21**	77.2 (12.0)	44 (30–59)	71.6 (23.9)	0.48 (0.49)	2 (2–4)	5 (4–7)	46.6 (49.8)	2.6 (1.5)	60.3 (48.9)	26.3 (27.5)
Australia	80.4 (39.7)	44 (31–60)	67.3 (22.4)	0.77 (0.94)	3 (2–4)	5 (5–7)	49.0 (50.0)	2.1 (1.1)	60.5 (48.9)	38.6 (33.2)
Brazil	88.2 (32.2)	41 (29–55)	75.0 (23.6)	0.52 (0.49)	3 (2–3)	6 (4–8)	47.5 (49.9)	2.6 (1.2)	54.7 (49.7)	10.9 (11.4)
Canada	75.8 (42.8)	48 (32–62)	70.4 (20.3)	0.77 (0.91)	3 (3–3)	5 (4–6)	49.2 (50.0)	2.0 (0.9)	53.6 (49.8)	37.7 (28.1)
Chile	87.6 (32.9)	39 (26–54)	73.3 (21.1)	0.66 (0.85)	3 (3–4)	5 (3–5)	45.6 (49.8)	2.8 (1.4)	53.0 (49.9)	15.0 (21.8)
China	78.1 (41.3)	49 (34–60)	80.8 (16.1)	0.44 (0.69)	2 (2–3)	–	49.8 (50.0)	2.9 (1.3)	87.6 (32.9)	22.8 (19.0)
Colombia	87.4 (33.1)	41 (28–56)	79.9 (23.2)	0.54 (0.84)	3 (2–3)	5 (4–7)	48.4 (49.9)	3.2 (1.4)	62.7 (48.3)	6.45 (5.44)
France	45.1 (49.7)	48 (33–62)	74.6 (22.0)	0.37 (0.48)	4 (3–4)	5 (4–7)	47.6 (49.9)	1.9 (0.8)	66.2 (47.3)	33.1 (17.8)
India	89.8 (30.2)	33 (25–46)	46.6 (30.7)	1.32 (1.17)	2 (1–3)	8 (5–10)	51.3 (50.0)	3.8 (2.2)	58.3 (49.3)	5.05 (6.98)
Italy	63.9 (48.0)	51 (37–62)	73.6 (21.1)	0.58 (0.80)	3 (3–3)	5 (3–7)	47.9 (49.9)	2.5 (1.1)	63.8 (48.0)	27.6 (19.1)
Spain	78.3 (41.2)	49 (35–61)	76.1 (19.7)	0.60 (0.79)	3 (3–4)	4 (2–6)	48.5 (50.0)	2.3 (0.8)	67.5 (46.8)	44.3 (28.4)
Uganda	83.9 (36.7)	25 (23–35)	77.2 (18.3)	0.94 (0.89)	3 (3–3)	5 (5–7)	12.3 (32.8)	3.7 (1.9)	22.8 (42.0)	3.35 (2.84)
United Kingdom	80.3 (39.7)	49 (34–62)	72.0 (20.9)	0.59 (0.85)	3 (3–4)	5 (4–7)	48.9 (50.0)	2.1 (0.9)	61.6 (48.6)	40.4 (30.8)
United States	67.9 (46.7)	42 (30–56)	65.7 (26.7)	0.92 (0.96)	3 (3–4)	5 (4–8)	49.5 (50.0)	2.2 (1.2)	60.5 (48.8)	48.8 (35.5)
Panel 2	Uptake (%)									
Overall - **2022**	86.8 (7.8)	42 (28–56)	67.6 (25.4)	0.39 (0.48)	3 (3–4)	4 (3–7)	50.4 (49.9)	3.2 (9.0)	52.0 (49.9)	26.5 (28.6)
Australia	88.2 (32.1)	38 (29–55)	66.6 (18.7)	0.59 (0.81)	3 (3–4)	5 (4–6)	64.9 (47.7)	2.1 (1.1)	48.1 (49.9)	42.1 (35.3)
Brazil	87.9 (32.5)	39 (26–62)	70.2 (24.1)	0.64 (0.96)	5 (3–5)	6 (4–7)	53.0 (49.9)	5.8 (15.)	41.9 (49.3)	8.80 (10.4)
Canada	87.5 (33.0)	37 (24–56)	68.0 (23.7)	0.67 (0.85)	4 (3–5)	5 (4–7)	61.8 (48.5)	2.0 (0.9)	39.8 (48.9)	40.4 (29.3)
Chile	98.6 (11.4)	32 (23–43)	73.5 (21.3)	0.42 (0.65)	3 (3–4)	3 (2–5)	55.8 (49.6)	2.6 (1.2)	30.3 (46.0)	17.8 (21.0)
China	82.4 (38.0)	44 (29–53)	78.4 (21.0)	0.31 (0.59)	3 (3–3)	–	48.9 (50.0)	3.3 (6.4)	73.5 (44.0)	25.4 (24.9)
Colombia	89.4 (30.7)	45 (32–62)	62.2 (33.4)	0.51 (0.70)	4 (3–5)	5 (2–7)	46.1 (49.8)	2.8 (2.4)	55.4 (49.7)	11.7 (9.03)
France	71.5 (45.1)	53 (41–63)	68.8 (26.0)	0.50 (0.68)	3 (3–4)	5 (5–7)	55.2 (49.7)	1.9 (0.8)	58.7 (49.2)	28.6 (15.3)
India	90.6 (29.0)	31 (24–40)	49.8 (35.8)	0.62 (0.84)	4 (2–4)	7 (5–8)	45.2 (49.7)	7.0 (26.)	48.9 (50.0)	7.75 (8.69)
Italy	86.2 (34.4)	53 (41–62)	69.2 (23.2)	0.50 (0.73)	3 (3–3)	5 (3–7)	54.2 (49.8)	2.4 (1.3)	65.5 (47.5)	29.7 (17.5)
Spain	95.7 (20.2)	33 (33–53)	70.8 (18.1)	0.31 (0.63)	4 (3–4)	1 (0–5)	51.1 (50.0)	2.2 (1.5)	79.7 (40.2)	52.9 (27.6)
Uganda	91.8 (27.3)	30 (25–40)	73.9 (19.4)	0.32 (0.60)	3 (3–5)	5 (4–7)	19.6 (39.7)	5.7 (6.6)	35.4 (47.8)	0.31 (0.37)
United Kingdom	88.8 (31.4)	47 (37–59)	60.0 (23.5)	0.59 (0.83)	4 (3–5)	5 (3–7)	52.5 (49.9)	1.8 (0.7)	53.2 (49.9)	29.1 (26.9)
United States	70.4 (45.6)	42 (26–61)	66.9 (22.5)	0.97 (0.91)	3 (3–4)	5 (3–8)	47.7 (49.9)	2.2 (2.6)	44.3 (49.6)	48.4 (43.4)

Standard Errors (SE) and Interquartile Ranges (IQR) in parentheses.
* indicates the use of IQR in parentheses. If not stated, Standard Errors are produced.

Heckley et al. (2016) [19], and Kessels and Erreygers (2019) [18] for the interested reader.

Statistical analyses were conducted using Stata 17.0 (StataCorp LP; College Station, TX).

3. Results

3.1. Descriptive statistics

The sample descriptive statistics of survey respondents are presented in Table 1. 5454 respondents were repeatedly sampled. Descriptive statistics are reported as means (standard deviation) or median (interquartile range). Binary variables (e.g., married, female) represent the proportion of the population with the stated attribute. Wave 2 respondents were nearly 10 percentage points more likely to be vaccinated than their intentions indicated, led by Chile (98.6 % uptake, 87.6 % acceptance). Among the three European Union countries in the sample - France, Italy, and Spain - there was a significant increase in positive vaccine sentiment, with increases of 26, 22, and 17 percentage points respectively. Respondents in wave 2 were two years younger at the median, and four percentage points less healthy than wave 1 counterparts. Wave 2 respondents were better educated and one degree more left-leaning politically. Wave 1 respondents were more likely to be married and lived in smaller households. Mean income was $250 PPP dollars higher in wave 2. China reported the highest average health levels in both waves at approximately 80 %, despite the overall decline in self-reported health levels between waves 1 and 2 across the sample. India reported the lowest health values in each wave, and was the only country to report average health levels below 50 %. Political ideology was consistent across the samples. India was the most right-wing, with self-reported median scores of 8 and 7 (where 10 is the most right-wing), compared to Spain and Chile, who reported median left-wing leanings (1 and 3, where 0 is most left-leaning). Uganda had the least female representation, with $>$ 80 % of respondents identifying as male in each wave.

3.2. Comparing country acceptance and uptake levels

National acceptance and uptake levels are presented in the left panel of Fig. 1. Acceptance levels in wave 1 are consistently around the 80 % mark. India and Brazil had the highest acceptance rates, nearing 90 %. France (45 %), Italy (63 %), and the US (67 %) had the lowest acceptance rates. Uptake levels were 10 percentage points higher on average than acceptance levels. Each country reported higher uptake than acceptance apart from Brazil. Perhaps unsurprisingly based on stated hesitancy, France and the US had the lowest uptake levels (~70 %), though Italy appears to have overcome initial hesitancy to reach 86 % uptake.

3.3. Quintile differences and rate ratios

We report descriptive statistics of acceptance and uptake by income quintile (Q1 = lowest-income quintile; Q5 = highest-income quintile) in Fig. 2 to commence the inequality investigation. The top left panel shows mean acceptance per quintile, while the top right shows mean uptake per quintile in each country. France, Italy, Spain, and the United States show the steepest inequality gradients in the quintile analysis in acceptance (left). Chile presents a relatively flat gradient across income quintiles for both acceptance and uptake. Italy and Spain maintain inequality gradients through to uptake, and are joined by China, while the United States and France are more varied across quintiles in uptake, despite maintaining absolute differences in mean uptake between Q1 and Q5. We report absolute differences between Q5 and Q1 (in percentage points) in Table 2. We also report a relative descriptive measure employing the rate ratio in Table 2. All countries had higher acceptance in Q5 than Q1, though this was only significant at the 5 % level (i.e., 95 % CI strictly above 0) in approximately half the countries. France had the highest absolute difference in acceptance between Q5 and Q1 (23 percentage points). The South American nations of Chile, Brazil, and Colombia exhibited the lowest absolute differences, at 3, 4, and 5 percentage points respectively. France and the United States showed the largest relative differences, with ratios of 1.69 and 1.31 respectively, indicating higher vaccine acceptance amongst the highest income quintile. In uptake, France again exhibited the largest absolute and relative differences favouring the high-income quintile. Australia and Uganda presented negative differences, showing higher uptake in Q1 relative to Q5, while Chile presented a rate-ratio of 1.00, and negligible absolute differences between Q1 and Q5. While we focus on the

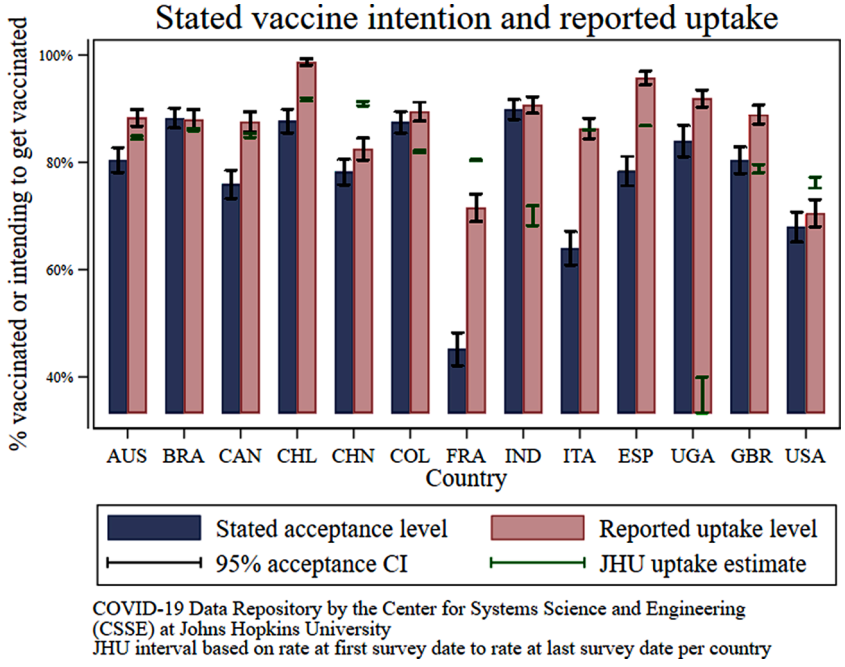

Fig. 1. Comparison between acceptance and uptake levels.

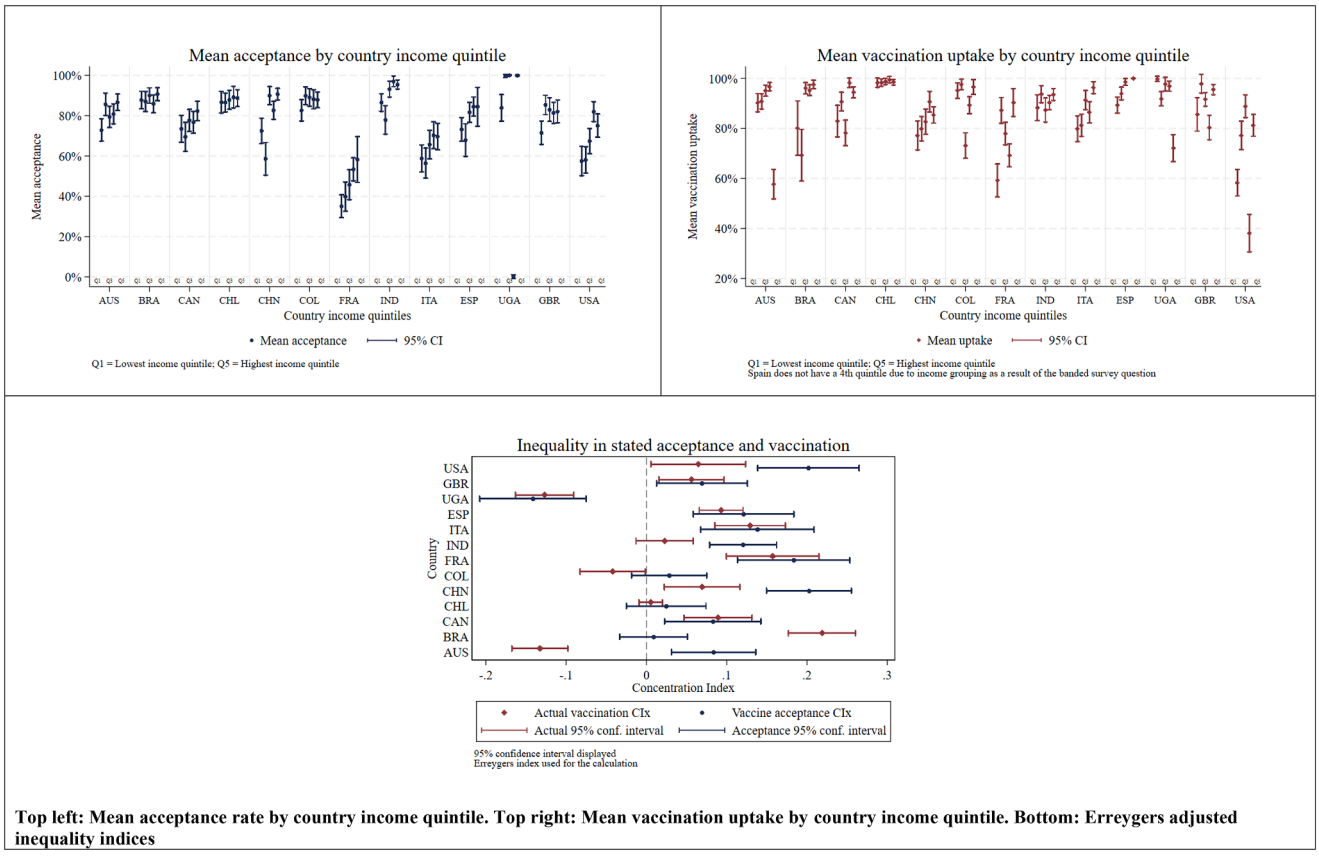

Fig. 2. Inequality in stated acceptance versus actual vaccination
Top left: Mean acceptance rate by country income quintile. Top right: Mean vaccination uptake by country income quintile. Bottom: Erreygers adjusted inequality indices.

Erreygers adjusted index to assess inequality for the remainder of this paper, further quintile comparisons can be drawn using Table 2.

3.4. Socioeconomic inequality in acceptance and uptake using the Erreygers adjusted index

The bottom panel of Fig. 2 shows the full-distribution inequality in acceptance and hesitancy within each country. As the rankings of relative and absolute inequality measures are similar, we report and comment on the quasi-absolute Erreygers measure, with quasi-relative results available in supplementary Table S3. Acceptance was concentrated among richer individuals, shown in the regressive (positive) concentration indices reported in 9 countries. China (0.203), the US (0.202), and France (0.184) reported the most regressive results. Only Uganda (−0.141) reported pro-poor (negative) acceptance levels – however this result should be viewed with caution due to the non-representativeness of the sample. Uptake was less regressive than acceptance. Australia (−0.133), Uganda (−0.127), and Colombia (−0.042) reported pro-poor estimates. Although 8 countries reported regressive uptake indices, Australia ($\Delta = -0.216$), China ($\Delta = -0.133$), India ($\Delta = -0.098$), and the US ($\Delta = -0.137$) reported more progressive estimates of uptake than acceptance, taken simply as the difference in index values between uptake and acceptance. Brazil ($\Delta = 0.210$) was the only country that reported a pro-rich change across the pandemic.

3.5. Decomposing socioeconomic inequality

The results of the RIF-regression decomposition are presented in Tables S4 and S5. The results are informative of: a) covariate associations of inequality in vaccine acceptance and uptake and b) changes in covariate associations over time. We remind the reader that these results are associations, and are not necessarily causal. Several other factors that were not included in the data collection could similarly have influenced sentiment, and its changes over time. Variables with negative (positive) coefficients are associated with progressive (regressive) influences on the concentration index. For example, if more individuals were married, inequality would decline, suggesting marriage is either associated with acceptance and lower income levels, or hesitancy and higher income levels; similar logic holds for all results. For vaccine acceptance, marital status was significantly associated with inequality in 8 countries. The coefficient was pro-poor (negative) in all countries but France. Political ideology was also significant in 8 countries, with a smaller magnitude of impact. In all sample countries apart from France and Italy, a more conservative political ideology was associated with an increase in inequality. An increased proportion of females was associated with increased inequality in acceptance everywhere but Brazil and Italy, and was significant and regressive in 7 countries. Age and health levels had a progressive association with the Erreygers adjusted index, while education had varied associations.

For vaccine uptake, health levels were significant and progressive. Age was significant in 10 of the countries and remained a progressive influence except in China. Marital status was also significant in 10 countries with progressive effects. Political ideology was again significant in 8 countries. Political ideology did not contribute significantly in uptake in Italy and the United Kingdom despite observed significance in acceptance, while in Australia, Colombia, France, and the US, political ideology was significantly correlated with uptake and not acceptance.

Table 2
Differences and rate ratios in acceptance and uptake across national income quintiles.

Country	Vaccine acceptance		Vaccine uptake	
	Difference [p.p.] (95 % CI)	Rate ratio (95 % CI)	Difference [p.p.] (95 % CI)	Rate ratio (95 % CI)
Australia	0.14 (0.05 - 0.22)	1.19 (1.06 - 1.32)	−0.22 (−0.69 - 0.25)	0.76 (0.24 - 1.28)
Brazil	0.04 (−0.04 - 0.12)	1.05 (0.95 - 1.14)	0.18 (−0.18 - 0.54)	1.32 (0.39 - 2.25)
Canada	0.1 (−0.01 - 0.2)	1.14 (0.97 - 1.3)	0.07 (−0.18 - 0.33)	1.12 (0.71 - 1.52)
Chile	0.03 (−0.08 - 0.15)	1.04 (0.9 - 1.18)	0 (−0.02 - 0.02)	1 (0.98 - 1.02)
China	0.2 (0.04 - 0.36)	1.3 (0.98 - 1.63)	0.08 (−0.08 - 0.24)	1.11 (0.89 - 1.34)
Colombia	0.05 (−0.05 - 0.16)	1.07 (0.94 - 1.2)	−0.01 (−0.12 - 0.1)	0.99 (0.87 - 1.11)
France	0.23 (0.1 - 0.37)	1.69 (1.22 - 2.16)	0.3 (−0.05 - 0.64)	1.95 (−15.39 - 19.3)
India	0.1 (−0.01 - 0.2)	1.12 (0.97 - 1.26)	0.04 (−0.11 - 0.19)	1.05 (0.87 - 1.24)
Italy	0.13 (0 - 0.26)	1.23 (0.99 - 1.47)	0.15 (−0.01 - 0.31)	1.2 (0.97 - 1.43)
Spain	0.11 (0 - 0.22)	1.15 (0.99 - 1.31)	0.1 (0.05 - 0.14)	1.11 (1.06 - 1.17)
Uganda	0.07 (−0.39 - 0.53)	1.12 (0.38 - 1.87)	−0.23 (−0.66 - 0.21)	0.77 (0.33 - 1.21)
United Kingdom	0.1 (0.01 - 0.19)	1.15 (1.01 - 1.28)	0.11 (−0.19 - 0.41)	1.36 (−6.98 - 9.69)
United States	0.17 (0.07 - 0.28)	1.31 (1.09 - 1.54)	0.24 (0.11 - 0.37)	1.42 (1.16 - 1.69)

Notes: Difference calculated as (mean) Q5 (highest income) – (mean) Q1 (lowest income) in percentage points.
Rate ratio calculated as (mean) Q5/ (mean) Q1.
Positive differences and ratios indicate likelihood of regressive inequality between highest and lowest income groups.
Standard errors calculated using bootstrap resampling methods.

4. Discussion

This investigation examined socioeconomic inequality and associated factors in acceptance and uptake of COVID-19 vaccination in 13 countries. Our main results, employing the Erreygers adjusted index, a comprehensive distributional inequality measure, suggest that acceptance and uptake were generally regressive. Nine countries reported pro-rich inequality in acceptance, and eight in uptake. Average inequality in uptake was lower than in acceptance by 46 % ($\overline{\Delta} = -0.039$). This is a promising result, indicating that initial inequality in attitudes to vaccination in a pandemic context can be reduced over time.

Vaccine inequality and inequity vary depending on contexts. In routine immunisation, there are often inequalities based on wealth or income, gender, education and location [21–24]. COVID-19 vaccine inequality first became a concern due to global vaccine shortages. Income has been consistently identified as a factor influencing vaccine acceptance and uptake at both individual and national levels, with wealthier individuals being more likely to be vaccinated and wealthier nations achieving higher coverage [25–29]. This paper takes an additional step, by investigating the distributional impacts of individual income-related hesitancy on overall socio-economic inequality in vaccine acceptance and uptake.

4.1. Validity of uptake and acceptance estimates compared to existing studies

An extensive literature has been produced on both general and COVID-19 specific vaccine hesitancy and acceptance [21,30]. To estimate socio-economic inequalities in vaccine uptake and acceptance, it is important that our surveys provide reliable estimates of baseline vaccine acceptance and uptake. We therefore compare our overall country estimates of acceptance and uptake to the literature, to anchor the validity and representativeness of our sample, and provide a basis for the inequality estimates, for which there are limited comparators. Our reported levels of acceptance and uptake are largely consistent with the literature, though there are some differences which we note. Drawing on the works of Lazarus et al. [31], Robinson et al. [25], Sallam [32], and others [33–35], we find support for ten of our country-level estimates on vaccine acceptance based on previously published estimates. However, our acceptance estimates in India and Uganda, where our sample under-represented lower income earners, were substantially higher than other works. Our estimates for China are 5–10 % lower than those in most studies, except for Zhang et al., which focused on parents and guardians [36].

Uptake figures were compared to reliable national administrative data collated and managed by Johns Hopkins University (JHU) [37]. We take administrative estimates aligned to the start and end-dates of the CANDOUR survey for each country. India and Uganda were the largest outliers relative to JHU data. This is indicative of further socioeconomic inequality in uptake, as our income-skewed sample has higher uptake than the national average. The remaining countries were similar to administrative data, though some variation was observed. We encourage readers interested in the levels and determinants of uptake and acceptance to view the cited and additional literature in this regard.

4.2. Inequality in COVID-19 vaccine sentiment

We observed 5 countries where differences between inequality estimates of acceptance and uptake were statistically significant, namely Australia, Brazil, China, India, and the US. Brazil (0.219) reported the most regressive results in uptake, and was the only country in this study that saw a statistically significant pro-rich increase in inequality in uptake relative to acceptance. Australia (−0.132) reported the most progressive result in this study. Differences in policy agility and effectiveness offer a potential explanation for the diverging experiences beyond the decomposition covariates we investigate. Australia controlled the initial stages of the pandemic through stringent lockdowns and restrictive travel policy, managing the spread of the virus and keeping infection numbers low, while cases soared in Brazil [38,39]. Despite different initial paths, both Australia and Brazil lagged global leaders in vaccination efforts. Australia corrected course by turning to proven healthcare structures after policy missteps in private sector and local vaccine distribution [38]. With control over case numbers and a predictable reproduction rate due to enacted restrictions, the Australian government turned its focus to economic support for its population. Measures included doubling the unemployment benefit and a wage subsidy scheme, which likely contributed to positive sentiment towards the government and its vaccine rollout from low-income earners who benefited most from these measures. This could have contributed to positive vaccine response amongst these and other groups, seeing semblances of normal life resume in Australia sooner than in other countries, potentially contributing to the progressive inequality observed in this study [40]. The decomposition analysis suggests that reductions in female hesitancy also contributed to the reduction in inequality in uptake. Brazil, meanwhile, led by Bolsonaro who did little to hide his anti-vaccine sentiment, lacked federal coordination. The campaign was politically convoluted, polarizing, and faced consistent supply challenges due to the politicization of the rollout, which hindered the country's ability to deploy the vaccine [39,41,42]. The observed inequalities were perpetuated by hesitancy and unmet demand in low-income communities with low levels of education [43]. A study has found logistical challenges (e.g., time off work, child supervision) borne disproportionately by low-income earners to be a likely mechanism driving inequality, though elements of this were mitigated by progressive primary health care coverage [44,45]. We cannot discount missing data as a possible cause, or partial cause, of the differences observed

between uptake and acceptance in Brazil, as we could not achieve a fully representative sample with re-weighting.

The change in political leadership in the US in 2021 likely had an impact, as the Democratic leadership re-energised vaccine mobilisation efforts to reach previously missed targets [46]. The regressive association of being conservative increased in magnitude in the decomposition – implying that higher-income right-leaning respondents were more likely to get vaccinated (or low-income refusal increased), potentially speaking to Republican mistrust of vaccine incentives promulgated by states under the newly elected federal Democratic leadership [46,47]. Previous research has found associations between far-right voting and vaccine hesitancy in the EU, which appears to be replicated in these results in the US [48]. The US, like Australia, saw significant reductions in the decomposition association between female hesitancy and inequality.

China's stringency index was the highest of the countries in the sample, with mandatory vaccination administered by some local governments, which would necessarily reduce inequality if mandates were effective across income groups [49,50]. China also had the advantage of a locally manufactured vaccine, CoronaVac, thereby avoiding the shortages faced by many countries. India could similarly rely on the local manufacture of vaccines, after the de-facto ban on exports of the locally manufactured AstraZeneca vaccine in favour of local use. Increased availability in both nations is likely to have reduced inequality as a result of unmet demand. After devastating peaks in the first wave in India [51], having a chronic disease became associated with pro-poor inequality, as individuals took greater steps to safeguard their health with vaccines relative to prior stated intention.

4.3. Policy implications

Various measures were adopted globally to encourage vaccination uptake; including travel limitations, vaccine passports, vaccine mandates, and differential restrictions based on vaccination status [52]. The differences between the acceptance and uptake measures indicate that these measures had some effect in achieving greater coverage and more equitable uptake than anticipated. However, these policies led to a global discourse on freedom of choice and potential rejection of COVID policies in response to strict measures [52,53]. The benefits of a tightly managed programme are illustrated in the examples of Australia and Brazil, but are not without cost. Vaccine mandates, for example, theoretically have the ability to solve social coordination problems and remove socioeconomic inequality by vaccinating all individuals regardless of income levels, but remove freedom of choice. There is a value judgement to be made by policy-makers regarding the efficacy of these policies in context, particularly amongst marginalised groups, and the possible trade-offs between equity, liberty, and societal health outcomes. Aside from moral value judgements, reduced coverage and inequality in vaccination increases the likelihood of escape variants which may render immunisation strategies redundant if the virus mutates to resist vaccines [54,55].

Public health officials and policy makers should be prepared to deploy additional measures to achieve equality and coverage in vaccination. Context specific cash incentives have been found to increase uptake and decrease hesitancy [56,57], while surveys can prove useful in locating and addressing hesitancy and inequality in local and specialised contexts [58].

4.4. Limitations

This study faces two limitations: (1) We were unable to obtain fully representative samples in India and Uganda. As such, the results in India and Uganda are not generalizable. (2) We have not included an ethnicity variable in this research. The recording of ethnicity in the CANDOUR dataset varies by country to meet local needs, leaving cross-country comparison challenging. However, we note that minority groups were found to have higher risk factors associated with COVID-19 infection and severity, and increased hesitancy rates relative to other racial groupings [59–61]. Recent literature has suggested expanding the ranking variable to a multivariable measure including elements of socioeconomic status, demographics, educational attainment, sex-based characteristics, and geospatial elements [24]. Extending the analysis could add to the literature given previously observed discrepancies between such multivariable socioeconomic measures and traditional measures [24].

5. Conclusion

This paper analyses the inequality landscape of COVID-19 vaccine sentiment using indices of socio-economic inequality in vaccine acceptance and uptake indices in 13 countries. We estimate socioeconomic inequality in vaccine acceptance and uptake, and decompose these indices to identify associations with inequality. We find that socioeconomic inequality in vaccination in 2022 was lower than socioeconomic inequality in acceptance in 2020, but it remained largely regressive. Policy makers should be prepared to adopt additional and targeted mitigating procedures to ensure that marginalised groups are not left behind in vaccination campaigns. Coherent and coordinated policy messaging alongside effective management to procure necessary resources (where feasible) could contribute to more equitable vaccination outcomes in future campaigns.

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CRediT authorship contribution statement

Zachary DV Abel: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis. **Laurence SJ Roope:** Writing – review & editing, Validation, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Raymond Duch:** Writing – review & editing, Validation, Supervision, Funding acquisition, Data curation, Conceptualization. **Sophie Cole:** Writing – review & editing, Writing – original draft, Visualization. **Philip M Clarke:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of interests

We declare no competing interests.

Data availability

The data used is available upon reasonable request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.healthpol.2025.105251.

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