Modelling the Global Prevalence of COVID-19: An Econometric Approach

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Abstract

Nearly all economies of the world suffered from the sudden outbreak of the coronavirus pandemic emanating from Wuhan City of China to the rest of the world. A number of studies have been conducted to investigate the drivers of the spread of the viral infection. We differ from existing studies by employing a cross-sectional quantile regression approach to uncover socio-economic conditions that are instrumental in the spread of COVID-19 in Africa, Asia, America and Europe. Across the continents, we observed that life expectancy, the size of the aged population and spending on the health sector have significant impacts on the spread of COVID-19. We also noted the specific roles of out-of-pocket spending, net migration and tourism attraction for Africa, America and Europe, respectively, in driving the viral spread. We therefore draw policy implications in terms of the need for improved spending on health sector across continents and the need to intensify health checks for travelers and immigrants, and also the need to emphasize regular check-ups for all individuals across continents since current realities have shown that no age-group is spared of contracting the viral infection.

Keywords: COVID-19 Prevalence, Africa, America, Asia, Europe, Quantile regression.
JEL Classification: B4; C5; I1.

Contents

Contribution of this paper to the literature:
In this study, a number of contributions were made to the literature on the prevalence of COVID-19. Most notably amongst them is the investigation of the common and region-specific factors driving the spread of coronavirus pandemic across 153 countries drawn from four continents including Africa, America, Asia and Europe.

1. Introduction

COVID-19 is a coronavirus disease that became a global public health emergency after World Health Organization (WHO) declared it a global pandemic on March 11th 2020. Atypical of this strand of virus as confirmed by health specialists is its ability to transmit from one host to another even before the 14-day gestation period, which made it difficult to be easily contained relative to other health crises, such as, Ebola Virus Disease (EVD) outbreak of 2014 and other past viral infections. Examples of these viral infections include the severe acute respiratory syndrome coronavirus (SARS-CoV) outbreak in Guandong, China in 2002; H5N1 influenza, a re-emergence in 2003, H1N1 2009; and the Middle East respiratory syndrome coronavirus (MERSCoV) in Korea. The major targets of these deadly epidemics are the lungs, and as a result, the patients experience acute lung injury and acute respiratory distress syndrome which results in pulmonary failure and fatality (Shereen, Khan, Kazmi, Bashir, & Siddique, 2020).

Specifically, at the earlier stage of the COVID-19 outbreak, over 90% of the cases were reported to have originated from Hubei Province, Wuhan, China in December 2019. However, the increasingly interconnectedness of world nations reinforced the rapid spread of coronavirus from Wuhan City of China. The mode of transmission is basically through person-to-person contacts within and outside of China (Center for Disease Control and Prevention (CDC), 2020; Chavez, Long, Koyfman, & Liang, 2021; Mcintosh, 2020). As of 31st March 2020, the United States, Spain, Italy and the United Kingdom topped the list of countries with the highest number of confirmed cases of COVID-19 in the world (World Health Organization (WHO), 2020). According to the daily case summary by WHO, as at 30th April 2020, the total number of coronavirus patients and deaths worldwide stood at 3,090,445 and 217,769 respectively. The report (World Health Organization (WHO), 2020) showed that the US accounted for 32.5% of the number of confirmed cases, followed by Spain (6.9%), Italy (6.6%), the UK (5.3%) and Germany (5.1%). Correspondingly, these countries had a combined share of 62.9% in the total number of coronavirus-induced fatalities.

In May 31st 2020, the number of global confirmed cases and deaths recorded further rose to 5,934,936 and 367,166 respectively. Of these cases, US still remains the topmost country with the highest number of confirmed with a share of 28.9%, followed by Brazil with 7.8%, Russia with 6.8%, UK with 4.6% and Spain with 4% (World Health Organization (WHO), 2020). The global number of confirmed cases in June 2020 reflect a significant upward surge in the spread of the virus. A total number of 10,185,374 and 503, 862 confirmed number of cases and deaths respectively were recorded in June 30th 2020. The US accounting for 24.9% of total number of confirmed cases globally ranks topmost on the list of countries cases. The next is Brazil with a share of 13.2%, then Russia with 6.4%, India with 5.6% and UK with 3.1% (World Health Organization (WHO), 2020).

More disturbing, however, is the fact that the viral infection has rapidly metamorphosed from a mere health crisis into a global economic crisis. In the first quarter of 2020, statistics showed that the US and China contracted by 4.8% and 6.8% respectively. Reports also revealed that Germany and the UK slipped into recession in the same quarter. In its revised World Economic Outlook for 2020, the IMF reviewed downwards the growth forecasts, in most cases to negative territory, for a number of countries, largely due to the unprecedented contagious effect of coronavirus outbreak. Specifically, the Fund projected that the global economy would contract by -4.9% in 2020, while top advanced countries are expected suffer an economic slump, depending on the level of severity of the viral infection in their respective economies. On a country-specific basis, the IMF projected that Italy, Spain, the UK, the US and Germany would contract by -12.8%, -12.8%, -10.2%, -8% and -7.8%, respectively, in 2020. From among the top emerging and developing economies (EMDEs), China is expected to record slower economic growth at 1% while Brazil, South Africa, Saudi Arabia, Russia, Nigeria are projected to contract by -9.1%, -8%, -6.8%, -6.6% and -5.4%, respectively (International Monetary Fund (IMF), 2020).

Given the aforementioned, an important question that comes to mind is: what optimal coping strategies and palliative measures should been put in place by all countries in order to avert coronavirus-induced economic contraction? On a general note, countries have adopted both economic and non-economic coping strategies and measures in order to contain the spread of COVID-19 in their respective domains. The most prominent non-economic strategies are social distancing and lockdown measures. In addition to lockdown restrictions, other recommended non-economic measures include: wearing of nose mask, regular cleaning of hands with sanitizer, encouraging the public to undergo coronavirus test, self-isolate, as well as, report confirmed cases (Surico & Galeotti, 2020). On the other hand, the provision of fiscal and monetary stimulus packages across countries – advanced and EMDEs – constitute the economic measures directed at moderating the adverse impact of the coronavirus-induced lockdown restrictions on households and businesses, respectively[1]. In order to ensure that the right quantum of economic and non-economic strategies is put in place by different countries depending on their structural peculiarities, we consider it expedient to investigate into the key factors driving the global prevalence of COVID-19.

To this end, the aim of this study is in three folds. The first is to identify the key factors driving the rapid spread of COVID-19 by considering the socio-economic characteristics of countries sampled from the list of advanced economies and EMDEs. Also, we address the issue of heterogeneity across countries within the same continent by employing the cross-sectional quantile regression approach. Finally, key policy measures that would not only assist in containing the spread of COVID-19, but would also mitigate the adverse impact of the epidemic on world economies would be recommended.

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[1]Refer to the IMF's Policy Tracker, retrievable via: https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19

The rest of the paper is structured as follows. Section Two covers materials and methods ranging from a review of the empirical literature, the theoretical framework to methodology and data issues. Section Three is devoted to empirical analysis and discussion of results, while Section Four concludes the study.

2. Materials and Methods

2.1. Review of the Empirical Literature

Existing literatures on key factors driving the prevalence of COVID-19 and its impact on both local and global economies is rather diverse. For instance, Wang et al. (2020) employed a cross-sectional and panel regression approach to analyze the determinants of coronavirus transmission. From their findings, high temperature and high relative humidity are key factors that influence the transmission of COVID-19. In the same vein, Alwaeli, Al-Sharifi, and Al-Sudani (2020), through scrutiny, special and temporal analysis method found climatic factors, particularly low relative humidity and high temperature drive the spread of coronavirus in Iraq. On the other hand, the study of Jindal (2020) counters this assertion from his findings that environmental temperature has no impact on the spread of COVID-19 as long as the virus is transferred at close proximity because the virus survives well in the human body temperature.

Funk, Salathé, and Jansen (2010) through a susceptible-infected-removed (SIR) model approach discovered that human behavior significantly influences the spread and control of infectious diseases. From the extant review of literature method, Ludvigsson (2020) observe age characteristic as the most factor determining the spread of coronavirus. The points out that, children have milder coronavirus disease course, better prognosis and extremely rare death to coronavirus than adults. Ding et al. (2020) employs a descriptive approach and discovers that population migration influences the spread of infectious disease. Employing a multivariable linear regression and binary logistic regression analysis, Zhong et al. (2020) reports that the spread of coronavirus is critically influenced by level of socioeconomic status, especially women with good knowledge, optimistic attitudes, and appropriate practices.

Barnett-Howell and Mobarak (2020) investigated the varying benefits of social distancing and suppression across rich and poor countries. The study utilized a country specific value of statistical life (VSL) estimates approach on 9 study countries (United States, Brazil, Pakistan, Nigeria Bangladesh, Japan, India, Indonesia, South Africa and Nepal). Their findings assert that the composition of population in rich countries is highly skewed towards the aged; hence, COVID-19 mortality effects are predicted to be much higher in rich countries than in poor countries even after accounting for differences in countries' health system capacity. Similarly, Ozili and Arun (2020) carried out a study on the measures (restrictive, monetary policy, fiscal policy and public health measures) adopted during the COVID-19 pandemic period and the impact of social distancing policies on economic activities and stock market indices. The study observed that restrictions on internal movement and higher fiscal policy spending have positive impact on the level of economic activities regardless of the rising number of confirmed coronavirus cases which has no significant effect on the level of economic activities.

Conversely, Brenton and Chemutai (2020) examined the responses of trade to COVID-19 crises in Africa. The study observed that trade helps to reduce prevalence of coronavirus disease by providing access to essential medical goods and services. The study also pointed out that in ensuring access to food, enhancing nutritional intake to boost the immune systems and ability to resist the virus, providing farmers with necessary inputs for the next harvest and supporting jobs in the face of a global recession reduces tendency for high unemployment and poverty crises. In the same vein, Bloom and David (2004) maintains that, international cooperation is key in preventing and containing epidemics. Their finding reveal that strengthening countries heath system helps to fend off disease outbreaks and limit the impact of those that do emerge.

With the aid of lives saved tool, Roberton et al. (2020) explored the indirect effects of COVID-19 pandemic on maternal and child mortality in 118 middle and low income countries. Their findings revealed that disruption of routine health care and decline in the access to food such as the collapse of health system tend to lead to increase the rate of child and maternal deaths. To Meo et al. (2020), the male gender with age 60 and above have higher rate of infection. Gémes et al. (2020) utilizing a sensitivity analysis described the prevalence and burden of prognostic factors of severe COVID-19 in Sweden. According to their findings, the burden and prevalence of medical condition such as asthma, diabetes and cancer increases as age increases and that that one in every five individuals is at increased risk of severe COVID-19 burden in Sweden. This parallels the findings of Clark et al. (2020), which estimated the number of individuals that may be at increased risk of severe COVID-19 illness due to underlying health conditions at 16% and 31% in Africa and Europe, respectively. Through OLS estimation, Ogundokun, Lukman, Kibria, Awotunde, and Aladeitan (2020) found that travelling history and contacts increase the chances of people being infected with COVID-19 by 85% and 88%, respectively in Nigeria. This result suggests the need for the government to ensure that the travel and tour agencies have better precautions and preparations in place before re-opening.

Utilizing a time sequence mean weighting technique, Qasim, Ahmad, Zhang, Yasir, and Azhar (2020) observed that countries with poor health facilities and services are at a greater risk of COVID-19 infection compared to other countries with adequate and advanced health facilities. In addition, the study of Muurlink and Taylor-Robinson (2020), identified cultural factors, particularly the extent to which long clothing are worn and the practice of adult separation by gender, to inadvertently influence the rapidity and spread of communicable diseases including COVID-19. Karatayev, Anand, and Bauch (2020) modelled the timing and organizational scale at which workplace and school re-opening strategies can minimize both the number of infections and person-days lost to closures, during the late-stage and early-stage epidemic. They found that local strategy of re-opening/re-closing workplaces and schools county-by-county results in far fewer person-days lost to closure with a slightly higher number of COVID-19 cases, even after allowing for high inter-country travel. The study of Taboe, Salako, Ngonghala, and Kakaï (2020), found that larger number of asymptomatic COVID-19 infected persons aggravate the spread of coronavirus in West Africa. They asserted early identification and isolation of asymptomatic persons would significantly curtail the spread of COVID-19.

In order to differ from past empirical studies regarding the current subject matter (see, for instance, (Brenton & Chemutai, 2020; Ding et al., 2020; Lin et al., 2020; Ludvigsson, 2020; Ozili & Arun, 2020; Wang et al., 2020; Zhong

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et al., 2020), to mention but few), our paper offers the following innovations. The growing interdependence among global economies makes it difficult for a country to single-handedly contain an epidemic, such as, COVID-19, until it became a global pandemic. While previous studies have identified factors driving the prevalence of epidemics (different forms of viral infections), no study has explicitly captured the underlying characteristics of specific regions and countries. This study seeks to fill this gap by considering the distinct socio-economic characteristics that are peculiar to the two classes of countries, namely, advanced economies and the EMDEs on a continental basis. Another gap in the literature is that the majority of past studies employed descriptive analyses and largely focused on medical and epidemiological perspectives. This study ultimately offers an econometric modelling of the global prevalence of coronavirus in some selected advanced countries and EMDEs. The end-result of our modelling exercise would help to suggest coping strategies that are suitable for each category of countries depending on their individual and regional peculiarities.

2.2. Theoretical Framework

This study draws strongly on the model of Knowles and Owen (1995) to derive the determinants of health capital indicators and those of output per-worker. Their model extends the Mankiw, Romer, and Weil (1992) augmented-Solow model to include health capital as a component of the broad-based human capital. The assumptions underlying the model of Knowles and Owen (1995) are as follows:

1. The production is of the Cobb-Douglas type that exhibits constant returns in respect of capital, labour, and human capital components (education and health indicators). That is,

$$Y_t = K_t^\alpha E_t^\beta X_t^\psi (A_t L_t)^{1-\alpha-\beta-\psi} \tag{1}$$

Equation 1 implies that real output is a function of physical capital, stock of educational human capital, stock of health human capital, labour input and technology; where subscript 't' stands for time; Y is real output; K is stock of physical capital; E is stock of educational human capital; X is the stock of health human capital; L is labour input; A is the level of technology; The parameters α, β, ψ, and $(1-\alpha-\beta-\psi)$ are respectively, the shares of physical capital, education capital, health capital, and effective labour in output, with the restrictions that 0 < α, β, ψ, and $(1-\alpha-\beta-\psi) < 1$; α, β, ψ, $\in [0,1]$; $\alpha+\beta+\psi < 1$

2. In per unit of effective labour terms, the production function becomes

$$y_t = k_t^\alpha e_t^\beta x_t^\psi \tag{2}$$

Where $k_t = \frac{K_t}{A_t L_t}$, $e_t = \frac{E_t}{A_t L_t}$, $x_t = \frac{X_t}{A_t L_t}$ $\tag{3}$

Equations 2 and 3 express the production in per capita (or effective labour) terms.

3. Labour and technology grows at an exogenous rates, n and g, respectively, so that labour and technology at period t are given as

$$L_t = e^{nt} L_0 \; ; \; A_t = e^{gt} A_0 \tag{4}$$

Equation 4 indicates the evolution of labour force overtime

4. The accumulation of physical, educational and health capital can be expressed as

$$\dot{K_t} = s_K Y_t - \delta K_t \tag{5}$$
$$\dot{E_t} = s_E Y_t - \delta E_t \tag{6}$$
$$\dot{X_t} = s_X Y_t - \delta X_t \tag{7}$$

Equations 5-7 show the evolution of physical, education and health human capital stock, respectively

The dynamics of physical, educational and health capital can be derived as follows:
From Equation 3, differentiating the capital per effective labour with respect to time gives

$$\dot{k_t} = \frac{(A_t L_t)\dot{K_t} - K_t(\dot{A_t}L_t + \dot{L_t}A_t)}{(A_t L_t)^2} \tag{8}$$

Equation 8 reduces to:

$$\frac{\dot{K_t}}{A_t L_t} - \frac{K_t}{A_t L_t}\left(\frac{\dot{A_t}}{A_t} + \frac{\dot{L_t}}{L_t}\right) \tag{9}$$

Given that $\dot{K_t} = s_K Y_t - \delta K_t$; $k_t = \frac{K_t}{A_t L_t}$; $\frac{\dot{A_t}}{A_t} = g$; $\frac{\dot{L_t}}{L_t} = n$; $\frac{Y_t}{A_t L_t} = y_t$, Equation 9 reduces to

$$\dot{k_t} = s_k y_t - (n + g + \delta) \tag{10}$$

Equations 8-10 presents the steps involved in generating the dynamics of physical in per effective labour terms
Following the same steps as above, the dynamics of educational and human capital can be obtained, respectively, as follows:

$$\dot{e_t} = s_e y_t - (n + g + \delta) \tag{11}$$
$$\dot{x_t} = s_x y_t - (n + g + \delta) \tag{12}$$

Equations 11-12 are the respective dynamics of education and health human capital in per effective labour terms; where s_k, s_e and s_x are the constant proportions of income that are invested in physical, educational and health capital, respectively; δ is the common depreciation rate;

5. At steady state, $\dot{k_t} = \dot{e_t} = \dot{x_t} = 0$. Then solving for the steady-state values of physical, education and health capital gives

$$0 = s_k y_t - (n + g + \delta)k_t^* \tag{13}$$
$$0 = s_E y_t - (n + g + \delta)e_t^* \tag{14}$$
$$0 = s_X y_t - (n + g + \delta)x_t^* \tag{15}$$

Equations 13-15 represent the equation of motions at steady state for all three capital stock types encapsulated in Equations 10-12, respectively.
So that

$$k_t^* = \frac{s_k y_t}{(n+g+\delta)} \quad (16)$$
$$e_t^* = \frac{s_E y_t}{(n+g+\delta)} \quad (17)$$
$$x_t^* = \frac{s_X y_t}{(n+g+\delta)} \quad (18)$$

Equations 16-18 are the steady-state levels of physical, educational and health capital in per effective labour terms and are defined as functions of their respective investment shares of output, depreciation rate, and growth rates in labour and technology.

Equation 16, Equation 17, and Equation 18 can be solved further to substitute for the value of output per unit of effective labour as follows.

From the three equations, one can find that

$$\frac{k_t^*}{s_k} = \frac{e_t^*}{s_E} = \frac{x_t^*}{s_X} = \frac{y_t}{(n+g+\delta)} \quad (19)$$

So that we have can have the following relations

$$k_t^* s_E = e_t^* s_k \quad (20)$$
$$e_t^* s_X = x_t^* s_E \quad (21)$$
$$k_t^* s_X = x_t^* s_k \quad (22)$$

Equations 19-21 show the steps involved in further solving for the steady-state levels of physical, educational and health capital per unit of effective labour.

Substituting the value of output per unit of effective labour into Equation 16, Equation 17, and Equation 18 and making use of the information from Equation 20, 21 and 22.
Recall from Equation 2 that:

$$y_t = k_t^\alpha e_t^\beta x_t^\psi$$

Then we have:

$$k_t^* = \frac{s_k k_t^\alpha e_t^\beta x_t^\psi}{(n+g+\delta)} \quad (23)$$
$$e_t^* = \frac{s_E k_t^\alpha e_t^\beta x_t^\psi}{(n+g+\delta)} \quad (24)$$
$$x_t^* = \frac{s_X k_t^\alpha e_t^\beta x_t^\psi}{(n+g+\delta)} \quad (25)$$

Equations 23-25 show the steps involved in further solving for the steady-state levels of physical, educational and health capital per unit of effective labour, respectively. They all contain one variable or the other and steady-state conditions require that the three capital types grow at constant rates.

Collecting like terms, the three equations reduce to:

$$k_t^{1-\alpha} = \frac{s_k e_t^\beta x_t^\psi}{(n+g+\delta)} \quad (26)$$
$$e_t^{1-\beta} = \frac{s_E k_t^\alpha x_t^\psi}{(n+g+\delta)} \quad (27)$$
$$x_t^{1-\psi} = \frac{s_X k_t^\alpha e_t^\beta}{(n+g+\delta)} \quad (28)$$

Equations 26-28 are two steps away from deriving the final expression of the steady-state levels of the three capital types, respectively.

Substituting the values of k_t, e_t, x_t in the three expressions from Equation 26, 27, 28 yields:

$$k_t^{1-\alpha} = \frac{s_k \left(\frac{s_E k_t}{s_k}\right)^\beta \left(\frac{s_X k_t}{s_k}\right)^\psi}{(n+g+\delta)} \quad (29)$$
$$e_t^{1-\beta} = \frac{s_E \left(\frac{s_K e_t}{s_E}\right)^\alpha \left(\frac{s_X e_t}{s_E}\right)^\psi}{(n+g+\delta)} \quad (30)$$
$$x_t^{1-\psi} = \frac{s_X \left(\frac{s_K x_t}{s_X}\right)^\alpha \left(\frac{s_E x_t}{s_X}\right)^\beta}{(n+g+\delta)} \quad (31)$$

Equations 26-28 are a step away from deriving the final expression of the steady-state levels of the three capital types, respectively.

Solving for the values of $k_t^*, e_t^*,$ and x_t^* in Equation 29, Equation 30, Equation 31, respectively, we have:

$$k_t^* = \left[\frac{s_K^{1-\beta-\psi} s_E^\beta s_X^\psi}{(n+g+\delta)}\right]^{1/\eta} \quad (32)$$
$$e_t^* = \left[\frac{s_E^{1-\alpha-\psi} s_K^\alpha s_X^\psi}{(n+g+\delta)}\right]^{1/\eta} \quad (33)$$
$$x_t^* = \left[\frac{s_X^{1-\alpha-\beta} s_K^\alpha s_E^\beta}{(n+g+\delta)}\right]^{1/\eta} \quad (34)$$

Equations 29-31 are, respectively, the steady-state levels of physical, education and health human capital, respectively; where $\eta = 1 - \alpha - \beta - \psi \quad (35)$

Equation 35 is the share of effective labour in total output

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Equation 32, Equation 33, and Equation 34 imply that the determinants of steady-state levels of physical, educational and health capital include the fractions of investment shares of output devoted to the accumulation of physical, educational and health capital (that is, s_k, s_E, and s_X, respectively), the share of effective labour (A_tL_t) in output, depreciation rate, and the growth rates in labour (L_t) and technology (A_t). Moreover, prevalence of diseases, as a stand-alone variable, does enter into the growth equation (see, equation 1) directly. It however affects economic growth via its impact on the stock of health human capital of the workforce (x_t). Although no known or settled body of economic theory is devoted to an explanation of the determinants of health capital stock at the macro level, nonetheless, according to McDonald and Roberts (2006), the next-best approach is to define a reduced-form model of health capital stock. This reduced-form health capital model postulates that health capital stock is a function of certain exogenous variables including: level of income, education and nutritional status, access to healthcare systems, material standard of living, health care spending (public spending and out-of-pocket spending), as well as, the incidence and/or prevalence of diseases, such as, COVID-19 (Dixon, McDonald, & Roberts, 2001; Hill, 1987; Hobcroft, McDonald, & Rutsein, 1984; United Nations, 1988). Consequently, we rely on the works of Dixon et al. (2001) which postulated a model for health capital stock (x_t) as follows:

$$x_t = (w_t, m_t, d_t) \qquad (36)$$

Equation 36 is a health capital model, where w_t measures material standard of living, m_t is health care provision per capita, d_t is the prevalence of diseases, such as, COVID-19. As a proxy for health capital, a number of studies adopted life expectancy (Refer to (Arrow, Dasgupta, & Mumford, 2014; Bloom & David, 2004; Murray & Chen, 1992; Murray & Lopez, 1997), for a review of the empirical literature). In line with the extant literature, we employ life expectancy (L_t) as a proxy for health capital. Hence, Equation 36 becomes:

$$L_t = (w_t, m_t, d_t) \qquad (37)$$

Equation 37 shows that there is unidirectional causality between life expectancy and its supposed determinants (material standard of living, health care provision per capita and prevalence of disease). To this end, we therefore ask an important question: Are feedback effects possible, most especially, between the prevalence of COVID-19 disease and life expectancy? Regarding the key factors driving the rapid spread of coronavirus, the existing epidemiological studies have identified, among others, age, medical technology, health system capacity, public healthcare expenditure, access to healthcare system and climatic factors as major causative factors (Barnett-Howell & Mobarak, 2020; Ludvigsson, 2020; Pan et al., 2020; Zhong et al., 2020). In addition, some authors including: Sultan et al. (2020) have revealed that COVID-19 disease to be highly prevalent among the elderly. By implication, countries with higher life expectancy would have larger number of victims among the adult population than other segments of the population (young children and the workforce). In fact, our preliminary findings as mentioned earlier in this paper (Refer to Section 1) showed that countries with the highest number of cases are mostly advanced countries, with higher life expectancy rates when compared to emerging and developing economies, such as African countries, with relatively lower life expectancy rates.

As a result of the forgoing discussion, we re-specify Equation 37 as:

$$D_t = (w_t, m_t, L_t) \qquad (38)$$

Equation 38 is a disease prevalence model; where D_t implies the prevalence of COVID-19 while other variables maintain their previous definitions.

2.3. Methodology and Data Issues
2.3.1. Estimation Procedure

As mentioned in the preceding section, the empirical model for this study hinges on the reduced-form health capital model, through which we established the relationship between disease prevalence and certain determining factors. In estimating the cross-sectional data, we would account for possible cross-sectional dependence due to proximity of countries across regions/continents, simultaneity and also endogeneity problems that could lead to bias regression that may arise between the variables of interest. To achieve this objective, the quantile regression approach was employed. As originally proposed by Koenker and Bassett Jr (1978), quantile regression provides estimates of the linear relationship between explanatory variables and a specified quantile of the dependent variable. One important special case of quantile regression is the least absolute deviations (LAD) estimator, which corresponds to fitting the conditional median of the response variable.

A typical cross-sectional quantile regression can be specified as:

$$y_i = x'_i\beta_\tau + \varepsilon_i \text{ and } Quant_\tau(y_i/x_i) = x'_i\beta_\tau \qquad (39)$$

Equation 39 is the specification for a quantile regression; where y_i is the response variable (prevalence of COVID-19 in this case); x_i is a vector of explanatory variables (which stand for common and region-specific socio-economic variables in this case); β_i is a vector of parameters to be estimated; ε_i is a vector of disturbance terms; $Quant_\tau(y_i/x_i)$ identifies the τth conditional quantile of y given x.

2.3.2. Measurement of Data and Sources

The scope of this study covers countries of the world with confirmed cases of COVID-19 as at 30th June, 2020. The choice of countries included was premised on data availability[2]. We measure COVID-19 prevalence as the ratio of confirmed cases as at as at 30th June 2020 to population size as at 2017 for the counties in our sample set. We annualize this indicator by multiplying the computed COVID-19 prevalence rate by 12 months so as to align with the annual frequency of other variables utilized in this study. We classify the probable underlying causes of coronavirus pandemic into common and region-specific socio-economic characteristics. Consequently, the common features that are peculiar to all countries include life expectancy, population within the age bracket of ages 65 and above (% of total population) and current health expenditure (% of GDP). These data were obtained and compiled from the World Bank's World Development Indicator (WDI, 2019), while the data on confirmed cases of

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[2]Countries were selected from four continents as follows: Africa (45), America (22), Asia (36) and Europe (41). Refer to Appendix 1 for the list of countries under each category.

coronavirus were obtained from the World Health Organization (WHO) Situational Report on COVID-19 cases for June 2020. We rely on epidemiological perspectives to argue for reverse causality from life expectancy to the prevalence of COVID-19 pandemic. Besides, other factors including number of aged persons and responsiveness of healthcare systems have been identified from the extant literature (see, for instance, (Barnett-Howell & Mobarak, 2020; Meo et al., 2020; Qasim et al., 2020; Robone, Rice, & Smith, 2011)). It has been estimated that approximately 80% of COVID-19 fatalities are attributed to people are above 60 years of age. Similarly, countries with robust and quality healthcare facilities are more likely to tame the spread of viral infection compared to countries with poor healthcare facilities. Robone et al. (2011) offered an empirical evidence of a positive relationship between health care spending per capita and the responsiveness of healthcare system. Also obtained from World Development Indicators (WDI) (2019) are data on region-specific socio-economic characteristics, whose selection is justified on a continent-by-continent basis as follows.

Africa

We identify *acute healthcare system inadequacy* as one of the age-long and structural challenges facing African countries. The continent's healthcare system is faced with key constraints, such as, low ratio of health professionals and hospital beds to population, inadequate health insurance coverage and ill-equipped medical-centers, among others (United Nations Economic Commission for Africa (UNECA), 2020). In Africa, access to health care services are generally low due to poor financial protection against health risks. Although total health expenditure has grown rapidly in the last two decades, the increase has been driven predominantly by out-of-pocket health spending of households (World Bank, 2016). Based on the data obtained from World Development Indicators (WDI) (2019), we estimated that 67% of African countries had a ratio of out-of-pocket health spending to government health expenditure to be greater than one-to-one, with some outlier countries, such as, Nigeria and Guinea-Bissau posting higher ratios at 5:1 and 9:1 respectively. This shows that the burden of health care spending in Africa rests substantially on households with limited or no access to healthcare insurance. We, therefore, employ the out-of-pocket spending on healthcare as key underlying factor driving coronavirus spread in Africa.

Asia

The COVID-19 virus originated from China which is located in the continent of Asia. A possible factor that can fester the spread of the virus in this continent is geographical proximity to China. We hypothesize that surrounding countries with close proximity to the epicenter of the COVID-19 virus will largely be influenced by the spread of the virus. According to Pedersen and Davies (2009), close geographical relations increase the likelihood of wider contraction rates and create an opportunity for transmission. Here, we employ the *distance in kilometers from the Capital of China (Beijing) to the rest of Capital Cities of other countries in Asia* (data obtained from CEPII database, retrievable via: http://www.cepii.fr/CEPII/en/bdd_modele/inscription.asp?id=6 as a proxy variable to capture the role of geographical proximity in the spread of coronavirus. This is also well established in the recent outbreak of the second wave of COVID-19 in Beijing and neighbouring countries, such as, India.

America

The American continent is the world's topmost immigrant destination. It hosts about 51 million immigrants, accounting for 19% of global immigration, with the United States being the largest recipients of international citizens (United Nations World Tourism Organization (UNWTO), 2019). Alluding to the findings of Saker, Lee, Cannito, Gilmore, and Campbell-Lendrum (2004), mass migration influences the spread of infectious diseases by bringing people into close contact with vectors, microbes and immunological makeup. Similarly, Wilson (1995) noted that human migration is a long time source of epidemic. A cursory look at net migration statistics, the US, Germany, Turkey, UK and Canada ranked the top five host countries for immigrants in 2017 (World Development Indicators (WDI), 2019). Remarkably, they also ranked among the countries with higher number of confirmed COVID-19 cases (see, (World Health Organization (WHO), 2020)). Furthermore, given the fact that the first cases of coronavirus transmitted from China to the rest of the world, we can further test the hypothesis that "high immigration areas are likely to record greater number of foreigners' induced viral infections relative to countries with low recipients of immigrants. For instance, the first case of coronavirus in Canada was imported by a returnee from the Wuhan City of China. We, therefore, employ *net migration* – the difference between immigration and emigration – as a proxy variable to account for the role of migration in the spread of coronavirus worldwide.

Europe

Europe is the most popular continent for travelers and tourists. The continent ranks the world's topmost tourist destination due to its rich history and heritage, favorable climatic condition, architecture and developed transport infrastructure[3]. According to World Tourism Organization (2018), Europe played host to 51% of the number of international tourist arrivals – equivalent to 714.51 million tourists. The continent also ranked the highest recipient of tourism revenue at 40% of total receipts in 2019 (United Nations World Tourism Organization (UNWTO), 2019). In line with the assertion of Wilson (1995), countries with higher travel records are more likely to experience a rapid spread of COVID-19 pandemic. We therefore identify the *number of international arrivals* as the major socio-economic condition that is peculiar to Europe.

3. Empirical Analysis and Discussion of Results

3.1. Descriptive Analysis

The summary statistics on all variables across the four continents captured in this study are summarized in Table 1. We observe that the American continent has the highest average prevalence rate of COVID-19 at 3.7%, followed by Europe (3.3%) and Asia (2%), with Africa having the lowest prevalent rate at 0.5%. This truly reflects the hierarchy of countries in terms of the number of confirmed cases globally with the United States, Brazil, India

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[3]See worldatlas.com

and Russia topping the list. Europe emerges the world's largest continent of adult population with an average share of 16.5% of total population. This is followed closely by the US with an average adult population share of 9.5% and Asia with an average share of 6.2% in their respective total population figures. Again, Africa domiciles the world's lowest share of adult population at 3.6% of total population on the continent. This ultimately buttresses the findings that Africa is home to the world's youngest population[4]. In terms of share of health sector expenditure in GDP, we observe that Europe and America outperform the other two continents (Asia and Africa) on the average. In addition, statistics show that Europe has the highest average life expectancy rate at 78 years, followed by Asia (74 years) and America (73 years). On the other hand, Africa has the world's lowest average life expectancy rate of 64 years. These findings are symmetrical to the adult population statistics and reflect the variation in health care spending across the four continents. In terms of region-specific factors, average out-of-pocket spending on health care in Africa is 35% of total health care financing in the continent. Similarly, net migration, distance of Asian countries from Beijing (China's capital city) and international arrivals averaged 113,639 migrants, 4,911.2 kilometres and 15,800,000 tourists in America, Asia and Europe, respectively. Information on other summary statistics (standard deviation, minimum and maximum values) show some degrees of variation across the four continents. To this end, we take up a further investigation into the factors - common and/or region-specific - that are driving COVID-19 prevalence in Africa, America, Asia and Europe in the rest of this section.

Table-1. Summary Statistics.

	Obs.	Mean	Std. Deviation	Minimum	Maximum
Common Factors					
*prev_*12					
AFRICA	44	0.535	0.791	0.111	3.135
AMERICA	22	3.676	4.559	1.181	17.061
ASIA	36	2.042	4.461	0.003	24.338
EUROPE	41	3.290	2.710	0.299	10.408
ad_pop					
AFRICA	44	3.602	1.809	1.920	10.952
AMERICA	22	9.509	4.411	4.561	18.722
ASIA	36	6.241	4.806	1.035	27.109
EUROPE	41	16.536	4.388	4.413	22.499
he_gdp					
AFRICA	44	5.569	2.089	2.781	13.421
AMERICA	22	7.632	2.939	1.181	17.061
ASIA	36	5.419	2.543	2.274	11.777
EUROPE	41	7.944	2.111	3.125	12.346
lfe					
AFRICA	44	63.545	6.419	52.24	76.499
AMERICA	22	73.322	3.927	61.6	79.3
ASIA	36	74.356	4.881	64.13	84.099
EUROPE	41	78.403	3.901	71.2	83.551
Region-Specific Factor					
AFRICA: *oope*	44	35.055	18.912	2.993	77.225
AMERICA: *n_migrate*	22	113,639	1,303,750	-3,266,243	4,774,029
ASIA: *distance*	36	4,911.283	2,646.841	955.651	14,937.48
EUROPE: *arrivals*	41	15,800,000	20,300,000	145,000	86,800,000

3.2. The Regression Results

Here, we present the quantile regression results on the determinants of coronavirus prevalence in the four continents under study. We utilized three quantile dimensions including the first quantile (33%), the second quantile (67%) and the last quantile (99%) of COVID-19 prevalence distributions across the four continents. This is informed by the need to account for observed differences in socio-economic characteristics across countries within each continent.

3.2.1. Quantile Regression Estimates of COVID-19 Prevalence in Africa

Our results show that at the lowest quantile (that is, 33% of data distribution), out-of-pocket spending and life expectancy are significant influencers of coronavirus prevalence in Africa (see Table 2). However, considering the highest quantile (99%), socio-economic factors including the level of adult population, health care spending, out-of-pocket spending on healthcare and life expectancy appear as the significant determinants of COVID-19 prevalence on the continent. We are able to obtain evidence for the fact that African countries on the highest scale of adult population distribution would exhibit higher prevalence of the pandemic compared with the countries on the lowest scale of the distribution. This confirms the findings of previous studies that aged persons has a very high risk of contracting and dying of the viral infection[5]. Our results also show that higher spending on the health sector is significantly and negatively related to coronavirus prevalence. Meanwhile, the impact of out-of-pocket spending on healthcare differs across quantiles, with the lowest quantile showing a higher risk of contagion while the highest quantile indicates a lower level of contagion[6]. This implies that regional efforts towards increasing public expenditure on the health sector would play a vital role in mitigating the spread of coronavirus across Africa. In addition, we also observe the significant role of higher life expectancy in fueling the spread of COVID-19, which is more pronounced, particularly, at the highest quantile. Following the coefficient of determination criterion,

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[4]WEF (2017). "The Future of Jobs and Skills in Africa: Preparing the Region for the Fourth Industrial Revolution". An Executive Briefing of the World Economic Forum.
[5]See, for instance, Barnett-Howell and Mobarak (2020), Ludvigsson (2020), Meo et al. (2020).
[6] See, for instance, Qasim et al. (2020).

estimates based on the highest quantile show a more adequate sensitivity analysis of coronavirus prevalence to key socio-economic indicators in Africa.

Table-2. Quantile Regression Estimates of COVID-19 Prevalence in Africa.

Variables	prev_12_Q33	prev_12_Q67	prev_12_Q99
ad_pop	0.0084	0.1469	0.6273***
	(0.123)	(0.1425)	(0.0206)
he_gdp	0.0069	-0.0077	-0.2044***
	(0.1133)	(0.1006)	(0.0124)
oope	0.0028**	0.0064	-0.010***
	(0.0011)	(0.0131)	(0.0015)
llfe	0.5461**	-0.6567	2.6191***
	(0.2312)	(2.895)	(0.36667)
constant	-2.3006**	2.4663	-9.2599***
	(0.9722)	(12.0184)	(1.5264)
R^2	0.0543	0.0631	0.2939

Note: ***, ** indicate the statistical significance of coefficients at 1% and 5% respectively; the values in parentheses are standard errors.

3.2.2. Quantile Regression Estimates of COVID-19 Prevalence in America

We observe that at the lowest quantile (that is, 33% of data distribution), net migration is the only significant driver of coronavirus prevalence in America (see Table 3). Meanwhile, considering the highest quantile (99% of data distribution), socio-economic factors including the level of adult population, life expectancy, health care spending and net migration emerge as the significant influencers of COVID-19 prevalence on the continent. We offer evidence for the fact that American countries on the highest scale of adult population distribution would exhibit higher prevalence of the pandemic compared with other countries on the lowest scale. The same evidence was offered for life expectancy. This also affirms the findings of previous studies that aged has a very high risk of contracting and dying of the viral infection[7]. Our results also reflect that higher spending on the health sector is significantly and negatively related to coronavirus prevalence on the American continent. Though, as expected, net migration is a positive influencer of coronavirus spread, its magnitude of impact is the lowest. Nonetheless, this result indicates the increasing vulnerability of the American continent on the backdrop of its position as the world's largest net migrant region. Based on the coefficient of determination criterion, estimates from the highest quantile regression show a more adequate sensitivity analysis of coronavirus prevalence to key socio-economic indicators in America.

Table-3. Quantile Regression Estimates of COVID-19 Prevalence in America.

Variables	prev_12_Q33	prev_12_Q67	prev_12_Q99
ad_pop	0.0153	-0.2682	1.9472***
	(0.2497)	(0.5216)	($5.33e^{-08}$)
llfe	-0.2101	15.6229	15.2189***
	(13.7581)	(50.8949)	($3.02e^{-06}$)
he_gdp	-0.727	-0.8119	-0.0741***
	(0.5231)	(2.083)	($1.14e^{-07}$)
n_migrate	$3.07e^{-06}$**	$3.12e^{-06}$	$2.47e^{-06}$***
	($1.1e^{-06}$)	($4.79e^{-06}$)	($2.39e^{-13}$)
constant	7.8095	-55.3699	-70.4618***
	(59.2013)	(220.3959)	($2.39e^{-13}$)
R^2	0.1501	0.2077	0.3383

Note: ***, ** indicate the statistical significance of coefficients at 1% and 5% respectively; the values in parentheses are standard errors.

3.2.3. Quantile Regression Estimates of COVID-19 Prevalence in Asia

Our results indicate that at the lowest quantile and middle quantiles, adult population and life expectancy are the significant influencers of coronavirus prevalence in Asia (see Table 4). Meanwhile, considering the highest quantile (99% of data distribution), in addition to the aforementioned factors, health care spending and the distance of Asian countries from China's capital – Beijing – are also significant drivers of COVID-19 spread across the continent. In contrast with other Africa and America, adult population exerts a negative influence on prevalence rate in Asia in a descending order from the lowest quantile to the highest quantile. This reflects the significant breakthrough of the coronavirus origin and the most populous country in world – China – in curtailing the spread of the virus since it became a pandemic in March 2020. This could be said to have helped to reduce drastically the prevalence rate in the Asian continent as reflected in its third position (see Table 1). With the exception of life expectancy, other socio-economic indicators including healthcare spending and distance show an entirely different signs relative to the a priori expectations. This does not however downgrade the relative importance of proximity effect and lower health care expenditure in driving the overall spread of coronavirus on the Asian continent. Meanwhile, the most significant factor is life expectancy, where COVID-19 prevalence has the highest sensitivity relative to the other three continents. This could be attributed to issues around demography as Asia remains the world's most populous continent. Following the coefficient of determination criterion, estimates from the highest quantile regression show a more adequate sensitivity analysis of coronavirus prevalence to key socio-economic indicators in Asia.

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[7]See, for instance, Sultan et al. (2020).

Table-4. Quantile Regression Estimates of COVID-19 Prevalence in Asia.

Variables	prev_12_Q33	prev_12_Q67	prev_12_Q99
ad_pop	-0.0566***	-0.2072*	-1.0882***
	(0.0095)	(0.1152)	(0.0205)
he_gdp	0.0172	0.1284	0.2848***
	(0.0152)	(0.1602)	(0.0321)
llfe	3.9369***	20.0815**	107.0914***
	(0.5822)	(8.839)	(1.3473)
ldistance	0.0228	0.8517	3.4955***
	(0.0757)	(0.7854)	(0.1746)
constant	-16.6326***	-91.1431**	-474.8195***
	(2.3843)	(37.7275)	(5.4457)
R^2	0.0467	0.2165	0.6273

Note: ***, **, * indicate the statistical significance of coefficients at 1%, 5% and 10% respectively; the values in parentheses are standard errors.

3.2.4. Quantile Regression Estimates of COVID-19 Prevalence in Europe

We observe that it is only at the upper quantile (99% of data distribution) that socio-economic factors including adult population, health expenditure, life expectancy and international arrivals are significant drivers of COVID-19 spread across Europe (see Table 5). In contrast with other continents, all variables have associated coefficients that contradict the a priori expectations. Meanwhile, the impact of rising adult population size on prevalence rate declines at the upper quantile relative to the middle quantile. Similarly, to suggest the need for higher health spending, the prevalence of COVID-19 to health spending declined between the middle and upper quantiles. Though the impact coefficients associated with life expectancy at the lower and middle quantiles are not statistically significant, the mere fact that these coefficients are positive suggests the role of higher life expectancy rate in driving up the spread of the coronavirus pandemic. The same explanation goes for the level of international arrivals where the impact coefficients at particularly the lower and middle quantiles indicate the role of tourist influx in magnifying the prevalence rate in Europe. This informed the decision of many European countries to impose stiff restrictions on travelers until date in replacement for travel ban previously imposed across countries. Following the coefficient of determination criterion, estimates from the highest quantile regression and to some extent from the middle quantile constitute a more adequate sensitivity analysis of coronavirus prevalence to key socio-economic indicators in Europe.

Table-5. Quantile Regression Estimates of COVID-19 Prevalence in Europe.

Variables	prev_12_Q33	prev_12_Q67	prev_12_Q99
ad_pop	-0.1194	-0.3013	-0.154***
	(0.0828)	(0.1938)	(0.0165)
he_gdp	0.2302	0.3345	0.2489***
	(0.1649)	(0.5468)	(0.0292)
llfe	5.2007	32.2612	-3.6836**
	(7.9429)	(23.1741)	(1.3789)
larrivals	0.1826	0.1489	-0.4971***
	(0.1993)	(0.7046)	(0.0417)
constant	-23.7269	-136.6092	32.4995***
	(32.2948)	(95.2082)	(5.7377)
R^2	0.1385	0.1647	0.336

Note: ***, ** indicate the statistical significance of coefficients at 1% and 5% respectively; the values in parentheses are standard errors.

4. Concluding Remarks

In this study, a number of contributions were made to the literature on the prevalence of COVID-19. Most notably, in addition to identifying the common factors driving the spread of coronavirus pandemic across all regions, we captured region-specific factors in our investigation. We utilized the quantile regression approach within a cross-section of 144 countries drawn from four continents including Africa, America, Asia and Europe. Succinctly, our major findings are as follows; *One*, common factors (life expectancy, level of adult population and health expectancy) significantly influenced the prevalence of COVID-19 in all continents. *Two*, African-specific factor - out-of-pocket spending - shows a high risk of contagion at the lowest quantile. *Three*, in the American continent, both at the lowest and highest quantiles, net migration positively and significantly influenced the spread of coronavirus pandemic. *Four*, in the continent of Asia, life expectancy is the most significant factor that drives the COVID-19 prevalence. *Five*, for Europe, the number of international tourist arrivals positively influenced coronavirus spread, particularly, at the highest quantile.

In view of the foregoing, our findings birthed the following policy recommendations. *First*, in Africa, much priorities should be directed at making provisions for a universal health insurance coverage. This would ultimately reduce out-of-pocket spending on healthcare and guarantee improved access to healthcare facilities. We expect this policy initiative to reduce the spread of infectious diseases including COVID-19 in the continent. *Second*, for America and Europe, which host large number of immigrants and international tourists, efforts should be intensified towards limiting non-essential travels. Also, health checks should be beefed up for entrants into these continents in order to mitigate the spread of coronavirus. *Finally*, for Asia, the most important factor influencing the spread of COVID-19 is higher life expectancy rates. Hence, decision makers should implement social and health specific policies targeted towards the aged, including restricting their presence in social gatherings and making sure they observe social distancing rule. This also applies to other age groups since current realities show that no individual (young or aged) is immune to contracting the viral infection.

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Appendix-1. List of Sampled Countries across 4 Continents

Africa		America	Asia		Europe	
Algeria	Nigeria	Argentina	Afghanistan	Timor-leste	Armenia	Serbia
Angola	Rwanda	Brazil	Armenia	UAE	Austria	Slovakia
Benin	Sao Tome & Principe	Canada	Bahrain	Uzbekistan	Azerbaijan	Slovenia
Botswana	Senegal	Chile	Bangladesh	Vietnam	Belarus	Spain
Burkina Faso	Seychelles	Costa Rica	Bhutan		Belgium	Sweden
Burundi	Sierra Leone	Dominican Rep.	Brunei Durussalam		Bosnia & Herzegovina	Switzerland
Cabo Verde	South Africa	Ecuador	Cambodia		Croatia	United Kingdom
Cameroon	Rwanda	El Salvador	China		Cyprus	Turkey
Central African Rep.	Tanzania	Guatemala	India		Czech Rep.	Ukraine
Chad	Togo	Haiti	Indonesia		Denmark	
Dem. Rep. of Congo	Tunisia	Honduras	Iran		Estonia	
Rep. of Congo	Uganda	Jamaica	Iraq		Finland	
Cote d'Ivoire	Zambia	Mexico	Israel		France	
Egypt		Nicaragua	Japan		Georgia	
Eswatini		Panama	Jordan		Germany	
Ethiopia		Paraguay	Kuwait		Greece	
Gabon		Peru	Lao PDR		Hungary	
The Gambia		Puerto Rico	Lebanon		Iceland	
Ghana		United States	Malaysia		Ireland	
Guinea		Uruguay	Maldives		Italy	
Guinea-Bissau		US Virgin Islands	Mongolia		Kazakhstan	
Kenya		Venezuela	Nepal		Kyrgyzstan	
Lesotho			Oman		Latvia	
Liberia			Pakistan		Lithuania	
Madagascar			Philippines		Luxembourg	
Malawi			Qatar		Netherlands	
Mali			Republic of Korea		Norway	
Mauritania			Saudi Arabia		Poland	
Mauritius			Singapore		Portugal	
Morocco			Sri Lanka		Rep. of Moldova	
Mozambique			Tajikistan		Romania	
Niger			Thailand		Russia	

Appendix 1 is a list of 144 countries drawn from four continents including Africa (45), America (22), Asia (36) and Europe (41). Selection of countries across continents is strictly based on data availability.