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

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Abstract

We estimate patterns of covariation between COVID-19 vaccination rates and a set of widely used indicators of human, social, and economic capital across 146 countries in July 2021 and February 2022. About 70% of the variability in COVID-19 vaccination rates worldwide can be explained by differences in the Human Development Index (HDI) and, specifically, in life expectancy at birth, one year after the campaign debut. Trust in doctors and nurses adds predictive value beyond the HDI, clarifying controversial discrepancies between vaccination rates in countries with similar levels of human development 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. The metrics of economic inequality, perceived corruption, poverty, and inputs into the health system have strong bivariate correlations with COVID-19 vaccination but no longer remain statistically significant when controlling for the HDI. Our analysis identified the contours of a social structure that sustains life and is reproduced through this process. COVID-19

vaccines have proven to be part of the Matthew effect of accumulating advantages and aggravating disadvantages that the pandemic inflicted on societies and communities across the world. At the same time, the remaining variability in 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.

Keywords: vaccination; COVID-19; life expectancy; trust; social structure; human development index.

1. 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, one year after the vaccine’s debut. In this paper, we discuss the relative contribution to predicting COVID-19 vaccination rates of a set of 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 perspectives of this accomplishment. Humans are social beings, and human life is socially constructed. Thus, we witness variations across societies and history in the success of various communities in overcoming survival challenges and upholding life (Fig. 1). 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.

The life expectancy of a specific society in a certain year also reflects the broader forces of interdependence. After all, the destruction of life through wars, pandemics, colonialism, and other forms of exploitation has often moved from one place to another and has redistributed the chances of survival. We can see, as shown in Fig. 1, the life expectancy depression that the Great Influenza of 1918 made in the United States, and the devastation brought by the Second World War in Japan. We can also see broad inequalities that reproduce past outcomes of violence and exploitation and persist despite global progress. It is important to take into account that life expectancy in a given society also reflects the capacity of humanity globally to protect life. At the same time, its variation can be used to examine related social outcomes and to understand the social processes that either further or impede life.

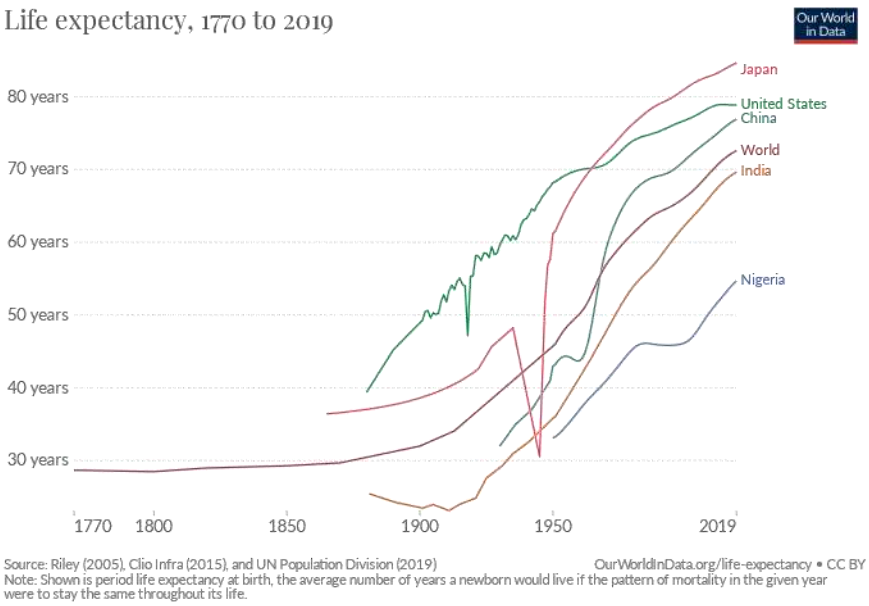

Fig. 1. Evolution in life expectancy in selected countries from 1770 onwards. Source: Our World in Data.

Ancient Greek mythology named three Fates who were responsible for human destinies: Clotho spun the thread of life, Lachesis gave it away, and Atropos cut it. Though not explicitly appointed as a Fate, *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 that keep track of the related deaths [3, 4]. There is convincing evidence that vaccination against COVID-19 has prevented numerous deaths globally [5].

At the same time, *rates of vaccination have varied widely during the pandemic*, and this is one of the factors reflected in the differential COVID-19 mortality from country to country. For example, Bulgaria and Romania, countries with the lowest vaccination rates against COVID-19 in the European Union (Fig. 2), have significantly higher death tolls than other European countries.

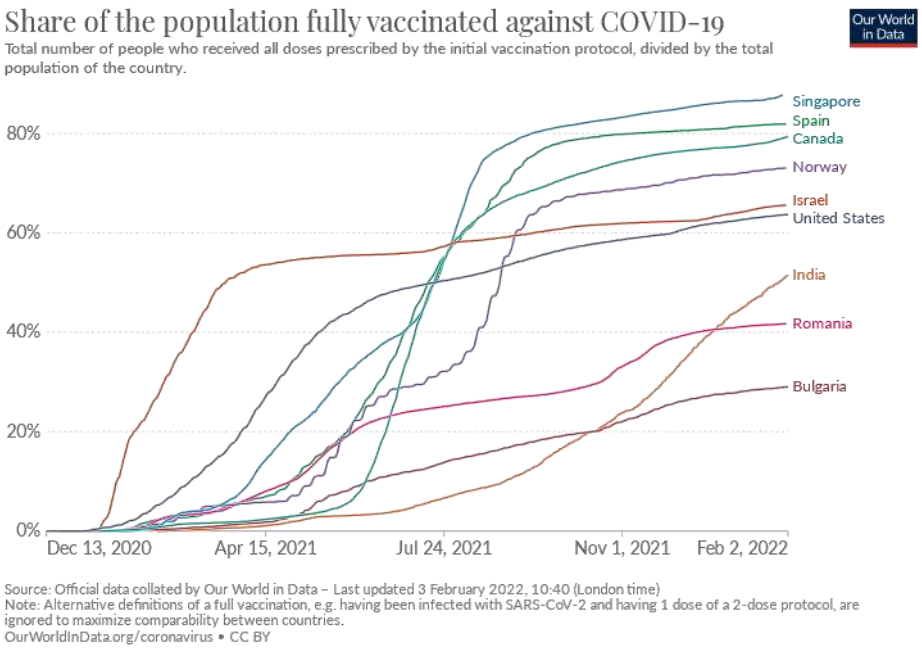

Fig. 2. Share of the population fully vaccinated against COVID-19 in selected countries. Source: Our World in Data.

In contrast, the United States started to fall behind on COVID-19 vaccination and to lose ground in mortality rates in comparison with countries such as the United Kingdom, Germany, and Canada (Figs. 2 and 3). Differential vaccine coverage poses significant risks for global public health through the emergence of new viral strains, which endanger the short-term benefits of the early vaccinated countries [6].

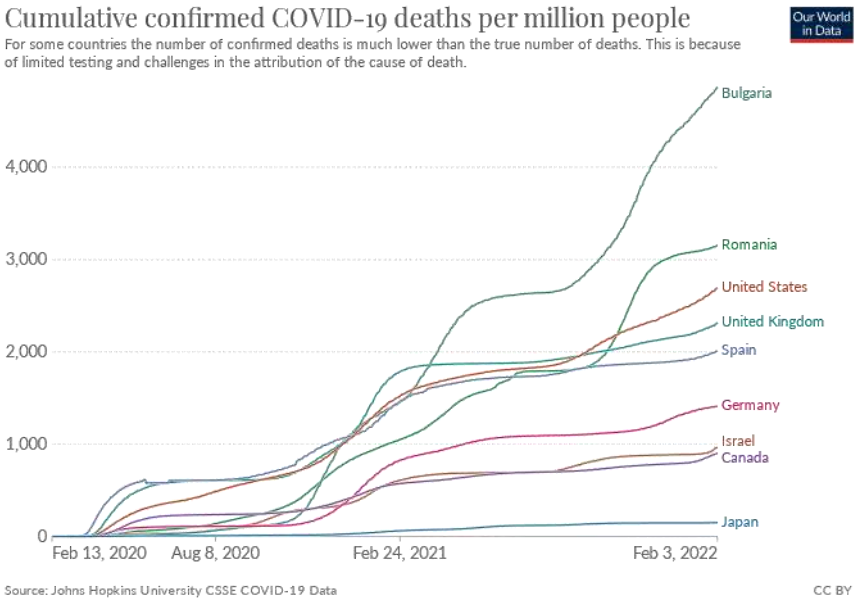

Fig. 3. COVID-19 death toll measured through the cumulative confirmed COVID-19 deaths per million people. Source: Our World in Data.

Societal resources shape a collectivity's ability to immunize its members against infection through vaccination [7]. However, 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, 9, 10, 11]. In this paper, 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 the 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. First, they have facilitated earlier access to newly developed vaccines. Second, they have powered the required logistics of a large-scale vaccination campaign that needs to address all regions and social categories, including the most vulnerable and hard to reach citizens. Several studies signaled a positive association between coverage of COVID-19 vaccination, the Human Development Index (HDI), and gross domestic product (GDP) per capita [12, 13, 14]. Trust in the state and in the health system has been associated with greater compliance with COVID-19 restrictions in Europe [15]. Trust in medical and scientific experts has been a strong correlate of pro-vaccination attitudes in general [16, 17, 18, 19] and of the declared intention to receive a COVID-19 vaccine internationally [20, 21, 22]. Social and economic inequality has been associated with lower vaccination rates aggregated at the county level [23]. Perceived corruption is associated with decreased vaccination coverage globally [24] and it also affects trust in mainstream health policy, exacerbating vaccination hesitancy [25].

2. Methods

We accessed publicly available data on COVID vaccination rates and other country-level indicators of human, social, and economic capital from the datasets of Our World in Data (OWID) [26] and the HDI; the associated metrics from the 2020 Human Development Report (HDR) of the United Nations Development Programme [27] and the Corruption Perception Index [28]; and data on poverty rates [29]. 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,[1] though most variables had several missing values and, thus, the number of countries available for each estimate was then lower, as indicated.

[1] The countries included in the analysis are, in alphabetical order: Afghanistan, Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahrain, Bangladesh, Belarus, Belgium, Benin, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Cambodia, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Croatia, Cuba, Czech Republic, Democratic Republic of Congo, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Estonia, Eswatini, Ethiopia, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Honduras, Hong Kong, Hungary, India, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyzstan, Laos, Latvia, Lebanon, Liberia, Libya, Lithuania, Madagascar, Malawi, Malaysia, Mali, Mauritania, Mexico, Moldova, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, North Macedonia, Norway, Oman,

Our 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 descriptive statistics and sources for the predictors included in the analysis are presented in Table 1. The control variable for partial correlations was the HDI, a synthetic measure of country-level capital that aggregates three dimensions: 1) a long and healthy life, measured by life expectancy at birth; 2) knowledge, measured by an education index composed of mean years of schooling and expected years of schooling; and 3) a decent standard of living, measured by gross national income per capita (GNI) [27].

Table 1
Descriptive statistics for the variables included in the analysis. Source: Authors' analysis of publicly available data from OWID, UNDP HDR, Transparency International, and The World Bank.

	Number of cases (N)	Minimum	Maximum	Mean	Std. Deviation
People fully vaccinated per hundred, Feb. 2022 (OWID)	146	0.23	93.55	44.50	27.59
People fully vaccinated per hundred, July 2021 (OWID)	144	0.01	66.00	15.65	17.83
Human Development Index 2019 (UNDP HDR)	152	0.36	0.96	0.72	0.16
Life expectancy at birth 2019 (HDI component, UNDP HDR)	153	53.28	84.86	72.52	7.85
Mean years of schooling 2019 (HDI component, UNDP HDR)	151	1.64	14.15	8.74	3.19
Expected years of schooling 2019 (HDI component, UNDP HDR)	148	5.30	21.95	13.43	3.01
GNI per capita 2019 in 2017 PPP (HDI component, UNDP HDR)	148	993.01	92,418.23	20,129.66	20,023.66
Atkinson Index of inequality in life expectancy (UNDP HDR)	149	2.50	40.90	14.72	10.68
Atkinson Index of inequality in education (UNDP HDR)	143	0.70	50.12	18.85	14.45
Atkinson Index of inequality in income (UNDP HDR)	131	8.50	57.00	23.03	9.28
Gini Index on inequality in income 2019 (UNDP HDR)	138	0.00	63.03	36.82	9.69
PISA Programme for International Student Assessment Score Reading 2018 (OWID, from OECD)	67	339.69	555.24	453.32	53.78

Pakistan, Palestine, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Serbia, Sierra Leone, Singapore, Slovakia, Slovenia, Somalia, South Africa, South Korea, South Sudan, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syria, Taiwan, Tajikistan, Thailand, Timor, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

PISA Programme for International Student Assessment Score Mathematics 2018 (OWID, from OECD)	68	325.10	591.39	456.79	56.78
PISA Programme for International Student Assessment Score Science 2018 (OWID, from OECD)	68	335.63	590.45	457.39	52.31
World Bank - Poverty ratio (%)	51	2.37	74.20	28.11	15.35
World Bank - National poverty ratio (%)	128	0.60	76.80	27.86	17.00
Extreme poverty rate (%) (OWID)	103	0.10	77.60	13.12	20.10
Corruption Perception Index CPI 2020 (Transparency International)	151	12.00	88.00	42.47	19.05
Share of people who trust their national government 2018 (%) (OWID, from Wellcome Trust)	124	10.95	99.22	51.51	18.11
Share of people who trust doctors and nurses in their country 2018 (%) (OWID, from Wellcome Trust)	134	43.43	98.20	80.79	11.56
Health expenditure % of GDP in 2017 (UNDP HDR)	144	1.18	17.06	6.63	2.61
Physicians per 1000 people 2019 (UNDP HDR)	145	0.23	84.22	19.31	16.94
Hospital beds per 1000 people 2019 (UNDP HDR)	135	1.00	129.80	28.95	24.33
Cardiovascular Disease Death Rate per 100,000 people (OWID)	145	79.37	724.42	260.84	123.43
Diabetes Prevalence (%) (OWID)	144	0.99	17.72	7.18	3.52
Infants lacking immunization for measles at 12 months, 2019 (%) (UNDP HDR)	148	1.00	63.00	13.12	14.15

3. Results

An exploration of bivariate correlations indicated a very strong relationship between COVID-19 vaccination rates and the 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 (see Fig. 4) to February 2022 (see Fig. 5). 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.

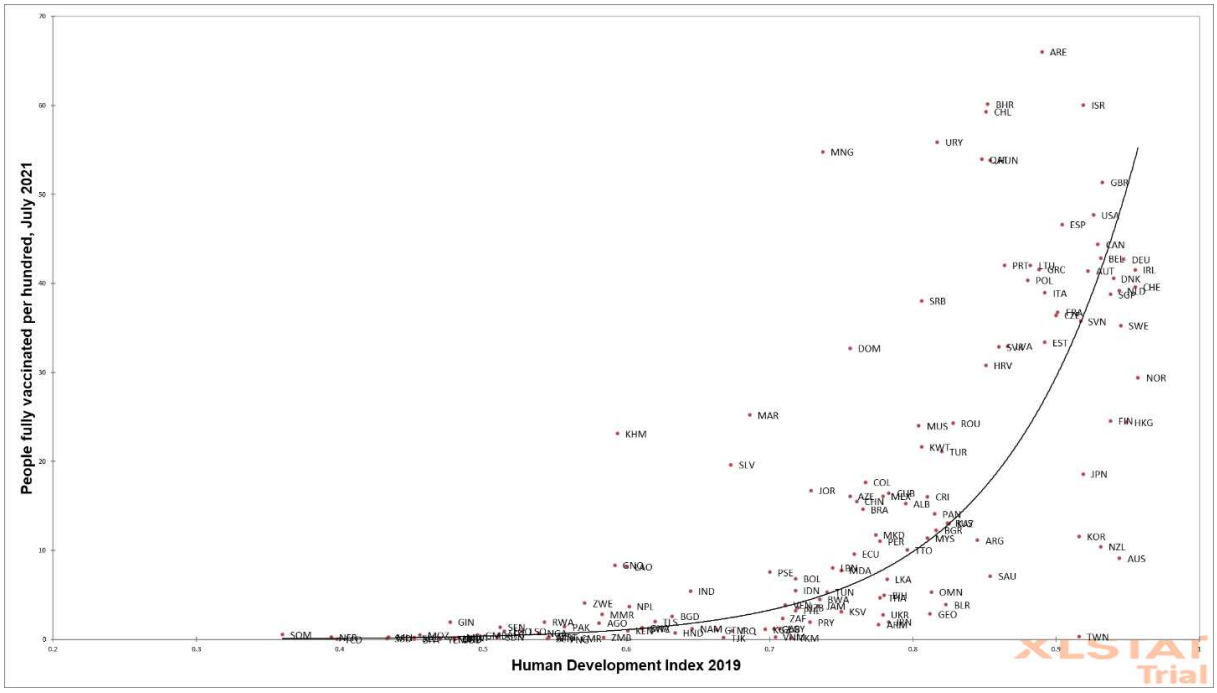

Fig. 4. Scatterplot of rates of fully vaccinated people in **July 2021** vs. HDI 2019. Source: Authors' analysis of data from Our World in Data and UNDP Human Development Reports. Linear Pearson correlation: $r = 0.695$ ($p = 0.000$).

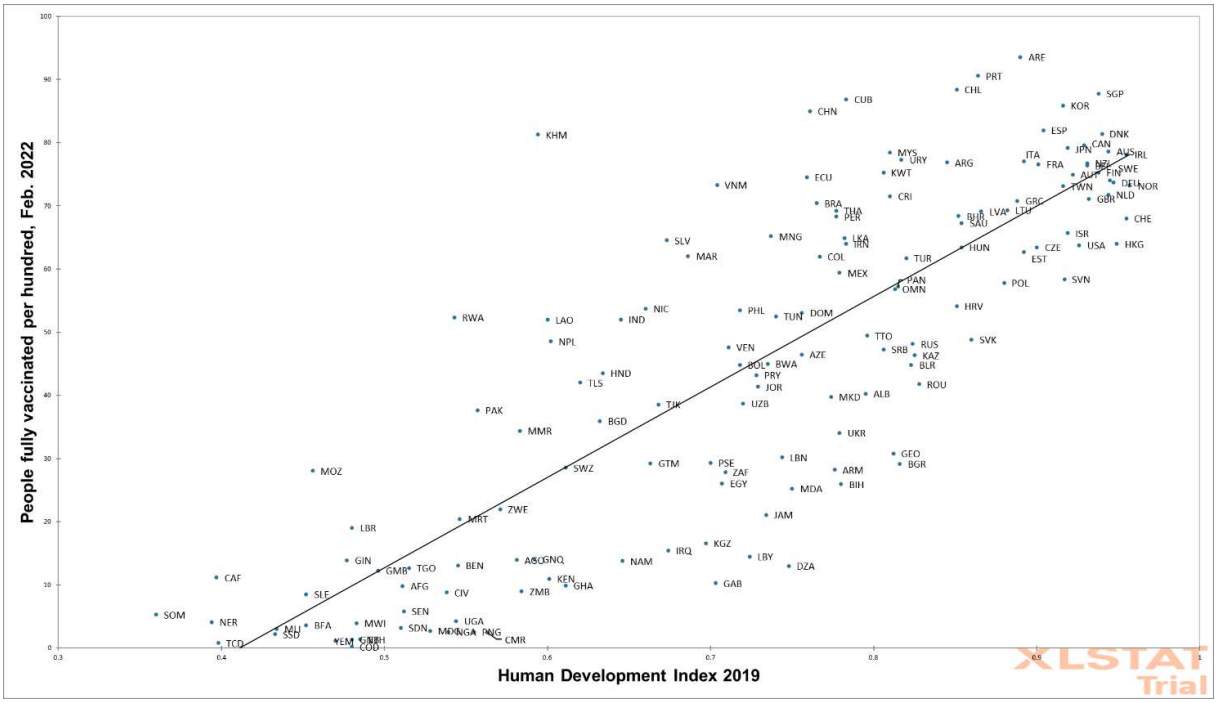

Fig. 5. Scatterplot of rates of fully vaccinated people in **February 2022** vs. HDI 2019. Source: Authors' analysis of data from Our World in Data and UNDP Human Development Reports. Linear Pearson correlation: r = 0.826 (p = 0.000).

A bivariate analysis of vaccination rates and multiple indicators of human, social, and economic capital indicates a broad pattern of covariation (see Table 2). *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 the aggregate HDI) are *life expectancy at birth and gross national income per capita,* two of the three dimensions of the HDI. First, life expectancy at birth correlates at 0.836 with the vaccination rate in February 2022, thus explaining about 70% of its total variance.[2] Second, gross national income per capital correlates at 0.706 with vaccination rates in February 2022, thus explaining about 50% of the total variance, which makes it the second strongest predictor in the bivariate analysis. Mean years of schooling, the third dimension of the HDI, also correlates at 0.688 with the February 2022 vaccination rate.

Table 2
Bivariate Bravais-Pearson correlations and partial correlations controlling for HDI 2019 between vaccination rates and indicators of human, economic, and social capital. Source: Authors' analysis on publicly available data from OWID, UNDP HDR, Transparency International, and The World Bank.

			1. Bivariate correlations			2. Partial correlations, controlling for HDI 2019	
			People fully vaccinated per hundred, Feb. 2022 (OWID)	People fully vaccinated per hundred, July 2021 (OWID)	Human Development Index (HDI) 2019	People fully vaccinated per hundred, Feb. 2022 (OWID)	
1.	People fully vaccinated per hundred, Feb. 2022 (OWID)	Pearson Correlation	1	0.739**	0.847**	N/A	
		Sig. (2-tailed)		0.000	0.000		
		N	146	130	139		
2.	People fully vaccinated per hundred, July 2021 (OWID)	Pearson Correlation	0.693**	1	0.695**	N/A	
		Sig. (2-tailed)	0.000		0.000		
		N	138	144	143		
3.	Human Development Index (HDI) 2019	Pearson Correlation	0.826**	0.695**	1	N/A	
		Sig. (2-tailed)	0.000	0.000			
		N	145	143	152		
4.	(Only for countries with HDI **lower than 0.65**) Human Development Index (HDI) 2019	Pearson Correlation	0.560**	0.365*	1	N/A	
		Sig. (2-tailed)	0.000	0.016			
		N	47	43	49		
5.	(Only for countries with HDI **equal to or higher than 0.65**)	Pearson Correlation	0.643**	0.639**	1	N/A	
		Sig. (2-tailed)	0.000	0.000			
		N	98	100	103		

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

	Human Development Index (HDI) 2019						
6.	Life expectancy at birth 2019 (HDI component)	Pearson Correlation	0.836**	0.647**	0.923**	N/A	
		Sig. (2-tailed)	0.000	0.000	0.000	Component of HDI	
		N	146	144	152		
7.	Mean years of schooling 2019 (HDI component)	Pearson Correlation	0.688**	0.594**	0.924**	N/A	
		Sig. (2-tailed)	0.000	0.000	0.000	Component of HDI	
		N	145	142	150		
8.	Expected years of schooling 2019 (HDI component)	Pearson Correlation	.788**	.643**	.915**	N/A	
		Sig. (2-tailed)	.000	.000	.000	Component of HDI	
		N	142	139	147		
9.	GNI per capita 2019 in 2017 PPP (HDI component)	Pearson Correlation	0.706**	0.744**	0.818**	N/A	
		Sig. (2-tailed)	0.000	0.000	0.000	Component of HDI	
		N	142	139	147		
10.	Inequality in life expectancy 2015-2020 (HDR dataset)	Pearson Correlation	-0.793**	-0.641**	-0.936**	N/A	
		Sig. (2-tailed)	0.000	0.000	0.000	Collinear with HDI	
		N	143	140	148		
11.	Inequality in education 2019 (HDR dataset)	Pearson Correlation	-0.663**	-0.530**	-0.847**	N/A	
		Sig. (2-tailed)	0.000	0.000	0.000	Collinear with HDI	
		N	137	135	143		
12.	Inequality in income 2019 (HDR dataset)	Pearson Correlation	-0.286**	-0.337**	-0.378**	Partial Correlation	0.037
		Sig. (2-tailed)	0.001	0.000	0.000	Sig. (2-tailed)	0.683
		N	126	123	131	df	123
13.	Gini Index 2019 (HDR dataset)	Pearson Correlation	-0.298**	-0.242**	-0.335**	Partial Correlation	-0.023
		Sig. (2-tailed)	0.001	0.006	0.000	Sig. (2-tailed)	0.799
		N	132	130	137	df	128
14.	PISA Score for Reading 2018 (OWID)	Pearson Correlation	0.529**	0.428**	0.791**	Partial Correlation	0.159
		Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.209
		N	65	67	67	df	62
15.	PISA Score for Mathematics 2018 (OWID)	Pearson Correlation	0.451**	0.375**	0.748**	Partial Correlation	0.044
		Sig. (2-tailed)	0.000	0.002	0.000	Sig. (2-tailed)	0.727
		N	66	68	68	df	63
16.	PISA Score for Science 2018 (OWID)	Pearson Correlation	0.513**	0.379**	0.732**	Partial Correlation	0.168
		Sig. (2-tailed)	0.000	0.001	0.000	Sig. (2-tailed)	0.182

	N	66	68	68	df	63
17. World Bank - Poverty ratio	Pearson Correlation	-0.641**	-0.580**	-0.670**	Partial Correlation	-0.225
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.116
	N	51	51	51	df	48
18. World Bank - National poverty ratio	Pearson Correlation	-0.637**	-0.494**	-0.705**	Partial Correlation	-0.167
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.066
	N	123	120	127	df	119
19. Extreme poverty rate (OWID)	Pearson Correlation	-0.654	-.468**	-.770**	Partial Correlation	-0.068
	Sig. (2-tailed)	0.000	.000	.000	Sig. (2-tailed)	0.496
	N	145	97	103	df	100
20. Corruption Perception Index CPI 2020 (Transparency International)	Pearson Correlation	0.689**	0.663**	0.766**	Partial Correlation	0.135*
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.109
	N	144	142	150	df	140
21. Share of people who trust their national government 2018 (OWID, from Wellcome Global Monitor)	**Pearson Correlation**	**0.053**	**-0.069**	**-0.066**	**Partial Correlation**	**0.217***
	Sig. (2-tailed)	0.564	0.462	0.463	Sig. (2-tailed)	0.018
	N	120	116	124	df	117
22. Share of people who trust doctors and nurses in their country 2018 (OWID, from Wellcome Global Monitor)	**Pearson Correlation**	0.575**	**0.413****	**0.536****	**Partial Correlation**	**0.267***
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.002
	N	129	126	134	df	126
23. Health expenditure % of GDP in 2017 (HDR dataset)	Pearson Correlation	0.348**	0.326**	0.387**	Partial Correlation	0.014
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.868
	N	138	136	144	df	135
24. Physicians per 1000 people 2019 (HDR dataset)	Pearson Correlation	0.620**	0.576**	0.775**	Partial Correlation	-0.033
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.698
	N	139	136	144	df	135
25. Hospital beds per 1000 people 2019 (HDR dataset)	Pearson Correlation	0.394**	0.309**	0.564**	Partial Correlation	-0.149
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.092
	N	131	128	134	df	127
26. Cardiovascular death rate (OWID)	Pearson Correlation	-0.497**	-.376**	-.410**	Partial Correlation	**-0.300**
	Sig. (2-tailed)	0.000	.000	.000	Sig. (2-tailed)	**0.000**
	N	145	137	144	df	**141**
27. Prevalence of diabetes (OWID)	Pearson Correlation	0.238**	.120	.269**	Partial Correlation	0.031
	Sig. (2-tailed)	0.004	.165	.001	Sig. (2-tailed)	0.714

	N	144	136	144	df	141
28. Infants lacking immunization for measles at 12 months, 2019 (HDR dataset)	**Pearson Correlation**	**-0.623****	**-0.404****	**-0.622****	**Partial Correlation**	**-0.231**
	Sig. (2-tailed)	0.000	0.000	0.000	Sig. (2-tailed)	0.006
	N	142	139	147	df	138

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The three components of the HDI have differential predictive power for COVID-19 vaccination success (see Table 3). A multiple regression model of the vaccination rate in February 2022 on the three dimensions of HDI (Model 1 includes the mean years of schooling, and Model 2 includes the 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 due to the fact that life expectancy, GNI per capita, and the mean and expected years of schooling are strongly intercorrelated, and thus, the latter do not contribute much in terms of additional explanatory power when they are combined into a single model.

Interestingly*, the educational component of the HDI is less powerful than life expectancy in a multivariate model*. The mean value of years of schooling in Model 1 is not a statistically significant predictor, but the expected value for years of schooling retains statistical significance. This does not mean that country-level education outcomes are irrelevant in respect to vaccination success but, rather, that the impact of education is mostly mediated by the associated gains in life expectancy.

Other indicators of educational outcome at the country level do not add predictive power beyond the HDI. For example, there are statistically significant bivariate correlations between vaccination rates and Programme for International Student Assessment (PISA) scores for reading, mathematics, and science (see rows 13, 14, and 15 in Table 2). Still, as we see in the same table, the partial correlations for each of the PISA scores become statistically insignificant when controlling for HDI (keeping in mind that PISA scores are only available for 67 countries). The partial correlations for PISA scores are also statistically insignificant when controlling for life expectancy or for gross national income. This indicates that, at the country level, literacies influence vaccination success insofar as they translate into higher life expectancy and gross national income.

Table 3

Multiple regression model of the rate of people fully vaccinated in February 2022 on HDI components: life expectancy, GNI per capita and mean years of schooling in 2019. Source: Authors' analysis of publicly available data from UNDP, HDR, and Our World in Data.

	Model 1	**Model 2**
	Dependent variable: People fully vaccinated per hundred, February 2022	**Dependent variable: People fully vaccinated per hundred, February 2022**

Independent variables:	Beta	Sig.	Beta	Sig.
Life expectancy at birth 2019	**0.674****	**0.000**	**0.522****	**0.000**
GNI per capita 2019 (in 2017 PPP)	**0.206****	**0.006**	0.113	0.121
Mean years of schooling 2019	0.003	0.968	N/A	
Expected years of schooling	N/A		**0.270****	**0.002**
Listwise N	142		142	
Adjusted R Square	0.700		0.719	

While 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, most often, overlapping with the human development index. As we can see in Table 2, partial correlations when controlling for the HDI are, as a rule, statistically insignificant. However, there are two indicators of social capital that contribute to predicting vaccination success beyond the HDI: namely, the share of people who trust doctors and nurses (partial correlation of 0.217, $p = 0.018$) and the share of people who trust their national government (partial correlation of 0.267, $p = 0.002$). *Trust seems to play a significant role in the country-level success of the COVID-19 vaccination campaign.*

Moreover, *indicators of health system effectiveness retain statistically significant partial correlations with the vaccination rate in February 2022 when controlling for the HDI*. Cardiovascular death rate has a partial correlation of –0.300 ($p = 0.000$), and the proportion of infants lacking immunization for measles before one year of age has a partial correlation of –0.231 ($p = 0.006$). Cardiovascular diseases are the leading cause of death globally. While their 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 and delaying death. The proportion of infants lacking immunization for measles is a more specific indicator, pointing to a country's performance in its vaccination infrastructure. Interestingly, the prevalence of diabetes is not correlated with the COVID vaccination rate when controlling for the HDI, despite diabetes being a risk factor for severe COVID infections, which was associated with priority and increased public awareness in the early vaccination campaigns.

In Table 4, 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, namely, trust in doctors and nurses, trust in national government, infants lacking MMR immunization, and the cardiovascular death rate, in order to see their relative explanatory contribution. In Model 3, the HDI remained the strongest predictor of vaccination success ($\beta = 0.603$, $p = 0.000$). The share of people who trust doctors and nurses has a marginally

significant coefficient (β = 0.131, *p* = 0.074), while trust in the national government is no longer statistically significant. The other two health outputs remained statistically significant. We then excluded trust in the national government in Model 4, given that it correlates highly with trust in doctors and nurses (Bivariate correlation = 0.488, *N* = 124, *p* = 0.000), and it was not relevant in Model 3. As a result of this model respecification, in Model 4, trust in doctors and nurses became statistically significant (β = 0.123, *p* = 0.040).

Model 4 indicates that the country-level COVID-19 vaccination rate can be understood as a function of an effective health system, in terms of prolonging life (life expectancy), managing mortality from chronic illness (cardiovascular disease [CVD] death rate), immunizing the population (measles vaccine coverage), and maintaining trustworthy relationships between medical specialists and patients.

Table 4
Multiple regression model of vaccination rates on HDI, trust indicators, and cardiovascular disease death rate. Source: Authors' analysis of publicly available data from UNDP HDR and Our World in Data.

	Model 3		**Model 4**		**Model 5**	
	Dependent variable: Covid-19 vaccination rate in February 2022				**Dependent variabile: Infants lacking immunization for measles at 12 months, 2019**	
	Standardized coefficient Beta	**Sig.**	**Standardized coefficient Beta**	**Sig.**	**Standardized coefficient Beta**	**Sig.**
Independent variables:						
HDI 2019 (HDR dataset)	0.603**	0.000	**0.569****	**0.000**	-.478**	.000
Share of people who trust doctors and nurses in their country, 2018 (OWID)	0.131	0.074	**0.123***	**0.040**	-.273**	.001
Cardiovascular death rate	-0.202**	0.000	**-0.201****	**0.000**	-.117	.121
Infants lacking immunization for measles at 12 months, 2019 (HDR dataset)	-0.160**	0.006	**-0.174****	**0.005**	Dependent variable	
Share of people who trust their national government, 2018 (OWID)	0.005	0.936	Not included		Not included	
Adjusted R Square	0.774		0.716		0.386	
Listwise N	118		127		127	

As shown in Table 4, Model 5,a similar understanding holds for measles vaccination. Specifically, the HDI is also the strongest predictor of the rate of infants lacking immunization for measles. Therefore, its relevance 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, probably mitigating some of the effects of globally circulating vaccine distrust discourses. The CVD rate does not add predictive power for measles vaccination beyond HDI and trust.

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. COVID-19 vaccination trajectories among countries in the same HDI categories have been quite different (see Fig. 2). While the United States and Israel were initially champions due to securing very early access, by July 2021 they had started losing ground compared with other high HDI countries, such as Canada or Singapore, which benefit from very high levels of trust in their medical systems [30].

Another contrasting story concerns Romania and Spain. Romania has had a temporary advantage and led Spain in the early days of the vaccination campaign, which was lost in June, when Spain started gaining ground, reaching one of the top global vaccination rates in February 2022. Since both are members of the European Union, with similar access to vaccines and consistent campaigns of distribution at the national level, this difference reflects vaccine hesitancy more than vaccine inequity or logistics issues. Trust in the healthcare system has been invoked to account for differences in vaccine hesitancy. Spain is credited with a high level of trust in vaccines and in its medical system [31], which was also apparent in a 2021 survey [30]. On the other hand, less than 40% of the Romanian public trusts public hospitals, according to recent data [32], following a decade-long struggle with corruption [33]. India, which has a very high rate of trust in doctors and nurses, which is reflected in the 2018 Wellcome Trust data (92.5%), and ranked highest in a 2021 multinational survey [30], has reached higher vaccination rates than Romania, despite its considerable challenges in vaccine availability. The low levels of public trust in the medical system, associated with a longstanding crisis [34, 31], also seem to account, in part, for Bulgaria's low rate of vaccination despite the high availability of vaccines typical of EU countries.

4. Conclusions

Our exploratory analysis of social patterns that uphold vaccination success, in the case of COVID-19, highlights *the role of the HDI as the strongest predictor* among a set of widely used measures of human, social, and economic capital. Among its three dimensions, *life expectancy is the most relevant for accounting for COVID-19 vaccination success*. It is important to keep in mind that these are synthetic indicators of the effectiveness of social organizations, reflecting the country-level outcomes of the interplay of local and global forces of creation and destruction.

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 the COVID-19 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 [11].

Our analysis also highlights the role of trust in doctors and nurses as a predictor of vaccination success. It remains statistically significant when controlling for the 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 vaccination and measles vaccination, while other indicators concerning economic inequality, perceived corruption, and inputs into the health system do not add predictive value beyond the HDI.

An examination of variations in trusting doctors and nurses also serves to clarify some of the public controversies concerning emerging divergences in vaccination rates in countries with relatively similar access to vaccination, such as Romania and Bulgaria, in comparison with Spain, or the United States in comparison with Nordic European countries.

Our analysis identifies the contours of a social structure that sustains life and is reproduced through this process. Life expectancy, expected years of study, and GNI per capita together account for about 72% of country-level variation in the vaccination rate worldwide in February 2022 (Table 2, Model 2). COVID-19 vaccines prove to be part of the Matthew effect of accumulating advantages and exacerbating disadvantages that the pandemic inflicted on societies and communities across the world [35]. 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 approximatively 85 ranged from rates of 40% to 80% for fully vaccinated people. 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.

5. Author contribution

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

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7. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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