Inequality in COVID-19 vaccination in Africa

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Abstract

Background. The COVID-19 pandemic has spread rapidly to all countries with significant health, socioeconomic, and political consequences. Several safe and effective vaccines have been developed. However, it is not certain that all African countries have successfully vaccinated their populations.

Objective. To study the distribution and determinants of COVID-19 vaccination in Africa from March 2021 to June 2022.

Methods. Using reliable open-access data, we used the proportion of fully vaccinated people with a complete schedule as a reference variable. To analyze the level of inequality in COVID-19 vaccination, we computed common inequality indicators including two percentile ratios, the Generalized Entropy index, the Gini coefficient, and the Atkinson index. We also estimated the Lorenz curve. To identify drivers of COVID-19 vaccination, we estimated univariate and multivariate regression models as a function of COVID-19-related variables, demographic, epidemiologic, socioeconomic, and health system-related variables. To overcome a potential endogeneity bias, we checked our results using simultaneous equation models.

Results. 53 African countries with available data were included in the study. The proportion of fully vaccinated people increased during the study period. However, this increase remained unequal across African countries. Based on the inequality indicators and the Lorenz curve, inequalities in COVID-19 vaccination across African countries were high, although they have decreased in recent months. Total COVID-19 cases and human development index were identified as significant determinant factors that were independently associated with COVID-19 vaccination.

Conclusions. Inequality in COVID-19 vaccination in Africa was high. Promoting adequate information to the general population and providing financial and logistical support to low-income countries can help expand COVID-19 vaccination in Africa.

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Introduction

A new infectious disease emerged on November 16, 2019, in Wuhan, Hubei Province (Central China), before spreading to the rest of the world. It is called coronavirus 2019 or COVID-19 disease, caused by the coronavirus SARS-CoV-2. The World Health Organization (WHO) first alerted the People's Republic of China and its other member states, and then declared a state of public health emergency of international concern on January 30, 2020.[1] Subsequently, WHO declared the outbreak of COVID-19 a pandemic on March 11 and called for essential protective measures to prevent the saturation of intensive care units and to strengthen preventive hygiene. In order to slow down the development of new contagion sites and to preserve the capacity of their hospitals, many countries have decided to implement containment measures, close their borders, and cancel sports and cultural events.[2] These decisions had economic, social, and environmental consequences and created uncertainty and fear for the global economy and for the education, health, and basic rights of populations.[3]

Equitable access to safe and effective vaccines is essential to controlling the COVID-19 pandemic. Very rapidly candidate vaccines have been developed and tested to evaluate their efficacy and safety. Some safe and effective vaccines have been produced and deployed as expected to change the situation.[4] Therefore, we need to ensure fair and equitable access to vaccines, to ensure that every country receives them and can deploy them to protect its population, starting with the most vulnerable.[5] Launched in late April 2020 at an event co-hosted by the Director-General of the WHO, the President of France, the President of the European Commission, and the Bill & Melinda Gates Foundation, a new mechanism to accelerate access to COVID-19 tools (ACT Accelerator) was born.[6] The ACT Accelerator is an innovative new global collaboration to accelerate the development, production, and equitable access to COVID-19 diagnostics, treatments, and vaccines. The ACT Accelerator brings together governments, scientists, businesses, civil society, philanthropic organizations, and global health organizations [Bill & Melinda Gates Foundation, Coalition for Innovations in Epidemic Preparedness (CEPI), FIND, GAVI Alliance, The Global Fund, Unitaid, Wellcome,

WHO, and the World Bank]. These organizations have joined forces to accelerate the end of the pandemic by supporting the development and production of needed COVID-19 tools to rapidly reduce mortality and severe disease, while protecting health systems, fully restoring social and economic activity in the short term and facilitating a high level of COVID-19 control in the medium term.[7] Despite these significant political efforts, several experts have expressed concerns about the distribution of COVID-19 vaccines and the COVID-19 vaccination process, particularly on the African continent.[5] In this study, we try to answer the following research questions: are COVID-19 vaccines distributed equally in Africa? If not, what are the determinants that influence COVID-19 vaccination in Africa?

Materials and Methods

Data and study design

We had access to COVID-19 vaccination data from Our World in Data.[8] This is a public open-access platform that aggregates reliable and comprehensive daily COVID-19 data from all countries. This data comes from official sources including governments, ministries of health, national reports, and official social media. We supplemented our data where necessary with data from the WHO for health data and the World Bank for socioeconomic data.[9,10]

The study location was the African continent including 53 countries: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Democratic Republic of Congo, Djibouti, Egypt, Equatorial Guinea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe. No data was available for Eritrea.

The study period was from March 2021 to June 2022. We chose to start our study in March 2021 because the vaccination campaign started at about that time in African countries. Furthermore, we have chosen to stop in June 2022 in order to have all the data available for the countries considered.

Study variables

To study the distribution of COVID-19 vaccination, we used the proportion of fully vaccinated people with a complete schedule as a reference variable, corresponding to the total number of people who received all doses (two) prescribed by the initial vaccination protocol divided by the total population of the country. We have made this choice because vaccine effectiveness is strongly affected by the number of doses received. Alternative definitions of full vaccination, *e.g.* having been infected with SARS-CoV-2 and having one dose of a two-dose protocol, are ignored to maximize comparability between countries. We used monthly values of COVID-19 vaccination based on the last known value at the end of each month.

To determine drivers of COVID-19 vaccination, we considered COVID-19-related variables including total cases per million and total deaths per million, demographic variables including population, median age, and people aged 70 and older, epidemiologic variables including life expectancy, cardiovascular death rate, and diabetes prevalence, health system-related variables including hospital beds per thousand and socioeconomic variables including GDP per capita based on purchasing power parity and human development index.

Study analysis

For the descriptive analysis, we plotted the monthly evolution of the proportion of people fully vaccinated in each African country during the study period. To analyze the level of inequality in COVID-19 vaccination, we computed common inequality indicators: two percentile ratios (p90/p50 and p75/p25), the Generalized Entropy index [GE(2)], the Gini coefficient and the Atkinson index [A(2)]. Percentile ratios allow direct comparisons between the top and center of the distribution (p90/p50), and the central boundaries between which the middle half of the observations lie (p75/p25). The GE(2) index is sensitive to changes in the tails of the distribution. The Gini coefficient is sensitive to changes in the middle of the distribution. The A(2) index is sensitive to differences in the distribution in the low levels versus the high levels.[11]

We also estimated the Lorenz curve to plot the distribution of COVID-19 vaccination in African countries. The horizontal axis represents the cumulative proportion of the countries' population, and the vertical axis represents the cumulative proportion of fully vaccinated people. Countries were ranked in ascending order according to their cumulative proportion of fully vaccinated people. A straight line of 45 degrees corresponds to a perfectly equal distribution. The more the curve moves away from the 45-degree line, the greater the inequality.[12]

We finally determined the factors that influence COVID-19 vaccination. As many African countries had initiated their COVID-19 vaccination campaign late and to avoid the risk of serial correlation bias, we restricted this analysis to June 2022.[13] First, univariate analysis was performed for all variables. Second, multivariate analysis was performed to identify the independent drivers of COVID-19 vaccination. As many variables may be highly correlated with each other and given the limited number of observations, we used a stepwise multivariate model based on a bidirectional elimination with a p-value of <0.050 and while considering all significant control variables as found in the univariate analysis. As a robustness check and in order to consider the endogeneity of some variables, particularly those related to COVID-19 severity, we also performed, when necessary, a Simultaneous Equation Model (SEM), which has been estimated using Two Stage Least Squares (2SLS).[14] Results were reported as coefficients with their standard errors. All p-values were two-sided, and those <0.050 were considered statistically significant. All statistical analyses were performed using STATA.[15]

Ethics

All the data used in this study were secondary, non-sensitive, and open-access data at the country level and therefore did not require ethical approval.

Results

Most African countries have initiated a vaccination campaign against COVID-19 for their population. 53 African countries with available data were considered in this study.

The proportion of fully vaccinated people increased during the study period, from March 2021 to June 2022 (Figure 1). However, this increase is unequal across African countries. At the end of June 2022, the African countries with the most fully vaccinated people were Seychelles, Mauritius, Rwanda, and Morocco with rates exceeding 60 percent while the African countries with the least number of fully vaccinated people were Burundi, Democratic Republic of Congo, Madagascar, Cameroon, Mali, Senegal, Tanzania, Burkina Faso, Malawi, Somalia, Nigeria and Sudan with rates below 10 percent.

Table 1 reports the inequality indicators in COVID-19 vaccination across African countries by month. Regardless of the inequality indicator used, we found a higher level of inequality in COVID-19 vaccination in Africa. However, this inequality in COVID-19 vaccine distribution, as measured by the proportion of people fully vaccinated in each African country, has decreased over time. Figure 2 shows the Lorenz curve of the distribution of COVID-19 fully vaccinated people by month. We observed the same decreasing trend regarding inequality in COVID-19 vaccination. As a result, the COVID-19 vaccines are reaching more and more people in Africa in the last months.

Although inequality in COVID-19 vaccination among African countries has decreased in recent months, inequality remained high if we consider that the ideal situation is one where everyone has received the vaccine, regardless of their country of residence. This raises the question of the determinants of COVID-19 vaccination. Table 2 presents the drivers of the COVID-19 vaccination at the end of June 2022 in Africa. For the univariate analysis, we found that COVID-19 vaccination was associated with total COVID-19 cases per million (coefficient=1.821, standard error=0.304, p<0.001), total COVID-19 deaths per million (coefficient=0.185, standard error=0.043, p<0.001), median age (coefficient=0.025, standard error=0.004, p<0.001), aged 70 and older (coefficient=0.119, standard error=0.019, p<0.001), life expectancy (coefficient=0.017, standard error=0.004, p<0.001), diabetes prevalence (coefficient=0.013, standard error=0.006, p=0.038), hospital beds per thousand (coefficient=0.063, standard error=0.021, p=0.004), GDP per capita (coefficient=0.013, standard error=0.004, p=0.001), and human development index (coefficient=1.004, standard error=0.195, p<0.001). For the multivariate analysis, we found that COVID-19 vaccination was independently associated with total cases per million (coefficient=1.288, standard error=0.373, p=0.001), and human development index (coefficient=0.520, standard error=0.226, p=0.025). As the variable total COVID-19 cases per million may be endogenous, we also performed a SEM which was estimated using 2SLS. The instrumental variable used was the population which was correlated with the independent variable (total COVID-19 cases per million) but uncorrelated with the dependent variable (COVID-19 vaccination). The results were unchanged (upon request). Finally, further univariate and multivariate analyses performed considering the observations of the other months, for each month separately, yield very similar results (upon request).

Discussion

In this study, we estimated the inequality in COVID-19 vaccination among African countries during the period from March 2021 to June 2022. We then identified the drivers of COVID-19 vaccination. Our results show that there was a strong inequality in COVID-19 vaccination among African countries. This inequality has been reduced over time, but it is still significant. COVID-19 cases and the human development index were the driver variables that significantly impacted the COVID-19 vaccination, regardless of the other observed characteristics.

The roll-out of COVID-19 vaccination during the study period showed that most countries in Africa were unable to reach the target of 70% of the population vaccinated, highlighting the need to focus on the targets set for high-priority groups in all countries of

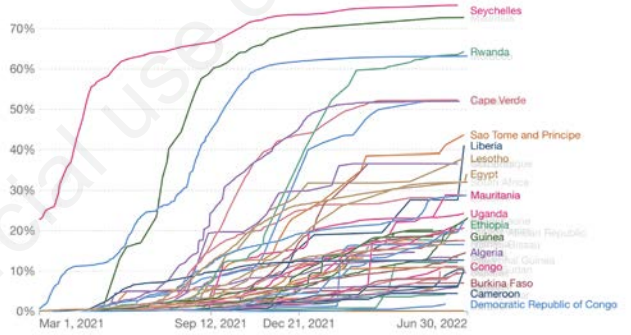

Figure 1. Changes in the proportion of fully vaccinated people over time in Africa.

Table 1. Indicators of inequality in the proportion of fully vaccinated people by month in Africa.

Year	Month	Countries(N)	p90/p50	p75/p25	GE(2)	Gini	A(2)
2021	March	7•	1731.50	330.33	1.72	0.78	0.99
2021	April	25•	48.00	9.29	6.74	0.89	0.98
2021	May	38•	156.00	18.88	5.20	0.84	0.98
2021	June	43•	72.14	8.00	4.13	0.81	0.95
2021	July	47•	70.64	7.30	3.16	0.77	0.96
2021	August	50•	96.68	11.10	2.08	0.74	0.95
2021	September	52•	54.81	10.24	1.10	0.63	0.90
2021	October	53	34.06	7.70	0.34	0.46	0.83
2021	November	53	20.12	6.43	0.88	0.60	0.98
2021	December	53	22.55	6.12	0.66	0.56	0.93
2022	January	53	19.57	6.37	0.56	0.53	0.91
2022	February	53	13.92	4.84	0.46	0.49	0.89
2022	March	53	11.77	4.16	0.41	0.46	0.87
2022	April	53	11.12	3.47	0.35	0.44	0.85
2022	May	53	9.09	3.41	0.33	0.42	0.84
2022	June	53	8.22	3.07	0.29	0.41	0.82

p90/p50, percentile ratio; p75/p25, percentile ratio; GE(2), Generalized Entropy index; Gini, Gini coefficient; A(2), Atkinson index. •Observations with a zero value for the proportion of fully vaccinated people could not be considered in the analysis.

the region. While this seems interesting at the theoretical level, it may prove difficult in practice as it is not always easy to identify specific populations in the African context.

The higher the number of COVID-19 cases in an African country, the higher the COVID-19 vaccination. Countries that suffered the most from the COVID-19 pandemic are those that made great efforts to achieve high vaccination rates. It is possible that the number of cases affects individuals' risk aversion and encourages them to be more vaccinated. Indeed, the level of risk aversion has been shown to influence individual health behaviors.[16] Information and health education for the entire population could thus facilitate vaccination coverage against COVID-19.[17] Lastly, the number of COVID-19 cases variable may be also an indicator of the country's capacity to screen and vaccinate.

The higher the human development index in an African country, the higher the COVID-19 vaccination. The human development index is a statistical composite index of life expectancy, education, and per capita income indicators. This variable can therefore be a proxy for a country's socioeconomic level. High-resource countries have more financial and logistical means to implement and monitor large-scale immunization than low-resource countries. Also, individuals with higher socioeconomic status are more aware of the importance of prevention and tend to perform more preventive care.[18] Material and technical assistance to low-resource countries and more targeted information to the most disadvantaged populations could increase COVID-19 vaccination coverage rates.

Experts have expressed concerns about the COVID-19 vaccination process and vaccine distribution.[19,20] Some studies have previously analyzed COVID-19 vaccination. Gupta and Morain examined how to establish an ethical attribution for COVID-19

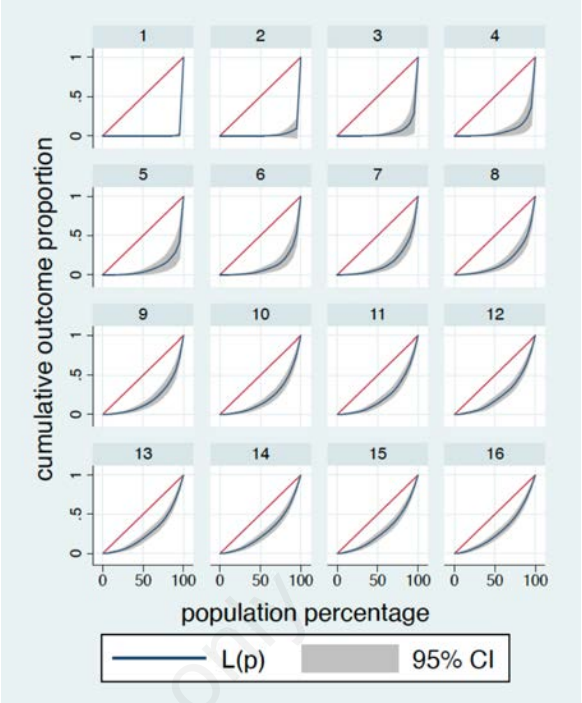

Figure 2. Lorenz curve of the distribution of fully vaccinated people by month in Africa. 1) March 2021; 2) April 2021; 3) May 2021; 4) June 2021; 5) July 2021; 6) August 2021; 7) September 2021; 8) October 2021; 9) November 2021; 10) December 2021; 11) January 2022; 12) February 2022; 13) March 2022; 14) April 2022; 15) May 2022; 16) June 2022.

Table 2. Determinants of full COVID-19 vaccination in Africa.

	Univariate analysis Coefficient (Standard error)	Multivariate analysis Coefficient (Standard error)
COVID-19 related variables Total cases per million•	1.821*** (0.304)	1.288** (0.373)
Total deaths per million••	0.185*** (0.043)	
Demographic variables Population•	0.000 (0.000)	
Median age	0.025*** (0.004)	
Aged 70 and older	0.119*** (0.019)	
Epidemiologic variables Life expectancy	0.017*** (0.004)	
Cardiovascular death rate	0.000 (0.000)	
Diabetes prevalence	0.013* (0.006)	
Health system related variables Hospital beds per thousand	0.063** (0.021)	
Socioeconomic variables GDP per capita••	0.013** (0.004)	
Human development index	1.004*** (0.195)	0.520* (0.226)

•By millions; ••By thousands; *P<0.050; **P<0.010; *** P<0.001.

vaccines.[21] Sun *et al.* examined the logistics of COVID-19 vaccine distribution.[22] Tatar *et al.* analyzed COVID-19 vaccine inequality and estimated a Lorenz curve of COVID-19 vaccine distribution using data through March 2021.[23] Suárez-Álvarez and López-Menéndez in a recent study examined the inequality of COVID-19 vaccination using data until December 2021. This study found a high inequality in COVID-19 vaccination worldwide. It has identified the economic level of the country as a determinant of the level of COVID-19 vaccination.[24]

Vaccination plays an important role in the fight against COVID-19. The inequitable distribution of COVID-19 vaccination is not only an ethical issue. It is also, and above all, a health and economic issue. The COVID-19 pandemic is still a global threat and inequality in COVID-19 vaccination could allow new COVID-19 lethal variants to emerge and spread rapidly.[25] In addition, uneven distribution of COVID-19 vaccination could have a negative impact on economic recovery, especially for low-income countries.[26]

Our study has several advantages. It is one of the few studies that investigate COVID-19 vaccination, specifically in Africa. It used data from the beginning of the vaccination campaign until June 2022. It also used several statistical tools to analyze the distribution of COVID-19 vaccination and identify its determinants. Possible disadvantages of this study may be the limited number of observations, the reliability and precision of data, and the level of analysis aggregated to the country level.

Future high-quality studies are needed to evaluate the effect of interventions that promote information and mobilization of general populations as well as those interventions that increase financial and logistical support for COVID-19 vaccination.

Conclusions

Our results showed that COVID-19 vaccination was unequally distributed across African countries. Although inequality in COVID-19 vaccination has decreased in the last few months, it still remains high. Country COVID-19 severity and socioeconomic environment were independently associated with COVID-19 vaccination. Promoting adequate information to the general population and providing financial and logistical support for low-income countries may help expand COVID-19 vaccination in Africa.

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