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Original Research

Vaccination, life expectancy, and trust: patterns of COVID-19 and measles vaccination rates around the world

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ABSTRACT

Objectives: We estimate patterns of covariation between COVID-19 and measles vaccination rates and a set of widely used indicators of human, social, and economic capital across 146 countries.
Study design: We conduct exploratory analyses of social patterns that uphold vaccination success for COVID-19 and measles.
Methods: We use publicly available data on COVID vaccination rates and other country-level indicators from Our World in Data, Human Development Report, Corruption Perception Index, and the World Bank to devise bivariate correlations and multiple regression models.
Results: About 70% of the variability in COVID-19 vaccination rates in February 2022 can be explained by differences in the Human Development Index (HDI) and, specifically, in life expectancy at birth. Trust in doctors and nurses adds predictive value beyond HDI, clarifying controversial discrepancies between vaccination rates in countries with similar levels of HDI and vaccine availability. Cardiovascular disease deaths, an indicator of general health system effectiveness, and infant measles immunization coverage, an indicator of country-level immunization effectiveness, are also significant, though weaker, predictors of COVID-19 vaccination success. Measles vaccination in 2019 is similarly predicted by HDI and trust in doctors and nurses.
Conclusions: The remaining variability in COVID-19 vaccination success that cannot be pinned down through these sets of metrics points to a considerable scope for collective and individual agency in a time of crisis. The mobilization and coordination in the vaccination campaigns of citizens, medical professionals, scientists, journalists, and politicians, among others, account for at least some of this variability in overcoming vaccine hesitancy and inequity.
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Introduction

Comedian Dave Barry recalled his mother telling him, 'Son, it is better to be rich and healthy than poor and sick'.[1] This still holds when examining COVID-19 vaccination patterns worldwide. In this article, we discuss the relative contribution to predicting COVID-19 and measles vaccination rates from a set from widely used, publicly available indicators of human, social, and economic capital.

There has been a significant increase in life expectancy over the last two hundred years in many societies. Humankind has become more adept, collectively, to sustain life for its members, although externalities, in terms of climate impact, have begun to raise doubt on the longer-term prospects of this accomplishment. Life expectancy serves as a synthetic measure of the capacity of society to prevent death in a certain period. Given that the avoidance of death is one of humankind's major goals, life expectancy is, therefore, a useful metric to capture the effectiveness of social organization for public health at a certain time and place.

Vaccination has played a considerable role in reducing the mortality inflicted by preventable diseases[2] over the last two centuries. Vaccines have been, therefore, an important cause of the recent increase in life expectancy across the world. This also holds true for the COVID-19 pandemic, which has visibly lowered life expectancy in most countries.[3,4] There is convincing evidence that vaccination against COVID-19 has prevented numerous deaths globally.[5,6]

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At the same time, rates of vaccination have varied widely during the pandemic. Societal resources shape a collectivity's ability to immunize its members against infection through vaccination.[7] COVID-19 vaccination has been unevenly implemented because of differences in availability of vaccines, uneven logistics of vaccine distribution, and people's variable trust in vaccines and mainstream science and expertise.[8–12] In this article, we explore and discuss the correlation between the success of vaccination campaigns against COVID-19 in mid-2021 and early 2022 and pre-pandemic life expectancy (estimated in 2019), alongside other measures of human, social, and economic capital, at country level. Our study aimed to answer an essential question: What can such broad patterns of co-variation in vaccination success tell us about the social structures and forms of agency that keep people alive?

Human, social, and economic resources have been of utmost importance in COVID-19 vaccination. They have facilitated earlier access to vaccines and powered the required logistics of a large-scale vaccination campaign. Several studies signalled a positive association between coverage of COVID-19 vaccination, the Human Development Index (HDI), and gross domestic product (GDP) per capita.[13–16] These studies suggest that GDP per capita and HDI are foci of attention in ecological analyses of COVID-19 vaccination, highlighting vaccine inequity and the importance of social development for a successful vaccination program, or serving as control variables for other predictors. Education and GDP per capita have been shown to contribute to the speed of the COVID-19 vaccination campaign.[17] A positive correlation between measles vaccination and HDI has also been noted.[18] Trust in the state and in the health system has been associated with greater compliance with COVID-19 restrictions in Europe.[19] Generalized trust has contributed to higher resilience against COVID-19 infections and deaths according to Lenton et al.,[20] though their study does not discuss the role of vaccination as a possible mediating variable. Trust in medical and scientific experts has been a strong correlate of pro-vaccination attitudes in general[21–24] and of the declared intention to receive a COVID-19 vaccine internationally.[25–27] An ecological study of 89 countries documents predictive value for community health skills, importance of religion, and social freedom, when controlling for GDP per capita.[28] Social and economic inequality has been associated with lower COVID-19 vaccination rates aggregated at country level,[29] and the Gini index has been shown to correlate with vaccination success in bivariate analysis, but not when controlling for GDP.[30] Indicators of corruption in the public sector are significant predictors of COVID-19 vaccination in August 2021 when controlling for GDP per capita and strength of the health system,[31] without controlling for life expectancy or education. Perceived corruption is associated with decreased vaccination coverage globally[32] and it also affects trust in mainstream health policy, exacerbating vaccination hesitancy.[33]

Although GDP per capita and HDI are often used as predictors in country-level studies, we opt to decentre the focus on societal wealth and to examine independently all three components of HDI—specifically, Gross National Income (GNI) per capita, life expectancy, and national education metrics. We also include a wider array of predictors in an exploratory, comparative analysis, including metrics of trust in the health system and metrics of health system performance. This enables us to empirically identify the high predictive importance of life expectancy, a variable that has been largely neglected in previous ecological analyses of COVID-19 vaccination.

Studies of COVID-19 vaccines have increased since 2020, as was expected,[34] but they usually focus on the COVID-19 vaccine without connecting it to other vaccines. We choose to compare predictors' relevance for COVID-19 vaccination with their relevance for measles vaccination, thereby connecting this emerging thread of research with the broader study of vaccination campaigns' success or failure.

Methods

We accessed publicly available data on COVID vaccination rates and other country-level indicators of human, social, and economic capital from the data sets of Our World in Data (OWID),[35] the metrics included in the 2020 Human Development Report (HDR) of the United Nations Development Programme,[36] the Corruption Perception Index computed by Transparency International,[37] and World Bank data on poverty rates.[38] We included in the study all countries and territories with a population larger than 1 million and available information for vaccination rates, according to OWID data, resulting in 146 units of analysis.[d] The indicators concerning the 'share of people who trust their national governments' and the 'share of people who trust doctors and nurses in their country' were centralized and published by OWID, using the Wellcome Global Monitor data set.[39]

Our first dependent variable of interest was the rate of fully vaccinated people, per hundred, measured at two points in time: July 31, 2021 (or the closest day to July 31, 2021) and February 4, 2022 (or the closest day to February 4, 2022). The second dependent variable, included for comparison purposes, is the rate of infants immunized against measles at 1 year of age, in 2019, as reported by HDR. The descriptive statistics and sources for the predictors included in the analysis are presented in the Supplementary Material, Table S.M.1. The control variable for partial correlations was HDI, which aggregates three dimensions: 1) life expectancy at birth; 2) an education index composed of mean years of schooling and expected years of schooling; and 3) GNI per capita.[36]

Results

An exploration of bivariate correlations indicated a strong relationship between COVID-19 vaccination rates and HDI (bivariate $r = 0.826$ in February 2022, $P = 0.000$). The relationship changed from an exponential to a linear shape during the vaccination campaign from July 2021 (Fig. 1) to February 2022 (Fig. 2). In mid-2021, there was a much more abrupt co-variation of vaccination success with HDI, compared with the later stage, when access to vaccines was more widespread and countries' own resources for large-scale collective action became more relevant.

Therefore, an exponential regression model ($R^2 = 66.7\%$) is better fitted for the observed data in July than a linear regression model ($R^2 = 48.3\%$). For February 2022, a linear model is better suited to model the relationship between HDI and vaccination rate ($R^2 = 68.0\%$) than an exponential model ($R^2 = 62.5\%$). A logarithmic model is marginally less fitted ($R^2 = 66\%$) than a linear one, anticipating a turn toward a logarithmic-shaped relationship as more countries on the HDI continuum evolve toward the plateau of high vaccination rates.

A bivariate analysis of vaccination rates and multiple indicators of human, social, and economic capital indicates a broad pattern of covariation (Table 1). Vaccination rates are higher, on average, in countries with better outcomes in health and education, higher inputs into the health system, lower inequality, lower poverty rates, lower perceived corruption, and higher trust rates.

The indicators that stand out in this pattern through their relative predictive power (other than aggregate HDI) are life expectancy at birth and GNI per capita. Life expectancy at birth

[d] The countries included in the analysis are listed in the Supplementary Material.

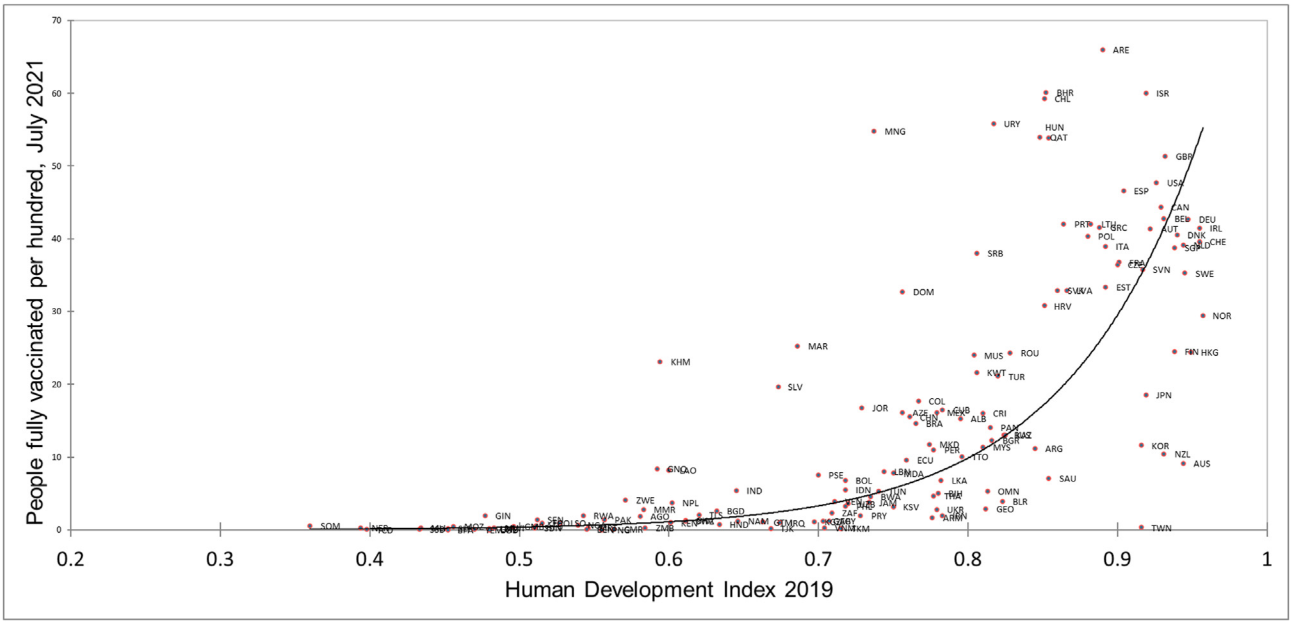

Fig. 1. Scatterplot of rates of fully vaccinated people in July 2021 vs. HDI 2019. Source: Authors' analysis of data from Our World in Data and UNDP Human Development Reports. Linear Pearson correlation: R = 0.695 ($P = 0.000$).

correlates at 0.836 with the vaccination rate in February 2022, explaining about 70% of its total variance.[e] GNI per capita correlates at 0.706 with vaccination rates in February 2022, explaining about 50% of the total variance, which makes it the second strongest predictor in the bivariate analysis. Mean years of schooling also correlates at 0.688 with the February 2022 vaccination rate.

The three components of HDI have differential predictive power for COVID-19 vaccination success (Table 2). A multiple regression model of the vaccination rate in February 2022 on the three dimensions of HDI (Model 1 includes mean years of schooling, and Model 2 includes expected years of schooling) indicates that, when controlling for the other dimensions, the strongest predictor remains life expectancy. The model including all three HDI dimensions does not lead to a substantial increase in predictive power. This is because life expectancy, GNI per capita, and mean and expected years of schooling are strongly intercorrelated and the latter do not contribute much in terms of additional explanatory power.

The educational component of HDI and GNI per capita are less powerful predictors than life expectancy in a multivariate model. Either of education or GNI per capita may be statistically significant, but not both, depending on the chosen indicator for education (Model 1 and Model 2). The mean value of years of schooling in Model 1 is not a statistically significant predictor, but GNI per capita is. In Model 2, the expected value for years of schooling retains statistical significance, but GNI per capita does not. In Model 3, we see that life expectancy is the strongest predictor for measles vaccination, followed by mean years of schooling. The same holds if we include expected years of schooling instead.

Going back to partial correlations, other indicators of educational outcome at country level do not add predictive power beyond HDI. There are statistically significant bivariate correlations between vaccination rates and Programme for International Student Assessment (PISA) scores (Table 1). Still, the partial correlations for each of the PISA scores become statistically insignificant when controlling for HDI, life expectancy, or GNI (PISA scores are only available for 67 countries). This indicates that, at country level, literacies influence vaccination success insofar as they translate into higher life expectancy and GNI.

Although a wide variety of indicators of human, social, and economic capital are correlated with vaccination success, both in July 2021 and February 2022, their predictive relevance is overlapping with HDI. As we can see in Table 1, partial correlations when controlling for HDI are, as a rule, statistically insignificant. Two indicators of social capital contribute to predicting vaccination success beyond HDI: the share of people who trust doctors and nurses and the share of people who trust their national government. Trust seems to play a significant role in the country-level success of COVID-19 vaccination and also of measles immunization.

Indicators of health system effectiveness retain statistically significant partial correlations with the vaccination rate in February 2022 when controlling for HDI. Cardiovascular (CVD) death rate has a partial correlation of −0.300 ($P = 0.000$), and the proportion of infants immunized for measles before 1 year of age has a partial correlation of 0.231 ($P = 0.006$). Although CVD prevalence is higher in more developed countries, the associated mortality is higher in less developed countries. This makes this indicator a powerful proxy to capture the effectiveness of a country's medical system and overall social organization in increasing lifespan. The proportion of infants immunized for measles is a more specific indicator, pointing to a country's performance in vaccination infrastructure. The prevalence of diabetes is not correlated with the COVID vaccination rate when controlling for HDI, despite diabetes being a risk factor for severe COVID infections, which was associated with priority in the early vaccination campaigns.

The pattern of correlations for predicting infant measles vaccination for 1-year olds is very similar with COVID-19 vaccination. The strongest bivariate predictors are life expectancy and HDI. When controlling for HDI, trust in the national government and trust in doctors and nurses remain statistically significant, but other indicators do not — except national poverty rates, which are relevant for measles but not for COVID-19 vaccination. Conversely, CVD

[e] The inequality of life expectancy, estimated in HDR, is also strongly correlated with vaccination rate, but it is collinear with life expectancy, and thus, it does not add predictive information.

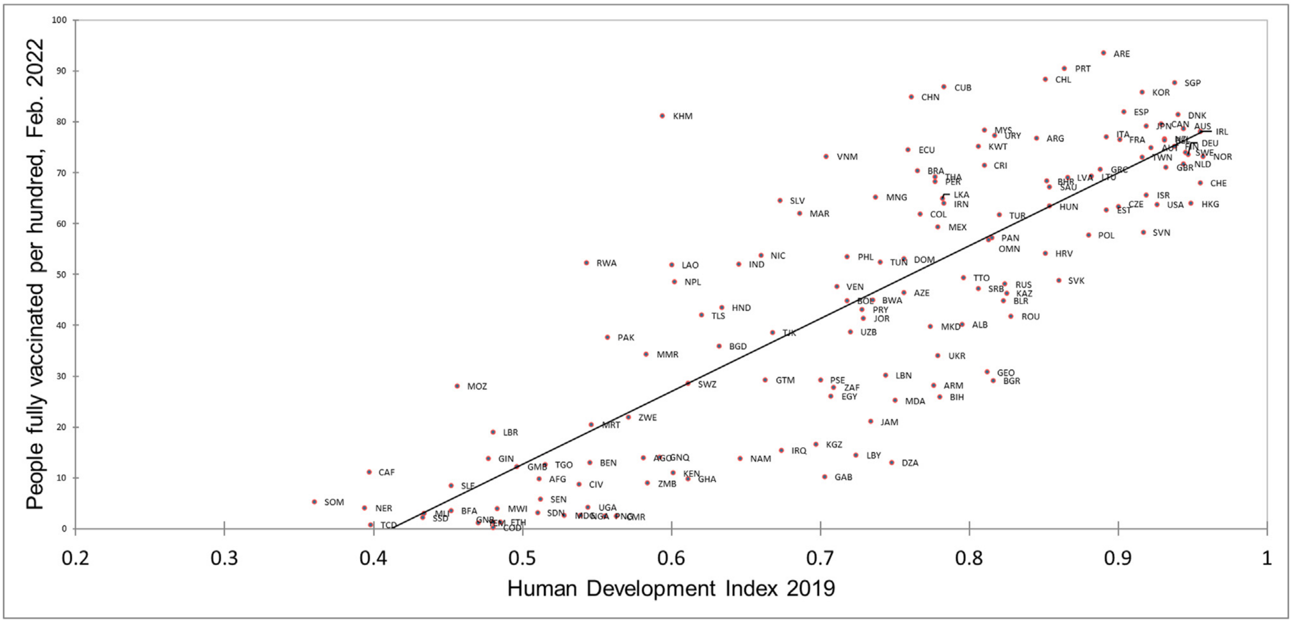

Fig. 2. Scatterplot of rates of fully vaccinated people in February 2022 vs. HDI 2019. Source: Authors' analysis of data from Our World in Data and UNDP Human Development Reports. Linear Pearson correlation: R = 0.826 (P = 0.000).

death rate remains significant for COVID-19 vaccination when controlling for HDI, but not for measles.

In Table 3, we estimated a multiple linear regression of vaccination rates in February 2022 on HDI and the predictors that retained statistical significance when controlling for HDI: trust in doctors and nurses, trust in national government, infants immunized for measles, and CVD death rate. In Model 4, HDI remained the strongest predictor of vaccination success. The share of people who trust doctors and nurses and trust in the national government are no longer statistically significant, when they are both included in the model. The other two health outputs remained statistically significant. We then excluded trust in the national government in Model 5, given that it correlates highly with trust in doctors and nurses. As a result of this model respecification, in Model 5, trust in doctors and nurses became statistically significant. In Model 5, the national poverty rate is also a marginally statistically significant predictor for COVID-19 vaccination.

As discussed before, a similar understanding holds for measles vaccination (Table 3, Model 6). HDI is also the strongest predictor of the rate of infants immunized for measles. The lower beta coefficient also reflects the nonlinear relationship, which is better approximated by a logarithmic curve, because of the vaccination plateau (Fig. 3). Therefore, the predictive relevance of HDI goes beyond COVID-19 vaccination, covering previous, better institutionalized vaccines as well. The rate of trust in doctors and nurses is also a significant predictor of measles vaccination. CVD rate does not add a statistically significant predictive power for measles vaccination. Neither does the national poverty rate, despite having a significant partial correlation when controlling for HDI.

The relationship between COVID-19 vaccination rates and trust in doctors and nurses, while controlling for HDI and other country-level health outcomes, is useful to clarify divergences that rank prominently in public debate. The Gallup 2019 report shows that, globally, 41% of people trust medical staff 'a lot', but there is wide variability in this distribution. The proportion is highest in Western Europe (68%) and Northern Europe (65%), Australia and New Zealand (65%), South Asia (61%), going to 52% in North America, 45–46% in Southern Europe and Southern Africa, 35% in the Middle East, Central America and Mexico, 30% in North Africa, 28% in South America, and plummeting to 25% in Eastern Europe, East Asia, and Central Africa.[39] What we find noteworthy is covariation with the success of COVID-19 vaccination, particularly regarding the lag of the US in relation to other high HDI countries, and the differences between Romania and Bulgaria in Eastern Europe compared with the countries of Southern Europe. Therefore, trust in medical staff can explain why COVID-19 vaccination trajectories among countries in the same HDI categories have been quite different (See Fig. S.M.1 in the Supplementary Material).

Specific pandemic policies have also played a role in the success of vaccination campaigns. We can examine their influence by using the Stringency Index computed in the Oxford COVID-19 Government Response Tracker program (OxCGRT),[40] which synthesizes governmental measures during COVID-19, covering closure and containment such as social distancing and lockdowns, health policies and vaccination, and economic support mitigating the impact of the pandemic. Since January 1, 2022, OxCGRT has begun reporting distinct values of stringency for vaccinated and unvaccinated people, in countries where policies are differentiated. By subtracting the vaccinated from the unvaccinated stringency index, we obtain a measurement of governmental incentives to vaccinate. The differential index values cannot be used in a quantitative analysis as predictors for vaccination rates in February 2022, because the data set is incomplete for the reference dates of January–February 2022, as many values have been added subsequently (March 2022 and later). Still, we can inquire into the countries with the highest differences in stringency, as highlighted by OxCGRT[41] and see how they fare as regards COVID-19 vaccination success, in February 2022. For each country included in the top list for highest maximum and average differences in stringency between the unvaccinated and the vaccinated, we examined whether the country is much higher (++), higher (+), below (−), or much below (−−) the linear regression line between vaccination and HDI, as presented in Fig. 2. We find that Ukraine (−−) lies much below the line, Germany (−) lies slightly below the line, whereas all others can be found either on the line (Oman and Hungary) or above the line: France (+), Lithuania (+), Turkey (+), Argentina

Table 1
Bivariate Bravais–Pearson correlations and partial correlations controlling for HDI 2019 between vaccination rates and indicators of human, economic, and social capital indicators.

Variables	Bivariate correlations					Partial correlations when controlling for the HDI 2019		
	Metric	People fully vaccinated per hundred, Feb. 2022 (OWID)	People fully vaccinated per hundred, July 2021 (OWID)	Infants immunized for measles for 1-year olds, 2019 (HDR)	Human Development Index (HDI) 2019	Metric	People fully vaccinated per hundred, Feb. 2022 (OWID)	Infants immunized for measles at 12 months, 2019 (%) (UNDP HDR)
People fully vaccinated per hundred, Feb. 2022 (OWID)	Pearson correlation	1	0.739**	0.623**	0.847**	N/A		
	Sig. (2-tailed)		0.000	0.000	0.000		x	
	N	146	130	142	139			
People fully vaccinated per hundred, July 2021 (OWID)	Pearson correlation	0.693**	1	0.404**	0.695**	N/A		
	Sig. (2-tailed)	0.000		0.000	0.000			
	N	138	144	139	143			
Human Development Index (HDI) 2019	Pearson correlation	0.826**	0.695**	0.622**	1	N/A		
	Sig. (2-tailed)	0.000	0.000	0.000				
	N	145	143	147	152			
Life expectancy at birth 2019 (HDI component)	Pearson correlation	0.836**	0.647**	0.638**	0.923**	N/A		
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Component of HDI		
	N	146	144	148	152			
Mean years of schooling 2019 (HDI component)	Pearson correlation	0.688**	0.594**	0.575**	0.924**	N/A		
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Component of HDI		
	N	145	142	147	150			
Expected years of schooling 2019 (HDI component)	Pearson correlation	0.788**	0.643**	0.575**	0.915**	N/A		
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Component of HDI		
	N	142	139	147	147			
GNI per capita 2019 in 2017 PPP (HDI component)	Pearson correlation	0.706**	0.744**	0.422**	0.818**	N/A		
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Component of HDI		
	N	142	139	147	147			
Inequality in life expectancy 2015–2020 (HDR data set)	Pearson correlation	−0.793**	−0.641**	−0.668**	−0.936**	N/A		
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Collinear with HDI		
	N	143	140	148	148			
Inequality in education 2019 (HDR data set)	Pearson correlation	−0.663**	−0.530**	−0.584**	−0.847**	N/A		
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Collinear with HDI		
	N	137	135	142	143			
Inequality in income 2019 (HDR data set)	Pearson correlation	−0.286**	−0.337**	−0.302**	−0.378**	Partial correlation	0.037	−0.099
	Sig. (2-tailed)	0.001	0.000	0.000	0.000	Sig. (2-tailed)	0.683	0.266
	N	126	123	130	131	df	123	127
Gini Index 2019 (HDR data set)	Pearson correlation	−0.298**	−0.242**	−0.262**	−0.335**	Partial correlation	−0.023	−0.092
	Sig. (2-tailed)	0.001	0.006	0.002	0.000	Sig. (2-tailed)	0.799	293
	N	132	130	134	137	df	128	130
PISA Score for Reading 2018 (OWID)	Pearson correlation	0.529**	0.428**	0.295*	0.791**	Partial correlation	0.159	0.082
	Sig. (2-tailed)	0.000	0.000	0.016	0.000	Sig. (2-tailed)	0.209	0.518
	N	65	67	66	67	df	62	63
PISA Score for Mathematics 2018 (OWID)	Pearson correlation	0.451**	0.375**	0.309*	0.748**	Partial correlation	0.044	0.113
	Sig. (2-tailed)	0.000	0.002	0.011	0.000	Sig. (2-tailed)	0.727	0.367
	N	66	68	67	68	df	63	64
PISA Score for Science 2018 (OWID)	Pearson correlation	0.513**	0.379**	0.285*	0.732**	Partial correlation	0.168	0.080
	Sig. (2-tailed)	0.000	0.001	0.019	0.000	Sig. (2-tailed)	0.182	0.522
	N	66	68	67	68	df	63	64
World Bank - Poverty ratio	Pearson correlation	−0.641**	−0.580**	−0.560**	−0.670**	Partial correlation	−0.225	−0.261
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Sig. (2-tailed)	0.116	0.061
	N	51	51	50	51	df	48	47
	Pearson correlation	−0.637**	−0.494**	−0.536**	−0.705**	Partial correlation	−0.167	**−0.213***
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Sig. (2-tailed)	0.066	**0.018**

World Bank - National poverty ratio	*N*	123	120	125	127	df	119	**121**
Extreme poverty rate (OWID)	Pearson correlation	−0.654**	−0.468**	−0.389**	−0.770**	Partial correlation	−0.068	0.065
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Sig. (2-tailed)	0.496	0.521
	N	145	97	102	103	df	100	99
Corruption Perception Index CPI 2020 (Transparency International)	Pearson correlation	0.689**	0.663**	0.480**	0.766**	Partial correlation	0.135*	−0.004
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Sig. (2-tailed)	0.109	0.965
	N	144	142	146	150	df	140	142
Share of people who trust their national government 2018 (OWID, from Wellcome Global Monitor)	**Pearson correlation**	0.053	−0.069	0.182*	−0.066	Partial correlation	**0.217***	**0.266***
	Sig. (2-tailed)	0.564	0.462	0.046	0.463	Sig. (2-tailed)	**0.018**	**0.003**
	N	120	116	121	124	df	**117**	**118**
Share of people who trust doctors and nurses in their country 2018 (OWID, from Wellcome Global Monitor)	**Pearson correlation**	0.575**	0.413**	0.497**	0.536**	Partial correlation	**0.267***	**0.272***
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Sig. (2-tailed)	**0.002**	**0.002**
	N	129	126	131	134	df	**126**	**128**
Health expenditure % of GDP in 2017 (HDR data set)	Pearson correlation	0.348**	0.326**	0.270**	0.387**	Partial correlation	0.014	0.054
	Sig. (2-tailed)	0.000	0.000	0.001	0.000	Sig. (2-tailed)	0.868	0.523
	N	138	136	142	144	df	135	139
Physicians per 1000 people 2019 (HDR data set)	Pearson correlation	0.620**	0.576**	0.511**	0.775**	Partial correlation	−0.033	0.076
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Sig. (2-tailed)	0.698	0.368
	N	139	136	145	144	df	135	141
Hospital beds per 1000 people 2019 (HDR data set)	Pearson correlation	0.394**	0.309**	0.399**	0.564**	Partial correlation	−0.149	0.078
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	Sig. (2-tailed)	0.092	0.375
	N	131	128	135	134	df	127	131
Cardiovascular death rate (OWID)	Pearson correlation	−0.497**	−0.376**	−0.221**	−0.410**	Partial correlation	**−0.300****	0.055
	Sig. (2-tailed)	0.000	0.000	0.008	0.000	Sig. (2-tailed)	**0.000**	0.520
	N	145	137	142	144	df	**141**	138
Prevalence of diabetes (OWID)	Pearson correlation	0.238**	0.120	0.125	0.269**	Partial correlation	0.031	−0.056
	Sig. (2-tailed)	0.004	0.165	0.139	0.001	Sig. (2-tailed)	0.714	0.509
	N	144	136	141	144	df	141	138
Infants immunized for measles at 12 months, 2019 (%) (UNDP HDR)	Pearson correlation	0.623**	0.404**	1	0.622**	Partial correlation	**0.231****	N/A
	Sig. (2-tailed)	0.000	0.000		0.000	Sig. (2-tailed)	**0.006**	
	N	142	139	148	147	df	**138**	

Partial correlations that are statistically significant for $P = 5\%$ are marked in bold.
Source: Authors' analysis on publicly available data from OWID, UNDP HDR, Transparency International, and The World Bank.
**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 2
Multiple regression model of the rate of people fully vaccinated in Feb. 2022 on HDI components: life expectancy, GNI per capita and mean years of schooling in 2019.

Independent variables:	Model 1 Dependent variable: People fully vaccinated (%), February 2022		Model 2 Dependent variable: People fully vaccinated (%), February 2022		Model 3 Dependent variable: Infants immunized for measles at 12 months (%), 2019	
	Beta	Sig.	Beta	Sig.	Beta	Sig.
Life expectancy at birth 2019	**0.674****	**0.000**	**0.522****	**0.000**	**0.513****	**0.000**
GNI per capita 2019 (in 2017 PPP)	**0.206****	**0.006**	0.113	0.121	−0.140	0.150
Mean years of schooling 2019	0.003	0.968	N/A		**0.275***	**0.011**
Expected years of schooling	N/A		**0.270****	**0.002**	N/A	
Listwise *N*	142		142		147	
Adjusted R square	0.700		0.719		0.408	

Source: Authors' analysis of publicly available data from UNDP HDR and Our World in Data.
Coefficients that are statistically significant for P = 5% are marked in bold.
** Coefficient is significant at the 0.01 level (2-tailed).
* Coefficient is significant at the 0.05 level (2-tailed).

(++), Colombia (++), Ecuador (++), Italy (++), Morocco (++), and Pakistan (++). This incipient analysis suggests a pattern of positive influence from differential stringency on vaccination success. Future research should further explore the influence of specific incentives on vaccination, using the OxCGRT data set and other measurements of governmental intervention.

Discussion

Our exploratory analysis of social patterns that uphold vaccination success, in the case of COVID-19 and measles, highlights the role of HDI as the strongest predictor among a set of widely used measures of human, social, and economic capital. This finding is convergent with previous research. However, while most studies focus on the income component of HDI, we find that, among the three HDI dimensions, life expectancy is most relevant in accounting for COVID-19 and measles vaccination success, despite being largely neglected in previous ecological analyses of COVID-19 vaccination.

Education outcomes, measured through mean years of schooling, expected years of schooling, or PISA results, add less explanatory power than life expectancy, in regard to COVID-19 and measles vaccination. This supports the argument that vaccination success is less a matter of overcoming deficits in scientific literacy, and more a matter of establishing public trust in a health system and science with proven anterior performance in keeping people healthy and alive.[12]

In accord with previous research at the individual level, our analysis also highlights the role of trust, specifically in doctors and nurses as a predictor of vaccination success. This indicator remains statistically significant when controlling for HDI and other generic and specific indicators of health system effectiveness (CVD mortality and measles vaccination coverage, respectively). Trust is statistically significant in partial correlation and multiple regression models of both COVID-19 and measles vaccination, while other indicators concerning economic inequality, perceived corruption, and inputs into the health system do not add predictive value beyond HDI. National poverty rates seem to remain a relevant predictor for both types of vaccination, though statistical significance is oscillating around the 5% threshold, depending on model specification.

COVID-19 vaccines prove to be part of the Matthew effect of accumulating advantages and exacerbating disadvantages that the

Table 3
Multiple regression model of vaccination rates on HDI, trust indicators, and cardiovascular death rate.

	Model 4		Model 5		Model 6	
	Dependent variable: COVID-19 vaccination rate in February 2022				Dependent variable: Infants immunized for measles at 12 months, 2019 (%)	
	Standardized coefficient Beta	Sig.	Standardized coefficient Beta	Sig.	Standardized coefficient Beta	Sig.
Independent variables:						
HDI 2019 (HDR data set)	**0.588****	**0.000**	**0.472****	**0.003**	**0.389****	**0.001**
World Bank National poverty rate	−0.030	0.677	**−0.145***	**0.044**	−0.109	0.283
Share of people who trust doctors and nurses in their country, 2018 (OWID)	0.177	0.065	**0.150***	**0.021**	**0.287****	**0.001**
Cardiovascular death rate	**−0.197****	**0.000**	**−0.219****	**0.000**	0.098	0.216
Infants immunized for measles at 12 months, 2019 (%) (UNDP HDR)	**0.135****	**0.020**	**0.143****	**0.038**	Dependent variable	
Share of people who trust their national government, 2018 (OWID)	−0.001	0.094	Not included		Not included	
Adjusted R square	0.753		0.703		0.395	
Listwise *N*	105		111		111	

Source: Authors' analysis of publicly available data from UNDP HDR and Our World in Data.
Coefficients that are statistically significant for P = 5% are marked in bold.
** Coefficient is significant at the 0.01 level (2-tailed).
* Coefficient is significant at the 0.05 level (2-tailed).

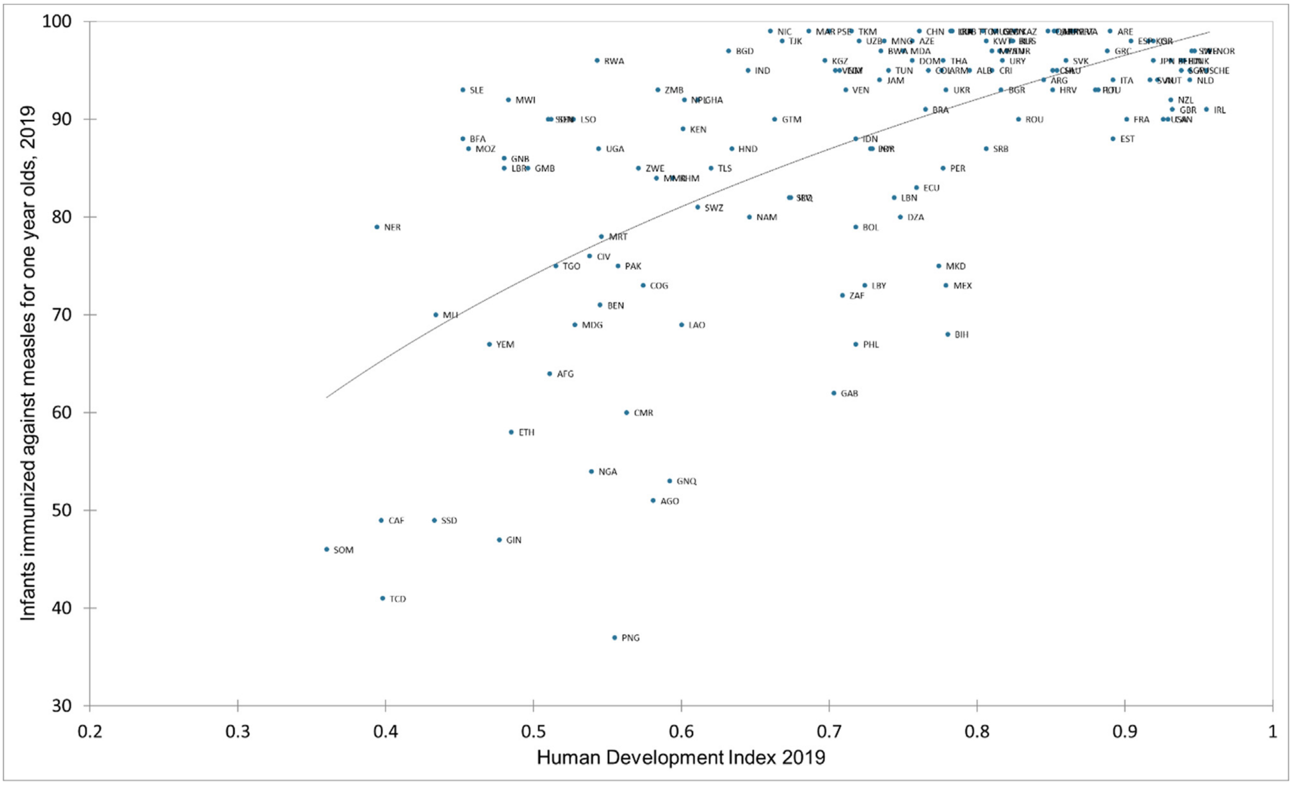

Fig. 3. Scatterplot of rates of infants immunized against measles for 1-year olds, 2019, vs. HDI 2019, with a logarithmic growth trendline. Source: Authors' analysis on data from UNDP Human Development Reports.

pandemic inflicted on societies and communities across the world.[42] At the same time, the remaining 28% of variability that cannot be determined through these sets of metrics points to a considerable scope for collective and individual agency in a time of crisis. For example, countries with an HDI of approximately 85 ranged from rates of 40%–80% for fully vaccinated people. Differential stringency of pandemic policies, between unvaccinated and vaccinated people, may have played a role in stimulating vaccination. The mobilization and coordination in the vaccination campaigns of citizens, medical professionals, scientists, journalists, and politicians, among others, account for at least some of this variability in overcoming vaccine hesitancy and inequity.

Public health policies and campaigns should focus on consolidating trust in the medical system, especially regarding doctors and nurses, because this is an important factor for the success of vaccination programs, independent from other social development factors aggregated by HDI. This finding could be especially influential in countries that, despite having access to vaccines, lag behind desired levels of vaccination coverage. The high relevance of life expectancy as a predictor for the vaccination rate suggests that future research in this field should move beyond the focus on national income as a proxy for social development, toward a more inclusive approach that takes into account the quantity and quality of life in a given society.

For the most part, the limitations of the present study are derived from its pursuit of a wide reach, in terms of countries and variables included in the analysis, and from its ecological and correlational approach. Given that some countries do not take part in specific international research programs or reporting initiatives, there is missing data for some of the independent variables (see Table S.M.1 in the Supplementary Material), which we handled through pairwise deletion. We did not take into account internal variability between states or regions of a given country. Measurement of all variables, at country level, could be affected by heterogenous definitions among different national contexts and by differential performance of national data collection infrastructures. It has been documented that COVID-19 testing has been more widespread in countries with a higher governmental capacity,[43] and this finding may also be relevant for the country-level metrics used in this study. Therefore, some of the bivariate or partial correlations that appear to be statistically insignificant may be affected by lower measurement quality, rather than indicating, with certainty, an absence of the respective association. Like other ecological studies, our research does not purport to test any causal relationship, but to identify, through exploratory analysis, possibly influential factors at macro level. Our discussion of the role of trust in health professionals and other aggregated metrics induces a risk of an ecological fallacy, as we document a country-level association for variables that are hypothetically connected at the individual level. Last but not least, there remains a risk of omitted confounding variables, hidden beyond the observed country-level patterns.

Author statements

Ethical approval

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Competing interests

None.

Author contribution

All authors made a significant contribution to the development of this manuscript and approved the final version for submission.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.06.027.

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