What lessons can Africa learn from the social determinants of COVID-19 spread, to better prepare for the current and future pandemics in the continent?

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Abstract
This paper examines the determinants of the spread of coronavirus disease 2019 (COVID-19) in Africa, based on the framework of social determinants of health. Applying Poisson Pseudo Maximum Likelihood (PPML) and quantile regressions to panel data and country-specific socioeconomic background data from 53 African countries, the study finds that enhancing capacity for early testing helps for timeous uncovering of cases, early isolation and contact tracing for effective control of the spread. Other factors such as managing of international movements through reduction of international exposure and ensuring better sanitation and hygiene were found to be relevant in diminishing COVID-19 spread, whereas alcohol consumption and population density heighten the spread. The work also highlights that stringent measures will be counter-productive unless they are coupled with measures to create and preserve livelihoods, together with humanitarian relief assistance to the poorest segments of the population. The results are robust to alternative techniques. As policy recommendations, we implore African governments to the promotion of sustainable livelihoods and social safety nets as measures to accompany stringent lockdowns; and good sanitation programmes to become a lifestyle of citizens. Careful attention should be paid to the socioeconomic trade-off in respect of international travel restrictions given the high dependence of most African economies on tourism.

1 | INTRODUCTION

While the nation-wide lockdown is having a devastating effect on our economy, it is nothing compared to the catastrophic human, social and economic cost if the coronavirus could spread among our people unchecked (Ramaphosa, 2020).

These words of the South African President, Ramaphosa, underscore the challenges that governments face in addressing both the public health and economic consequences of the coronavirus disease 2019 (COVID-19) outbreak. On 30 December 2019, the Chinese Wuhan health authority issued an epidemiological alert of a new COVID-19-causing coronavirus—severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Huang et al., 2020). However, it was only on 11 March 2020, that the World Health Organization (WHO, 2020a) declared the disease as a global pandemic.
Africa recorded its first case in Egypt on 14 February 2020, followed by Nigeria on 27 February. By early March, Algeria, Cameroon, Egypt, Morocco, Nigeria, Senegal, South Africa, Togo and Tunisia had reported over 40 cases. By early August 2020, there were a million cases and 22,000 deaths, according to Africa Centres for Disease Control and Prevention (Africa CDC, 2020).

Figure 1 shows the evolution of the aggregate total and new cases in Africa from February 2020. Both new and cumulative cases rose steadily from February to a peak of new cases around the end of July 2020, when it began to fall. New cases came to a minimum of 7507 cases per day by the end of September 2020. From there, it began to rise again to a current 24,568 per day as of 4 January 2021. Cumulative cases have risen quite steadily to above 2 million by January 2021.

South Africa accounts for 39% of current African cases, with cumulative infections of 1.1 million, representing an infection incidence of 18,772 cases per million population. Morocco is the second highest, accounting for 15.8% of cases in Africa, followed by Tunisia, Egypt and Ethiopia. The top 10 countries with the highest current cases account for 86.2% of all Africa's cumulative infections. It is also worth noting that these countries have the highest testing rate in the sample.

The WHO (2020b) issued a 16-points country and technical guideline for the purpose of informing countries about their preparedness and response to global pandemics. However, according to the World Economic Forum (WEF, 2020), the health care system of the African continent is weak, and the population seen as immunocompromised, due to economic deprivations, malnutrition and comorbidities. Coupled with the significant inequities in African health systems, a number of critical levers recommended for COVID-19 control are not within reach to African health policy makers. For example, weak health care and public health systems hinder the abilities to test, isolate, quarantine, treat and track contacts. Consequently, my calculation based on available data show that only 46% of countries undertake effective and consistent testing. For most African countries, the only available curtailing options are closures of international frontiers, partial or complete lockdown of among others, businesses, schools and social services. These have been accompanied by mandatory wearing of masks, social distancing and self-quarantine. Such measures are usually less adhered to, due to deprivations and weak government capacity to enforce.

However, these measures inevitably lead to economic hardships, which may persist long after the pandemic. The United Nations Economic Commission for Africa has estimated that the revenues of Africa's top 10 fuel exporting economies will fall by at least US$65 billion as a result of COVID-19 constraints. This problem is much more precarious for poorer African countries, with limited resources, high levels of socioeconomic vulnerability and poverty coupled with weak governance mechanisms. Anderson et al. (2020) have highlighted the impossibility of such governments to...
be able to minimize COVID-19 infection rates and the related economic impacts. Curbing the disease and future pandemics would depend on the broader determinants of health.

Existing studies on the COVID-19 pandemic have paid attention mostly to one or a few cause factors at a time such as age (Gardner et al., 2020) and obesity (Sattar et al., 2020). Wealth (Krisberg, 2016), economic activities (Adda, 2016), poverty, inequality, demographic factors and socioeconomic status (Ajakaiye & Mwabu, 2012; Jeon et al., 2010; Sahn, 2012; Ssewanyana & Kasirye, 2012; Mugo, 2012) have been highlighted in a broader consideration of health. There is therefore a need to identify the key socioeconomic determinants of the spread of the disease in Africa. Such analyses can derive lessons to help African countries better select appropriate socioeconomic and environmental factors that can best complement the health systems to curb the current and future pandemics.

2 | METHODOLOGICAL FRAMEWORK AND ECONOMETRIC STRATEGY

The determinants of the spread of the COVID-19 pandemic can be assessed within the framework of the social determinants of health. The WHO’s (2008) classification of the social determinants of health comprise: the conditions in which people are born, grow, work, live and age; and the wider forces and systems that define the conditions of their daily life. In today's literature, social aspects of health explain substantially more of health outcome changes than simply medical care (Horwitz et al., 2020; Marmot et al., 2012).

Following the literature (de Andrade et al., 2015; Horton, 2013; Marmot et al., 2012) I specify a formal framework linking disease outcome to various social, economic, physical and environmental contexts of a country in which individuals find themselves. The first model follows Ngepah (2021), relating daily cases to a set of time-varying variables ($X$) associated with the dynamics of the disease, and the annual-level time-invariant determinants ($Z$).

$$ H_{it} = \alpha_0 + X_{it}\beta + Z_{it}\gamma + \delta DAY_{it} + \epsilon_{it}, $$

where $H_{it}$ is an indicator of health in our case, cumulative infections for country $i$ at day $t$; $X$ is a vector of time-varying variables and $Z$ a vector of time-invariant country-specific variables; $\alpha_0$ is the intercept; $\beta$, $\delta$ and $\gamma$ are coefficients to be estimated; $DAY$ is the number of days from the first case detected in a country; and $\epsilon$ is a classical mean zero disturbance.

3 | VARIABLES AND DATA

The dependent variable is cumulative daily infections per million. The data capturing infections, tests and government stringency measures are daily data for 53 African countries with an average of 295 maximum days per country from the first recorded case to present (4 January 2021).

In selecting the covariates for the models, we have to be systematic. It is widely accepted that the more testing is done, the more hidden cases are discovered, hence testing rate will have a positive effect on recorded cases of infections. The testing process is crucial for early detection, and isolation for treatment. Therefore, testing is an important factor in the real-time monitoring of transmission and for subsequent containment of the disease (Hellewell et al., 2020). I use cumulative tests per thousand of the population.

Government response ($LST$) is an important control variable. It is a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest response).

The rest of the right-hand side variables are time-invariant, taking the value of the average of observations for the last 5 years ending 2019 for a given country. Although these variables do not vary with time, they vary across countries, depicting the social, economic, physical and environmental conditions that prevailed in a country immediately following the disease outbreak. The selection of these variables for the model is based on literature and how we know the virus has been spreading.

International exposure is captured using three variables: logs of registered air transport carrier departures ($LATC$); air transport passengers carried ($LATP$); and international tourism arrivals ($LITA$).

Population dynamics—1 use logs of national population density ($LNPD$), urban population density ($LUPD$), the population share of over 65 ($L65$) and median age ($LMA$).

Sanitation together with population dynamics hygiene and sanitation-related behavioural factors play important roles in the transmission of communicable diseases. I use the share of population using safely managed sanitation services ($LSAN$).
Substance consumption can expose individuals to disease in two ways. The first is consumption and abuse of most substances like alcohol happening in certain social settings that facilitates contact with potential sources of diseases. The second is effect of these substances on the health of the individual. Griswold et al. (2018) have highlighted that alcohol use explains about 10% of mortality among the 15–49 years age group globally. Most importantly, Dunbar et al. (2017) show that alcohol drinkers tend to have more friends and feel more engaged with, and trusting of, their local community, which can be a significant channel of transmission. Other studies have confirmed similar effects of alcohol among young university students (Crawford et al., 2019). Another mechanism is the disinhibition channel (Källmén & Gustafson, 1998; Steele & Southwick, 1985), postulating that sober individuals’ behaviours are inhibited, but when influenced by alcohol the inhibitions weaken, leading to less control over behaviour. I use the log of alcohol consumption per capita (LAC) to capture the role of alcohol.

Extreme deprivations can lead to significant movements in search of livelihoods. This can contribute to significant spread of a communicable disease like COVID-19. Deprivation is also associated with hunger and poor nutrition, which may increase vulnerability to infections. I control for deprivations using the log of extreme poverty (LEP). The log of gross domestic product per capita (LGDPPC) is used to control for income levels across countries as a key economic variable. Equation (2) contains the individual variables and the descriptions are in Table 1.

\[
LTCM_t = \alpha_0 + \beta_1 LTT_t + \beta_2 LST_t + \gamma_1 LATP_t + \gamma_2 LATC_t + \gamma_3 LITA_t + \gamma_4 LUPD_t + \gamma_5 LNPD_t + \gamma_6 L65_t + \gamma_7 LMA_t + \gamma_8 LSAN_t + \gamma_9 LAC_t + \gamma_{10} LEP_t + \gamma_{11} LGDPPC_t + \gamma_{12} AFRICA_t + \delta DAY_t + \epsilon_t.
\]

## 4 ESTIMATION TECHNIQUES

Two estimators are used in This study, first, with Poisson Pseudo Maximum Likelihood (PPML), and then by means of quantile regression.

| Table 1 | Individual variables and description |
|---------|--------------------------------------|
| Variables | Description (logs of) | Source |
| LTCM | Total cases per million of population | Our World in Data |
| LST | Term capturing the stringency of government anti-COVID-19 measures | Our World in Data |
| LTT | Total tests per 1000 of population | Our World in Data |
| LNPD | National population density | Our World in Data |
| LUPD | Urban population density | WDI |
| LP65 | Over-65 population share | Our World in Data |
| LMA | Median age | Our World in Data |
| LATP | Air transport passengers carried | WDI |
| LATC | Registered air transport carrier departures | WDI |
| LITA | International tourism arrivals | WDI |
| LAC | Alcohol consumption per capita | WDI |
| LSMOKE | Smoking prevalence for age 15+ | Our World in Data |
| LSAN | Percentage of population using safely managed sanitation services | WDI |
| LEP | Extreme poverty | Our World in Data |
| LGDPPC | GDP per capita | Our World in Data |
| AFRICA | African dummy, taking 1 if country is Africa and 0 otherwise | Our World in Data |
| DAY | Number of days since the first detected case in a country | Our World in Data |

Sources: Our World in Data (Ritchie, 2020); World Bank (2020) WDI.
4.1 PPML

The choice of the PPML estimator is justified primarily by possible heteroscedasticity due to the fact that infections in most cases quickly rise from first case to tens of thousands. Secondarily, infections are count data and a Poisson-type analysis will be suitable. Figure 2 shows the distribution of infections per million of the population. Clearly, the distribution is a Poisson and further lends credence to the PPML modelling.

The PPML has shown its usefulness in estimating data with rapidly (exponentially) rising observations such as with COVID-19 infection. The estimator has been shown, in the context of international trade, to perform well in the presence of the above-named issues (Silva & Tenreyro, 2011). The associated model for PPML estimation is specified as follows:

$$H_{it} = \exp[^{\alpha_i + \beta_i Z_i + \gamma_i \text{day}_i + \epsilon_i}].$$

(3)

4.2 Quantile regressions

Although the PPML estimates are averages over the distribution, extra information can be exploited with quantile regressions to draw inferences at different points along the distribution of the dependent variable. The quantile estimator is also able to compare estimates for different quantiles. This is particularly useful in recommending what societal variables become most significant for curbing the spread at catastrophic levels of a pandemic like COVID-19, when existing health systems become overwhelmed. The model for linear quantile regression for the qth quantile can be expressed as:

$$H_{it} = \alpha_{q0} + X_{it} \beta_q + Z_i \gamma_q + \delta_q \text{day}_i + \epsilon_{it}. \quad (4)$$

The assumption is that the qth quantile of $\epsilon_{it}$ is zero. The $\alpha_{q0}$, $\beta_q$, $\gamma_q$, and $\delta_q$ would be derived from the solution of:

$$\min_q \left\{ \sum_{i} q \left| H_{it} - (\phi(X, Z)) \right| + \sum_{i} (1-q) \left| H_{it} - (F(X, Z)) \right| \right\}. \quad (5)$$

We implement the estimator in Equation (5) for 25th, 50th and 75th quantiles.

I also estimate feasible generalized least squares (FGLS), which has been shown to deal well with problems of heteroscedasticity and serial correlations (Guo & Tanaka, 2019). However, the FGLS severely underestimates standard errors (Reed & Ye, 2011); therefore, I rely on the PPML and the quantile regressions for inference. The choice of quantile regression and PPML is also supported by the coefficient plots of the point estimates of ordinary least squares (OLS) compared with quantile estimates (Figure 4). I also use panel instrumental variable regressions to control for endogeneity. The lags of the past two periods are used together to instrument for the current.

**FIGURE 2** The frequency distribution of infections per million
5 | KEY RESULTS AND DISCUSSION

5.1 | Summary statistics and correlations

The summary statistics in Table 2 show that on average, 156 persons per million of the populations of the sample countries are infected, with significant dispersions across countries. There are on average, four persons per thousand of population tested, with some countries achieving as low as zero persons and other as high as 125. The fact that countries who test more tend to have higher reported cases means that countries with low levels of testing have systematic under-reporting. In the sample, only about 46% of countries carry effective testing; consequently, I estimate one model with, and another without testing.

The correlation coefficients in Table 3 suggest positive relationship between the log of infections per million and the logs of testing, stringency, variables associated with international exposure, population dynamics and sanitation and substance use. Due to the strong nonlinear nature of the data, reliable results can only be inferred from appropriate econometric models.

6 | ECONOMETRIC RESULTS

6.1 | PPML point estimate results for cumulative infections

Table 4 reports the results of a simple pooled ordinary least squares (POLS) in Columns 1 and 2, PPML in Columns 3 and 4, FGLS in Columns 5 and 6, and panel instrumental variable regression (IVREG) in Column 7. Including testing limits degrees of freedom significantly by reducing the number of observations from 6857 to 3158, due to the fact that testing is only about 46% of the sample. For this reason, I estimate one model with and another without testing. The sign and coefficients of the log of cumulative testing and the log of government stringency index across all the models suggest robustness to the issues raised previously. All other variables are all in log form and therefore the estimated coefficients can be interpreted as elasticities.

The coefficients of the log of total testing is strongly positive and significant. The point estimate of 1.6 (Column 3) means that 1% increase in testing on average leads to 1.6% increase in recorded cumulative infections. This finding is consistent with the call for enhanced testing rates, because it will lead to discovery of more cases and contact-tracing (Hellewell et al., 2020).

A percentage increase in government stringency measures leads to 0.60% increase in cases of COVID-19. This is not surprising given that most governments imposed stringent lockdown after the disease had spread to some extent. The
FIGURE 4  Comparative coefficients of OLS versus quantile regressions. Note: OLS, ordinary least squares
lockdowns have also increased desperation due to deprivations, which inevitably lead to citizens not respecting the conditions. As discussed in the introduction, the set of levers for most African countries is quite limited and stringency measures become the only options in most cases. Without alternatives or livelihood succour for citizens, relying on stringency alone would subsequently exacerbate the spread. As the disease progressed, only a few countries like South Africa accompanied stringency with social assistance to citizens.

All three variables associated with international exposure are positive and significant except the log of international air transport passengers carried (LATP), which is negative and significant, likely due to collinearity. However, the sum of the coefficients remains positive (0.036). A 1% increase in international air transport passengers carried and

| Variable | Obs  | Mean  | SD   | Min   | Max   |
|----------|------|-------|------|-------|-------|
| LTCM     | 15,540 | 5.05  | 2.55 | -5.30 | 9.98  |
| LTT      | 4561  | 1.39  | 2.14 | -11.60| 4.83  |
| LST      | 13,849| 3.97  | 0.51 | 1.02  | 4.61  |
| LATC     | 12,557| 8.83  | 2.09 | 2.30  | 12.10 |
| LATP     | 12,557| 12.80 | 2.32 | 6.80  | 16.99 |
| LITA     | 13,365| 13.29 | 1.63 | 9.55  | 16.32 |
| LUPD     | 12,203| 7.86  | 0.85 | 6.00  | 9.74  |
| LNPD     | 15,054| 3.98  | 1.27 | 1.09  | 6.44  |
| LMA      | 15,627| 3.03  | 0.21 | 2.71  | 3.62  |
| L65      | 15,627| 1.24  | 0.34 | 0.77  | 2.39  |
| LSAN     | 15,627| 3.53  | 0.69 | 1.99  | 4.61  |
| LAC      | 14,453| 1.22  | 0.99 | -0.92 | 2.60  |
| LEP      | 12,109| 2.94  | 1.45 | -0.69 | 4.35  |
| LGDPPC   | 15,332| 7.32  | 1.01 | 5.35  | 9.57  |
| DAY      | 15,627| 148.34| 85.82| 1.00  | 333.00|

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|----------|------|------|-------|-------|
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| DAY      | 148.34| 85.82| 1.00  | 333.00|

*p < .01.
| Variables | (1) POLS | (2) POLS | (3) PPML | (4) PPML | (5) FGLS | (6) FGLS | (7) IVREG |
|-----------|---------|---------|---------|---------|---------|---------|---------|
| LTT       | 0.976*** |         | 1.549*** |         | 0.569*** |         | 0.779*** |
|           | (0.008)  |         | (0.028)  |         | (0.015)  |         | (0.012)  |
| LST       | 0.977*** | 1.715*** | 0.603*** | 0.939*** | 0.307*** | 0.269*** | 0.915*** |
|           | (0.029)  | (0.034)  | (0.034)  | (0.038)  | (0.022)  | (0.012)  | (0.042)  |
| LATC      | 0.273*** | 0.039    | 0.806**  | −0.049*  | 0.048    | −0.020   | −0.035   |
|           | (0.036)  | (0.025)  | (0.026)  | (0.026)  | (0.246)  | (0.097)  | (0.049)  |
| LATP      | −0.929***| −0.128***| −1.338***| −0.167***| −0.684***| −0.075   | −0.982***|
|           | (0.028)  | (0.026)  | (0.021)  | (0.024)  | (0.187)  | (0.094)  | (0.039)  |
| LITA      | 0.866*** | −0.052** | 0.640*** | 0.670*** | 1.163    | −0.060   | 2.145*** |
|           | (0.124)  | (0.022)  | (0.096)  | (0.017)  | (0.799)  | (0.086)  | (0.169)  |
| LUPD      | 2.258*** | 0.252**  | 3.180*** | 0.515*** | 1.737*** | −0.154   | 2.192*** |
|           | (0.042)  | (0.042)  | (0.043)  | (0.033)  | (0.278)  | (0.163)  | (0.065)  |
| LNPD      | −0.510***| 0.119**  | −0.844***| −0.093***| −0.328***| 0.086    | −0.499***|
|           | (0.019)  | (0.018)  | (0.014)  | (0.014)  | (0.118)  | (0.062)  | (0.029)  |
| LMA       | 16.661***| 4.859*** | 18.925***| 7.988*** | 15.627** | 4.764*** | 26.037***|
|           | (1.039)  | (0.342)  | (0.625)  | (0.286)  | (6.958)  | (1.316)  | (1.504)  |
| L65       | −3.066***| −2.000***| −1.564***| −3.385***| −4.599   | −2.831***| −8.490***|
|           | (0.488)  | (0.142)  | (0.348)  | (0.134)  | (3.277)  | (0.559)  | (0.674)  |
| LSAN      | −1.261***| −0.072   | −0.830***| −0.766***| −1.588** | −0.200   | −2.604***|
|           | (0.138)  | (0.045)  | (0.104)  | (0.035)  | (0.875)  | (0.163)  | (0.191)  |
| LAC       | 1.001*** | 0.010    | 1.386**  | 0.353*** | 0.666*** | −0.205** | 0.849*** |
|           | (0.023)  | (0.026)  | (0.030)  | (0.020)  | (0.106)  | (0.092)  | (0.031)  |
| LEP       | 0.489*** | 0.185**  | 0.686**  | 0.040**  | 0.200    | 0.056    | 0.428*** |
|           | (0.018)  | (0.024)  | (0.012)  | (0.018)  | (0.127)  | (0.090)  | (0.026)  |
| LGDPPC    | 0.349*** | 1.024*** | −0.296***| 0.892*** | 0.562**  | 0.889*** | 0.275*** |
|           | (0.035)  | (0.043)  | (0.039)  | (0.034)  | (0.222)  | (0.156)  | (0.049)  |
| DAY       | 0.006*** | 0.025*** | −0.000   | 0.014*** | 0.012*** | 0.027*** | 0.009*** |
|           | (0.000)  | (0.000)  | (0.000)  | (0.000)  | (0.001)  | (0.000)  | (0.000)  |
| Constant  | −66.311***| −25.867***| −73.590***| −34.842***| −60.313***| −14.428***| −96.590***|
|           | (3.391)  | (1.107)  | (2.047)  | (0.870)  | (22.800) | (4.173)  | (4.881)  |
| Observations | 3158 | 6857    | 3158    | 6857    | 3158    | 6857    | 2881    |
| R-squared  | 0.974    | 0.783    | 0.978    | 0.853    |         |         |         |
| Number of cid | 13   | 24   | 13   |         |         |         |         |

Note: Standard errors in parentheses.  
***p < .01.  
**p < .05.  
*p < .1.
international tourism arrivals results in 0.81% and 0.64% increases in COVID-19 infections respectively. The implication is that the countries who responded by closing borders would have reduced infections by 0.036% on average. However, it is important to balance this on the loss of revenue and livelihood based on the fact that most developing economies, especially of Africa, depend heavily on international movements and tourism. As the elasticity of economic deprivation (0.686%) is higher than the net effect of international exposure, a carefully balanced act is needed by governments in their attempt to both curb the spread of the disease and preserve livelihoods.

Urban population density and median age have positive and significant coefficients. National population density and share of over-65 population have negative and significant coefficients. A percentage increase in urban population density results in a 3.2% increase in cumulative infections, but a percentage increase in national population density leads to 0.84% reduction in cumulative infections. The United Nations, in its 2014 urbanization report, projected that Africa's urban population will grow from 395 million in 2010 to 1.34 billion in 2050, accounting for 21% of the world's urban population (UN, 2014). Africa's urbanization trend is on track; however, due to economic underdevelopment and infrastructure gaps, most of Africa's urban population are in poverty and living in slums. The projected urbanization trend may spell challenges unless a significant upgrade of health and other social and economic infrastructure is undertaken. Although a good share of Africa's population is rural, the urban density is the highest in the world, meaning that the small share of population living in cities are too close together, coupled with limited social and health infrastructure (Figure 3).

The coefficient of median age suggests that a 1% increase in median age results in about an 8% increase in infections. In the sample, the average median age in Africa is about 21 years, with a range of 15 to 37 years. Within this range, any increase in median age will only result in more vigour, and hence more social and economic activity, leading to faster spread of any pandemic. However, there is evidence that higher median age increases COVID-related mortality (Ngepah, 2021) but for a higher range of variation than the African sample. This implies that though an increase in African median age may increase infections, it may not significantly increase mortality risk. On the contrary, a percentage increase in over-65 share reduces infections by 1.6%. Although COVID-mortality might be high among older people (Ngepah, 2021), infections are lower due to less dynamism than the youths.

Sanitation shows a strong infections-reducing effect. A 1% increase in the population using managed basic sanitation results in a 0.83% reduction in infections. This highlights the critical importance of enhancing the health and sanitation infrastructure to curb the spread of the current pandemic and better prepare for future pandemics.

A 1% increase in per capita alcohol consumption is associated with a 1.39% rise in cumulative infections. This is largely expected as alcohol consumption likely affects behavioural patterns of individuals and may cause them to be more exposed to vectors. Secondly, alcohol consumption is mostly done in social settings and poses a risk in propagation of the disease.

A 1% increase in extreme poverty is associated with 0.69% higher infections. Economic deprivation brings about significant unrest and movements in search of better livelihoods. Consequently, pandemics would spread faster among the extremely poor. Unsurprisingly, and contrary to deprivation, a 1% rise in per capita income, which captures living standards, is associated with 0.30% less infections.

### 6.2 Quantile estimates for cumulative infections

The quantile estimates in Table 5 divides the distribution of the dependent variables into three quantiles (q25, q50, q75). The first three columns include testing, with Columns 1–3 carrying the coefficients for q25, q50 and q75 respectively. Columns 4–6 are estimates without the testing variable.

The coefficients of testing decrease slightly from quantiles 25 to 75. Although a percentage increase in testing rate results in a 1% increase in cumulative infections in q25, the effects in q50 is 0.89% and 0.79% for q75. This depicts the fact that although more testing reveals more cases, at very high cases, more testing results in marginally less new cases. In countries with extremely high cases, the growth rate of discovery of new cases would decrease as the curve is being flattened.

The coefficient of registered air transport carrier decreases from the 25th percentile to 50th percentile and above. This is congruent with the fact that the earlier cases were linked to international travel, and the fact that with the closure of international borders after the first cases in a country, subsequent air transport carriers have been for cargo and not human transports. The elasticity of international tourism arrivals fell from 1.12% in q25% to 0.93% in q50, and rose to 1.46% in q75, also capturing the same fact that early cases were imported from abroad, and subsequent stringent measures limited transmission. However, towards the end of 2020, tourism arrivals rose again somewhat, due to
relaxation of measures. At this stage, and with higher cumulative cases globally, elasticity increased. These results suggest that borders closures were effective.

The coefficients of government stringency measures are high and positive across all three quantiles, supporting the idea that stringent measures without accompanying relief measures would be counter-productive. The stringency elasticity is lowest in q25 at 0.73%, and rises to 1.13% before falling to 0.85% in q75.

### Table 5: Quantile estimates for cumulative infections

| Variables | (1) q25 | (2) q50 | (3) q75 | (4) q25 | (5) q50 | (6) q75 |
|-----------|--------|--------|--------|--------|--------|--------|
| **LTT**   | 1.032*** | 0.893*** | 0.788*** | 0.037  | 0.022  | 0.045  |
| **LST**   | 0.730*** | 1.125*** | 0.852*** | 2.087*** | 1.681*** | 1.482*** |
| **LATC**  | 0.553*** | 0.129**  | 0.271*** | 0.002  | −0.023 | 0.051* |
| **LATP**  | −1.174*** | −0.826*** | −1.009*** | −0.046 | −0.091* | −0.094*** |
| **LITA**  | 1.117*** | 0.932*** | 1.459*** | −0.114*** | 0.011  | −0.082*** |
| **LUPD**  | 2.463*** | 2.101*** | 2.087*** | 0.367*** | 0.100* | −0.015 |
| **LNPD**  | −0.606*** | −0.425*** | −0.453*** | 0.136*** | 0.066** | 0.240*** |
| **LMA**   | 18.233*** | 16.724*** | 21.015*** | 2.848*** | 4.311*** | 6.016*** |
| **L65**   | −3.618*** | −3.481*** | −5.463*** | −0.034 | −1.998*** | −3.534*** |
| **LSAN**  | −1.473*** | −1.469*** | −2.092*** | 0.072  | −0.190*** | −0.135*** |
| **LAC**   | 1.037*** | 0.900*** | 0.766*** | −0.075* | 0.082* | −0.046 |
| **LEP**   | 0.481*** | 0.472*** | 0.543*** | 0.293*** | 0.055  | 0.214*** |
| **LGDPPC**| 0.188**  | 0.510*** | 0.564*** | 0.860*** | 0.909*** | 1.188*** |
| **DAY**   | 0.006*** | 0.008*** | 0.008*** | 0.026*** | 0.024*** | 0.022*** |
| **Constant** | −72.072*** | −67.008*** | −80.676*** | −25.064*** | −21.693*** | −24.889*** |

**Note:** Standard errors in parentheses.

***p < .01.

**p < .05.

*p < .1.
The elasticities of urban population density changed from 2.5% to 2.1% and finally to 2.09% in q25, q50 and q75 respectively. The magnitude of national population dynamics though smaller, also decreases slightly in similar manner. Urban population density contributes in the spread of the infections. The role of median age increases from 18.23% in q25, to 21.01% in q75. Overall, the elasticities of these variables taken together confirm the hypotheses that whereas early cases are largely explained by international travel, later and explosive evolution of the infections is due to internal population dynamics.

The effect of sanitation increases as cases rise. A 1% increase results in a 1.47% reduction in infections in both the 25th and 50th quantiles, and a 2.09% reduction in the 75th quantile. Sanitation is therefore a very effective measure in reducing infections and its effects are higher and more significant at high levels of cumulative infections.

The magnitude of the effects of alcohol decreases from 1.04% in q25, to 0.90% and 0.77% in q50 and q75 respectively. It is possible that as the effect of the pandemic becomes clear to everyone, individuals may adjust their social behaviours with more responsible use of alcohol, leading to slightly lower elasticities.

The elasticity of deprivation increases from 0.48% in q25% to 0.54% in q75. Certainly, over time as the pandemic progresses, and lockdown measures are eased, poor people would become more desperate and would engage in direr activities to sustain livelihood.

Figure 4 shows the quantile and OLS estimates and the confidence interval bands. None of the OLS coefficients consistently lie within the confidence interval band of the quantile estimator, further confirming their nonlinear nature.

7 | ENSURING AFRICA’S RESILIENCE TO COVID-19 AND PREPAREDNESS FOR FUTURE PANDEMICS

A number of findings of importance to public health policy design in Africa can be highlighted from these findings. Of the different variables, testing coverage, the stringency of government response, international exposure, population dynamics, sanitation, alcohol use and economic deprivations appear useful for socioeconomic policy designs to complement African public health policies in managing the spread of the COVID-19 and preparing for future pandemics.

The one thing that the current pandemic has exposed in Africa is the lack of adequate testing capacity for early isolation, contact tracing and treatment. This underscores the fact that other socioeconomic policies are there to complement effective public health policies and systems. The degree of progress in testing is an indication of public health capacity for disease management in that it entails availability of equipment, and human and physical capacity. This study shows that testing translates into a nearly one-to-one percentage change, consistent with the fact that high testing leads to discovery of more cases and contact-tracing (Hellewell et al., 2020).

The stringency of the actions that most governments have taken instead exacerbated infections. Although the timing of lockdown measures matter, accompanying supportive measures are very important. It appears that the stringent lockdowns increased desperation due to deprivations, which inevitably led to citizens not respecting the conditions. Policy levers are limited for most African countries, leaving stringency measures as the only option. Without livelihood succour for citizens, stringency would exacerbate the spread. African countries have to spend more on appropriate pro-poor socioeconomic infrastructure to empower the deprived, but also save enough for disaster-relieving social assistance.

Managing international borders with effective preparedness for early and prompt action can prove very effective in curbing the spread and giving room for health systems to cope. Countries that acted early enough in restricting international movement would have gained significantly in curbing not only the initial rate of international transmission of the disease, but also the subsequent rate of citizen-to-citizen transmission. Effective and early actions in this regard can go a long way. However, the fact that the tourism sector is an important income-generating sector in most African countries underscores the importance of accompanying economic support measures together with measures in curbing the spread of the current and possible future pandemics.

Upon successful border management to curb infections due to international movements, the second and most import element is internal population dynamics. By 2050, Africa will account for 21% of the world’s urban population. Due to economic underdevelopment and infrastructure gaps, most of Africa’s urban population are in poverty and living in slums. The projected urbanization trend may spell challenges if urbanization is not accompanied by a significant upgrade of health and other social and economic infrastructures. Although a good share of Africa’s
population is rural, the urban density is the highest in the world, meaning that the small share of population living in cities are too close together, coupled with limited social and health infrastructure. Management of urban spaces and ensuring adequate urban infrastructure and habitat is key. The movement-restricting measures can only prove effective to the extent that citizens’ livelihoods are somehow preserved or some form of assistance is made available. Restricting population movements without considering other unintended socioeconomic effects will weaken the impact of lowering population dynamics. If a country persists long enough in restrictions of local movements, adverse socioeconomic conditions kick in and many citizens start violating the lockdown measures unless effective socioeconomic support is given. Therefore, measures to contain internal population dynamics has to be accompanied by some socioeconomic support, especially if these measures are to last long.

This study reveals that the availability of good sanitation infrastructure and adoption of good sanitation and hygiene practices can prove to be one of the most important policy levers that African countries can employ in curbing the spread of a pandemic like COVID-19. The more sanitation measures are taken at the higher levels of infections, the more reduction in infections are obtained. As the future of global health may be marked quite periodically by various infectious diseases, this study recommends that in normal times, good hygiene practices should be inculcated into the behavioural aspects of African citizens. Policy measures should ensure that such good sanitation programmes should become a lifestyle of a society. This is the kind of measure that can prove very effective in flattening the infectious curve of the current pandemic and reduce the exposure of a population to future similar pandemics. This finding has significant implications in raising the awareness of African governments in respect of provision of clean water services to every community, together with programmes for lifestyle change towards good hygiene and sanitation practices.

The use of alcohol can be strongly associated with social gatherings and other social practices that expose much of Africa’s population to the disease. In terms of the spread of an infectious pandemic like COVID-19, countries with less alcohol consumption per capita will tend to have a relatively slower spread of the disease. Alcohol consumption can alter an individual’s sense of caution, and result in riskier behaviour that would lead to higher exposure to the disease. Alcohol can also lead to higher levels of contacts through associated social relationships, hence exposing a population to higher levels of infection. Despite this finding, on the one hand, banning alcohol altogether may lead to more agitations in the population due to the addictive nature of alcohol, and hence lead to higher effect of population dynamics on the spread of disease. On the other hand, allowing the uncontrolled use of alcohol would clearly lead to higher infection rates. The solution for countries could therefore be an optimally controlled allowance of alcohol accompanied by restrictions in public places of drinking. The fact that the alcohol economy forms part of most African countries’ national business activities and informal livelihood, especially in the urban areas, is also a concern. Diversifying individuals’ livelihood away from the alcohol business can prove useful in times of pandemics.

Economic deprivation in the form of extreme poverty significantly enhances infections. Communicable diseases would be expected to spread faster among the extremely poor of the population. Poverty reduction therefore has a bearing in curbing the spread of pandemics. This underscores the recommendation that policy measures must ensure that sustainable livelihoods are created and guaranteed for the poorest segments of the population. I have emphasized that humanitarian relief assistance in the form of social support must accompany measures taken during a pandemic like COVID-19.

8 | CONCLUSION

This paper has investigated the socioeconomic factors that can prove valuable in complementing African public health systems in the face of rising COVID-19 infections and to ensure Africa’s preparedness for future similar pandemics. Within the framework of social determinants of health, a model of COVID-19 infections was developed. The COVID-19 related data capturing infections, tests and government stringency measures together with other socioeconomic variables are from Our World in Data and the World Bank’s World Development Indicators.

I employed various econometric techniques to overcome various statistical issues in the data and for robustness, I relied on PPML and quantile estimators to draw inference. The results of the analyses highlight a number of findings that bear on public health policy design. The findings show that: *enhancing for early testing* helps to discover more cases, but also helps in isolation of those cases and tracing contacts in time for effective control of the spread, so that later on, less infections may be recorded. Testing therefore plays some role in flattening the curve. Tailoring government stringency actions in a way that reduces the possibility of stifling the livelihoods of the poor, and accompanying them with some social assistance for effectiveness. *Preparedness for managing of international movements*
through reduction of international exposure can prove very effective in managing the rate of spread and giving room for health systems to cope. However, the fact that international tourism arrivals is the main channel of impact show that there is a great deal of socioeconomic trade-off to be made by African governments in respect of international travel restrictions. Managing population dynamics is good for curbing infections but restricting population movements without considering other unintended socioeconomic effects will weaken the impact of lowering population dynamics. Ensuring better sanitation and hygiene practices is one of the most important factors in curbing the spread of a pandemic like COVID-19. Policy measures that ensure good sanitation programmes, if they become a lifestyle of a society, will prove very effective in flattening the infectious curve of the current pandemic, and reduce the exposure of African populations to future similar pandemics. Reducing alcohol use also helps in curbing infections. Alcohol use can lead to higher levels of contacts through associated social relationships, hence exposing a population to higher levels of infection. Diversifying urban informal livelihoods to rely less on the alcohol economy will prove effective in case of restrictions or bans on alcohol to curb the spread of pandemics. In light of the significant role of economic deprivations in spreading infections among African populations, the finding calls for a very fine balancing act in the control of alcohol use. Policy measures must ensure that sustainable livelihoods are created and guaranteed for the poorest segments of the population.

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How to cite this article: Ngepah, N. (2021). What lessons can Africa learn from the social determinants of COVID-19 spread, to better prepare for the current and future pandemics in the continent? *Afr Dev Rev, 33*, S45–S59. https://doi.org/10.1111/1467-8268.12530