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## Article

# The Monetary Value of Human Life Losses Associated with COVID-19 in Africa: A Human Capital Approach

Josés Muthuri Kirigia <sup>1,\*</sup> and Germano Mwabu <sup>2</sup> <sup>1</sup> African Sustainable Development Research Consortium (ASDRC), Nairobi P.O. Box 6994-00100, Kenya<sup>2</sup> Department of Economics and Development Studies, University of Nairobi, Nairobi P.O. Box 30197-00100, Kenya; gmwabu@gmail.com

\* Correspondence: kirigajoses@gmail.com

## Abstract

**Background:** By 30 June 2021, the 54 African sovereign nations had reported 5,465,790 laboratory-confirmed COVID-19 cases (including 142,171 deaths). This study aimed to estimate the monetary value of human life losses, indirect and direct costs, and the potential cost reductions due to vaccinations for advocacy use by Ministries of Health in Africa. **Methods:** We employed both the human capital approach to value human lives lost and an abridged total cost-of-illness methodology to estimate the indirect and direct costs of COVID-19 across 54 African countries. The secondary data analyzed was from different sources. **Results:** The 142,171 human lives lost had an estimated discounted total monetary value of Int\$6,684,101,196, i.e., Int\$47,015 per life loss and Int\$4.88 per person in the population. The estimated total cost of the actual reported 5,514,709 COVID-19 cases was Int\$7,155,473,174, which comprised a total direct cost of Int\$3,981,927,049 (55.6%) and an indirect cost of Int\$3,173,546,125 (44.4%). We projected that vaccination of all the eligible people in the population would potentially save the African continent approximately Int\$41,624,735,824. The average total saving per person is approximately Int\$30.4. **Conclusions:** The COVID-19 pandemic resulted in substantial monetary value of human life losses and indirect and direct costs.



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**Keywords:** COVID-19; gross domestic product; value of life; indirect cost; direct cost; human capital approach; Africa

**JEL Classification:** H51; I10; I19

## 1. Background

The African continent, consisting of 54 sovereign countries and four territories (Mayotte, Réunion, Saint Helena, Western Sahara), has an estimated total population of 1.37 billion people ([Worldometer, 2021](#)) and a total gross domestic product (GDP) of International Dollars (Int\$) 6.86 trillion in 2021 ([International Monetary Fund \(IMF\), 2021](#)). The African Union (AU) projects an economic growth of −0.8% (for 2021) due to Coronavirus Disease (COVID-19), compared to the initial projection of +3.4% for 2020 ([African Union \(AU\), 2020](#)).

As of 30 June 2021, the African continent (comprising 54 sovereign states and four territories) had 5,514,709 confirmed COVID-19 cases, comprising 4,824,876 recovered cases, 547,261 active cases, and 142,572 deaths ([Worldometer, 2021](#)). Of the latter, 142,171 deaths were reported by the 54 African sovereign nations, and the remaining 401 deaths (0.28%) by the territories of Saint Helena (0), Mayotte (174), Réunion (226), and Western Sahara

([Worldometer, 2021](#)). The study focuses on the 5,465,790 cases reported by the sovereign states and does not include the 48,919 cases reported by the four territories.

To mitigate the adverse socio-economic effects of COVID-19, the AU recommended that African governments should “boost investments that strengthen health systems to enable faster treatment [of infections] and containment” of the pandemic (p. 32) ([African Union \(AU\), 2020](#)). However, there is evidence that the performance of health-related systems in Africa, both before and during the pandemic, has been suboptimal. For instance, concerning (a) national health systems (NHSs), the Universal Health Service Coverage Index was below 50% in approximately 70% of countries (36 out of 54) ([WHO, 2021a](#)); (b) in the social determinants of health (SDH) systems, over 50% of the total population in 37 countries did not have basic sanitation services, drinking-water, and handwashing facilities at home ([WHO, 2021b](#)); (c) in the national health research systems (NHRSs), the average World Health Organization (WHO) African region NHRS barometer score on the capacity to produce and utilize research findings was below 60% in 2018 ([Rusakaniko et al., 2019](#)). The underperformance of especially NHSs has been attributed to underinvestment ([Asante et al., 2020](#)) and economic inefficiencies ([Nabyonga-Orem et al., 2023](#)). Therefore, there is a need to generate evidence for advocacy to increase investments and improve the efficiency of allocating and utilizing health development resources, continually enhancing the performance of health-related systems in Africa, especially during pandemics.

According to [Rice \(2000\)](#) and the World Health Organization ([WHO, 2009, 2001](#)), estimates of the money value of human life expressed in terms of foregone lifetime earnings are needed by health development policymakers for use in raising public health awareness and advocating with governments, private sector, and other stakeholders for increased and sustained investments in health-related systems for attainment of United Nations Sustainable Development Goal 3 (SDG3) on ensuring healthy lives and promoting well-being for all people (including those at risk of COVID-19 infection) at all ages ([United Nations \(UN\), 2015](#)). Since the ministers of finance and the private sector chief executive officers who control resources for addressing health determinants are not usually public health experts, they may not fully appreciate the adverse effects of non-fatal disability and premature mortality from COVID-19 on macroeconomic indicators, such as the GDP ([WHO/AFRO, 2006](#)). Therefore, Ministries of Health could utilize evidence of the monetary value of human lives and productivity losses in their advocacy and collaboration with other government sectors and stakeholders to prevent or reduce deaths and non-fatal disabilities.

[Niewiadomski et al. \(2025\)](#) conducted a systematic review of the evidence on productivity losses resulting from health problems associated with the COVID-19 pandemic, based on data from population-level studies. Out of 38 studies eligible for review, 79% used the Human Capital Approach. Of the 33 studies eligible for quantitative comparison, the authors found that the productivity losses ranged from 0 to 2.1% of gross domestic product. [Hanly et al. \(2022\)](#) applied the human capital approach to estimate premature mortality productivity costs (indirect costs) associated with COVID-19 across nine countries (Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden and Switzerland) in Europe. Similar studies are relatively limited on the African continent.

Thus, a rapid study was necessary to utilize the most recent secondary data to address three research questions. (a) What is the discounted monetary value of the cumulative number of human lives lost due to COVID-19 in Africa from the beginning of the pandemic till 30 June 2021? (b) What is the approximate magnitude of the direct health systems costs incurred in preventing and managing COVID-19 infections in Africa? (c) What is the approximate cost saving anticipated from COVID-19 vaccinations?

The specific study objectives were the following: (a) To estimate the discounted monetary value of the cumulative number of human life losses in Africa associated with

COVID-19 as of 30 June 2021. (b) To estimate the indirect and direct costs associated with the actual reported COVID-19 infections in Africa. (c) To project potential savings or reductions in indirect and direct health system costs, assuming 100% of the target population in Africa is vaccinated against COVID-19.

## 2. Methods

This section outlines the methods employed to achieve the study objectives stated above.

### 2.1. Study Area and Population

As already stated, the analysis reported in this paper is on the 54 sovereign states of the African continent (See Supplementary Table S1). Therefore, the analysis focuses on Africa's sovereign states, with 5,465,790 laboratory-confirmed COVID-19 cases (including 142,171 deaths) as of 30 June 2021 ([Worldometer, 2021](#)). Supplementary Table S2 summarizes the 4,794,317 recovered cases, 529,302 active cases, and 142,171 deaths from COVID-19 reported among sovereign states as of 30 June 2021 ([Worldometer, 2021](#)).

### 2.2. Study Design

We utilized a cross-sectional study design to collate administrative data on variables used in the analysis from secondary sources.

### 2.3. Conceptual Framework for Valuation of Human Life

#### 2.3.1. Overview

As [Drummond et al. \(2015\)](#) explain, three approaches exist to assign monetary values to health outcomes, such as human life. First, the willingness to pay (WTP) (or contingent valuation) approach uses survey methods to reveal the maximum amount households (or individuals) would hypothetically be willing to pay for a program (or intervention) that could potentially reduce the probability of a loss of a statistical life (i.e., the life of an unknown person) ([Mooney, 1977](#)). Some strengths of the WTP approach, as highlighted by [Mooney \(1977\)](#) and [Jones-Lee \(1982, 1985\)](#), include its ability to value non-economic aspects of the intervention (e.g., the intrinsic pleasure of being alive or disease-free) and its incorporation of consumer preferences. On the other hand, the approach's main weaknesses are as follows: healthcare consumers (patients) may not be rational and sovereign decision-makers, assume that individual preferences are static, WTP is a function of income and wealth only, and may be prone to response bias ([Jones-Lee, 1982; Mooney, 1977](#)). Moreover, applying the WTP approach was impossible due to the ongoing community circulation of various COVID-19 variants and the challenges of obtaining telephone numbers to administer WTP questionnaires remotely.

The second approach is the implied values (or revealed preferences) method (IVA). The IVA is based on the values placed on preventing loss of life by past individuals or political decision-makers ([Mooney, 1977](#)). One strength of IVA is that it relies on actual, implied life values in various health-related policy contexts. A politically designated person (e.g., a Member of Parliament) provides the values, and the information is readily available in public sector documents ([Mooney, 1977](#)). However, the weaknesses of IVA include the following: decisions to invest in specific health projects are not determined by popular vote and might thus suffer from selection bias; similar lives may be valued differently depending on the public sector with which the person providing values is affiliated; the requirement values provided need to be consistent across the statistical lives being valued and cannot be met by such implicit and arbitrary valuations based on political processes and their outcomes ([Mooney, 1977; Jones-Lee, 1982](#)).

The third method is the human capital approach (HCA), which was first applied by Petty (1699) in the 17th Century and whose theoretical underpinning was developed much later by Fein (1958), Mushkin and Collings (1959), Weisbrod (1971), and Landefeld and Seskin (1982). HCA values life in terms of the present value of future output lost (as proxied by potential earnings lost) due to premature mortality from any cause, e.g., malaria (Chima et al., 2003), non-communicable diseases (Kankeu et al., 2013), and COVID-19 (Musango et al., 2024). The method's strengths include ease of understanding by policymakers, the use of objective data on earnings, and the routine collection of data on morbidity and mortality (Mooney, 1977). However, according to Mooney (1977), the weaknesses of HCA include its focus on the livelihoods that people obtain from good health rather than the benefits of health per se, disregard for current preferences of potential beneficiaries, attachment of greater weight to the lives of the wealthy, and discrimination against those not in the labor market, e.g., homemakers, the retired, the unemployed, the severely handicapped, and children below the minimum work-age limit. In the study reported in this paper, the HCA was applied due to its strengths, the unfeasibility of collecting primary data due to the global COVID-19 pandemic at the time, and the availability of secondary data on GDP per capita, current health expenditure per capita, average life expectancy, and the number of COVID-19 deaths for all countries in Africa.

### 2.3.2. An HCA Model for Estimating the Discounted Monetary Value of Human Life Losses Associated with COVID-19

In line with the WHO guidelines on the measurement of the economic impact of disease and injuries (WHO, 2009) and recent empirical COVID-19 studies (Musango et al., 2024), the current study estimated the monetary value of discounted aggregate flows of the current and future consumption of *non-health* goods and services foregone due to premature mortality (at 16 age groups) attributed to COVID-19. The current study used non-health GDP per capita in the estimations of the value of each statistical human life lost to COVID-19 in Africa. The non-health GDP per capita is the difference between GDP per capita and current health expenditure per capita for each sovereign state. According to Grossman (2000), an individual derives utility (happiness) from health, rather than from the consumption of healthcare. Thus, the demand for healthcare and other health inputs is derived from the basic demand for health.

The African continent's total monetary value ( $TMV_{\text{Africa}}$ ) of human life losses associated with COVID-19 is the sum of each of the 54 countries' total monetary value ( $TMV_{j=1,\dots,54}$ ) (Kankeu et al., 2013; Weisbrod, 1971). Formulaically, the value is the following:

$$TMV_{\text{Africa}} = \sum_{i=1}^{i=54} TMV_{j=1,\dots,54} \quad (1)$$

Further, each of the  $j$ th country's TMV of human life losses from COVID-19 was estimated using the following formula (Kankeu et al., 2013; Musango et al., 2024):

$$TMV_j = \sum_{i=1}^{i=16} MV_{i=1,\dots,16} \quad (2)$$

where,

$\sum_{i=1}^{i=16} (\cdot)$  is the sum of discounted monetary values of human losses from COVID-19 in age groups 1 = 0–4 years, 2 = 5–9 years, 3 = 10–14, 4 = 15–19 years, 5 = 20–24 years, 6 = 25–29 years, 7 = 30–34 years, 8 = 35–39 years, 9 = 40–44 years, 10 = 45–49 years, 11 = 50–54 years, 12 = 55–59 years, 13 = 60–64 years, 14 = 65–69 years, 15 = 70–74 years, and 16 = 75 years and older; and  $MV_i$  is the monetary value of a life lost for the  $i$ th age group. Only South Africa and Tunisia reported COVID-19 deaths in the 16 age groups. The breakdown of deaths associated with COVID-19 by the 16 age groups was unavailable for 52 countries. Since the



COVID-19 deaths age breakdown was not available for other African countries, the age distribution for the two countries was used to break down the deaths sustained in the remaining 52 countries.

The *discounted*  $MV_i$  per age group was estimated using the following equation (Kankeu et al., 2013; Musango et al., 2024):

$$MV_i = \sum_{t=1}^{t=n} \left\{ \left( 1 / (1 + r)^t \right) \times (GDPPC_j - CEHPC_j) \times (ALE_j - AAD_i) \times (TCOVD_j \times P_i) \right\} \quad (3)$$

where  $\sum_{t=1}^{t=n}(\cdot)$  is the summation from the first year of life lost ( $t = 1$ ) to the last year of life lost ( $t = n$ ) per death in an age group;  $r$  is the discount rate, i.e., 3% in the current study;  $GDPPC_j$  is the GDP per capita for the  $j$ th country in 2021;  $CEHPC_j$  is the current expenditure on health per capita in the  $j$ th country in 2021;  $ALE_j$  is the national average life expectancy in country  $j$ ;  $AAD_i$  is the average age at the onset of death in  $i$ th age group;  $TCOVD_j$  is the total number of human lives lost from COVID-19 in the  $j$ th country as of 30 June 2021; and  $P_i$  is the proportion of COVID-19 deaths borne by age group  $i$ . The base year for the calculations was 2021.

### 2.3.3. Data and Data Sources

The monetary value of human life losses associated with COVID-19 in 54 African countries was calculated using eight data types. First, the discount rates of 3%, 5%, and 10% are commonly used in health-related studies, such as those by Musango et al. (2024), Haacker et al. (2020), Attema et al. (2018), and Edejer et al. (2003). Second, the data on the cumulative number of human lives lost from COVID-19 per country in Africa as of June 30, 2021, from the Worldometer Coronavirus Disease (COVID-19) Pandemic Database (Worldometer, 2021) (See Supplementary Table S2).

Third, the per capita GDP (GDPPC) in 2021 International Dollars or purchasing power parity (PPP) per country from the IMF World Economic Outlook Database (See Supplementary Table S3) (International Monetary Fund (IMF), 2021). Fourth, the current expenditure on health per capita in 2021 International Dollars was projected using information from the WHO Global Health Expenditure Database (See Supplementary Table S4) (WHO, 2019a).

Fifth, the distribution of COVID-19-associated deaths across 16 age groups was unavailable for all 54 countries. It was only available for South Africa (Statista, 2021a) and Tunisia (Statista, 2021b). As explained in Section 2.3.2, the age distribution for the two countries was used to break down COVID-19 deaths in other African countries. Therefore, using the age structure of COVID-19 deaths in South Africa and Tunisia to break down deaths sustained in the remaining 52 African countries assumes that the distribution in these two countries reflects their general population distribution.

Table 1, column 2 presents South Africa's age distribution of COVID-19 deaths (Statista, 2021a). The 16 age-group proportions for South Africa were applied to Angola, Botswana, Burundi, Comoros, Democratic Republic of the Congo, Eswatini, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Rwanda, Seychelles, South Africa, South Sudan, Tanzania, Uganda, Zambia, Zimbabwe, i.e., the East African Community [EAC] and Southern African Development Community [SADC] countries.

On the other hand, the COVID-19 deaths age group distribution for Tunisia is displayed in Table 1, column 3 (Statista, 2021b). These proportions were applied to member countries of the Arab Maghreb Union [AMU] (Algeria, Libya, Mauritania, Morocco, Tunisia), the Central African Economic and Monetary Community [CEMAC] (Cameroon, Chad, the Central African Republic, Equatorial Guinea, Gabon, the Republic of Congo, Sao Tome and Principe), and the Economic Community of West African States [ECOWAS] (Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo). Although Angola and

the DRC are members of both CEMAC and SADC, Burundi and Rwanda are members of both EAC and CEMAC. The age distribution for South Africa was applied to these four countries.

**Table 1.** South Africa and Tunisia’s age distribution of COVID-19 deaths.

Age Group (Years)	South Africa (Percent) *	Tunisia (Percent) **
0–4 years	0.275	0.014
5–9 years	0.175	0.000
10–14 years	0.175	0.014
15–19 years	0.375	0.078
20–24 years	0.575	0.071
25–29 years	1.075	0.107
30–34 years	2.075	0.170
35–39 years	3.275	0.448
40–44 years	4.575	0.618
45–49 years	6.575	1.051
50–54 years	8.975	2.223
55–59 years	12.675	4.482
60–64 years	14.175	9.192
65–69 years	13.175	18.802
70–74 years	10.675	23.114
75 years and older	21.175	39.615

Source: \* Statista (2021a); \*\* Statista (2021b).

Sixth, the average life expectancy (ALE) for each country was extracted from the Worldometer Database (See Supplementary Table S5) (Worldometer, 2021). The world’s highest average life expectancy at birth, 88 years for females in Hong Kong, was used in the sensitivity analysis from the same database.

#### 2.3.4. Data Analysis

Equations (1)–(3) were estimated using Microsoft Excel software (Microsoft Corporation, New York, NY, USA), and the analysis involved 12 steps.

Step 1: Equations (2) and (3), presented in Section 2.3.2, were constructed into 54 Excel sheets (i.e., one sheet per country) to calculate the  $MVi$  per  $i$ th age group. The summation operation derives the  $j$ th country’s TMV of human life losses from COVID-19.

Step 2: Equation (1) was incorporated into a separate Excel sheet to derive the  $TMV_{Africa}$  of human life losses associated with COVID-19, i.e., to calculate the total monetary value for each of the 54 countries.

Step 3: In each country, the number of COVID-19 deaths per age group is equal to the total number of deaths from COVID-19 multiplied by the respective age group proportion (see Supplementary Table S6). For example, Algeria had lost 3708 lives to COVID-19 by 30 June 2021, and the proportion of these deaths in the 45–49-year age group was 0.0105128569399062 (1.051%). Thus, the number of deaths borne by the 45–49-year-olds equals 39, i.e., 3708 times 0.0105128569399062.

Step 4: Since the latest current expenditure on health per capita (CEHPC) available at the time in the WHO Global Health Expenditure Database was for 2018 (at the time of the analysis), it was necessary to forecast each country’s CEHPC for 2021 us-

ing existing 2017 and 2018 data (see Supplementary Table S4). The CEHPC growth rate between the years 2017 (CEHPC2017) and 2018 (CEHPC2018) equals  $[(\text{CEHPC2018} - \text{CEHPC2017})/\text{CEHPC2017}]$ . For example, Algeria's CEHPC in 2017 was Int\$970.26824951, and its CEHPC in 2018 was Int\$962.71936035. The growth rate between 2017 and 2018 equals  $-0.00778020837414019$ , i.e.,  $[(962.71936035 - 970.26824951)/970.26824951]$ . Thus, the projections across the years 2019 to 2021 assume that the growth rate between 2017 and 2018 will be sustained, i.e., it will remain constant.

**Step 5:** The non-health GDP per capita (NHGDPPC<sub>j</sub>) for each of the 54 countries was calculated by subtracting the respective CEHPC from GDPPC (see Supplementary Table S4). For instance, since Algeria's GDP per capita was Int\$11,435 and CEHPC was Int\$940 in 2021, the non-health GDP per capita equals Int\$10,495, i.e., 11,435 minus 940.

**Step 6:** The average age at onset of death (AAD<sub>i</sub>) for each of the first 15 age groups in Table 2 was calculated as a simple average, e.g., the AAD for 0–4-year-olds equals 2 years, which is  $(0 + 4)/2$ . We assumed an AAD of 75 years for those 75 years and older. There was no individual country-specific data on the number of deaths at each age that could have shown variations across countries. Therefore, the mid/average age for each of the 16 age groups was used to construct the average age at death.

**Table 2.** Average age of onset of COVID-19 death per age group.

Age Group	Average Age of Onset (Years) *
0–4 years	2
5–9 years	7
10–14 years	12
15–19 years	17
20–24 years	22
25–29 years	27
30–34 years	32
35–39 years	37
40–44 years	42
45–49 years	47
50–54 years	52
55–59 years	57
60–64 years	62
65–69 years	67
70–74 years	72

Source: \* Author's estimates.

**Step 7:** The undiscounted years of life lost (UDYLL) for each age group was estimated as the difference between the respective country's ALE and the group's AAD<sub>i</sub>. For example, given that the ALE for Algeria was 77.5 years and the AAD for the 45–49 age group was 47 years,  $\text{UDYLL} = 77.5 - 47 = 30.5$  years.

**Step 8:** The UDYLLs estimated in Step 7 were discounted (at a rate of 3%) because people prefer health (or monetary) benefits today rather than in the future. [Drummond et al. \(2015\)](#) explained that people might have a positive rate of time preference because they have a short-term view of life, uncertainties regarding the future, and positive economic growth. The discounted year of life (DYLL) was calculated by multiplying each UDYLL by the corresponding discount factor. For example, the discount factor for



the first YLL =  $1/(1+r)^t = 1/(1+0.03)^1 = 0.970874$ . The discount factor for the thirty-first YLL =  $1/(1+r)^t = 1/(1+0.03)^{31} = 0.399987$ . The summation of discount factors from the first YLL to the thirty-first YLL (see Step 7) in Algeria yields 20 discounted YLL (DYLL).

Step 9: The discounted monetary value ( $MV_i$ ) per  $i$ th age group is the product of DYLL, NHGDPPC <sub>$j$</sub> , and the number of COVID-19 deaths per age group (TCOVD <sub>$j$</sub> ). The calculation can be illustrated using the age group 44–49 years in Algeria, where DYLL<sub>44–49</sub> = 20 years (from Step 8), NHGDPPC = \$10,495 (see Step 5), and TCOVD<sub>44–49</sub> = 39 deaths (see Step 3). The MV for 44–49-year-olds = DYLL<sub>44–49</sub> × NHGPP × TCOVD<sub>44–49</sub> = 20 × 10,495 × 39 = Int\$8,186,100. The monetary values for the remaining 15 age groups were calculated similarly, applying Equation (3).

Step 10: Applied Equation (2) to sum up the monetary values of human lives lost in the 16 age groups to yield the TMV for each country.

Step 11: Equation (3) was used to sum up the TMVs across the 54 countries to derive the total continental loss.

Step 12: Sensitivity analysis. In the baseline model used to estimate each country's TMV, we assumed (a) a 3% discount rate and (b) each country's ALE. There is no consensus in the published literature regarding the two variables; thus, uncertainty exists. In such a situation, it is standard practice in epidemiology (Thabane et al., 2013) and health economics (Drummond et al., 2015) to rerun the model with different variable values to assess the robustness and credibility of the result(s), e.g., the TMV in our case. Therefore, as conducted in past health economics studies in Africa and elsewhere, we re-estimated the economic model using 3%, 5%, and 10% discount rates, while holding other variables, such as the number of COVID-19 deaths per country, per capita GDP, and CEHPC, constant. Furthermore, in line with past practice, the economic model was rerun three times using each country's ALE (See Supplementary Table S5); the highest ALE in Africa was 77.5 years, and the world's highest ALE was 88 years among females in Hong Kong (Worldometer, 2021).

#### 2.4. Conceptual Framework for Estimating the Cost of COVID-19 in Africa

The total economic cost of COVID-19 (TC<sub>COVID-19</sub>) encompasses total indirect costs (TIC<sub>COVID-19</sub>), total direct costs (TDC<sub>COVID-19</sub>), and psychic/intangible costs (TPC<sub>COVID-19</sub>), i.e.,

$$TC_{COVID-19} = TIC_{COVID-19} + TDC_{COVID-19} + TPC_{COVID-19} \quad (4)$$

##### 2.4.1. Total Indirect Cost Algorithm

$$TIC_{COVID-19} = VPYLL_{COVID-19} + VPTL_{NFL} + VFTL \quad (5)$$

where VPYLL<sub>COVID-19</sub> is the value of potentially productive YLL due to premature death from COVID-19 among those within the working-age bracket (i.e., 15–64 years) in country  $j$ ; VPTL<sub>NFL</sub> is the value of productive time lost among non-fatal COVID-19 cases in a specific working-age bracket; VFTL is the value of work time lost among all family members (and friends) of working-age accompanying and/or visiting patients.

$$VPYLL_{COVID-19} = TMV_{15-64} \times LFPR \quad (6)$$

where TMV<sub>15–64</sub> is the  $j$ th country's total monetary value of YLL in 15–64 age bracket (see Section 2.3.2); LFPR is the proportion of  $j$ th country's working-age population that actively engages in the labor market, either by working or looking for work (see Supplementary Table S7) (World Bank, 2021). In principle, the workforce participation rates in the ten age groups within the 15–64-year productive bracket would be expected to vary. In addition, there is evidence that those aged 50 years and above are more incapacitated by COVID-19 infections than those in younger age groups (15–49 years). However, due to the unavail-

ability of disaggregated data on LFPR by the ten age groups between 15 and 64 years, we assumed that the LFPR does not vary by age.

$$VPTL_{NFL} = (NRC \times NDD_R \times WD) + (NAC \times NDD_A \times WD) \quad (7)$$

where,

NRC is the number of persons that recovered from COVID-19 infection in country  $j$ ;  $NDD_R$  is the number of disability days per recovered person, i.e., from the time one tested positive to the time one tested negative for COVID-19; WD is the wage per day, which is assumed to be equal to  $j$ th country GDPDC divided by the number of working days per year; NAC is the number of active COVID-19 cases;  $NDD_A$  is the number of disability days per active COVID-19 case.

$$VFTL = (NV \times NAP \times NVD \times WD) \quad (8)$$

where,

NV is the number of COVID-19 laboratory-diagnosed cases in country  $j$ ; NAP is the average number of working-age family members and friends accompanying and visiting COVID-19 patients; NVD is the average number of days visited by a family/friend per COVID-19 patient. Unfortunately, in the study reported in this paper, it was not feasible to estimate both the productive time lost among non-fatal working-age COVID-19 cases and the accompanying/visiting family members and friends ( $VPTL_{NFL}$  and  $VFTL$ ) because of research resource constraints and community spread of infections.

In the current study,  $TIC_{COVID-19}$  of a country  $j$  is assumed to be equal to the  $VPYLL_{COVID-19}$ , i.e., the total value of potentially productive YLL due to premature death from COVID-19 among those within the working-age bracket (i.e., 15–64 years). Therefore, the average indirect cost per COVID-19 death in country  $j$  ( $ATIC_j$ ) was estimated using the following formula:

$$ATIC_j = VPYLL_{COVID-19} / TCOVD_j \quad (9)$$

where,

$VPYLL_{COVID-19}$ , as previously defined, is the value of potentially productive YLL due to premature death from COVID-19 among those within the working-age bracket (i.e., 15–64 years) in country  $j$ ;  $TCOVD_j$  is the total number of COVID-19-associated deaths within the 15–64-year age bracket in country  $j$ . For example, in Algeria,  $VPYLL_{COVID-19}$  equals Int\$ 50,625,695 and  $TCOVD_j$  equals 684. Thus,  $ATIC_{15-64} = 50,625,695 / 684 = 74,040.2$ .

#### 2.4.2. Total Direct Cost Algorithm

In the context of COVID-19, the total direct cost of COVID-19 ( $TDC_{COVID-19}$ ) has three components. First, the monetary value of quantities of inputs (resources) borne by the government and private sector organising and operating national health system services related to prevention (personal hygiene—handwashing, sanitizing, washing potentially contaminated clothes), wearing facial masks, physical distancing, health education (information, education, communication), diagnosis, contact tracing, isolation/quarantine, community-based management (of mild and moderate cases), hospital management and rehabilitation of severe cases, and transport of persons with COVID-19 symptoms to testing and treatment centers, and transport of accompanying family persons ( $TNHSC_{COVID-19}$ ).

Second, the monetary value of quantities of inputs borne by other sectors involved in combating the community spread of COVID-19 infections ( $TOSC_{COVID-19}$ ). For example, inputs incurred by Ministries of Water and Sanitation in availing potable water; inputs incurred by the Ministries of Interior Security in policing implementation of COVID-19-

related public health regulations, such as the mandatory wearing of facial masks, physical distancing, policing of travel bans, policing of operating hours of restaurants, policing of seat spacing and disinfecting in public transport vehicles; and Ministries of Transport role in issuance and implementation of COVID-19-related public health regulations related to all modes of transport internally and external entry and exit points.

Third, the direct out-of-pocket payments (OOPs) incurred by households related to payments for preventive inputs (e.g., facial masks, hand sanitizers, soap, water, hand towels); transportation of COVID-19 patients and accompanying family members (or friends) to testing and isolation/treatment centers; COVID-19 diagnostic tests; health workers consultation services; medicines for COVID-19-positive persons at health system institutions and community/home setting; COVID-19 vaccine; and informal payments to access vaccines ( $TOOPS_{COVID-19}$ ) (Onwujekwe et al., 2023).

Algebraically, we have the following:

$$TDC_{COVID-19} = (TNHSC_{COVID-19} + TOSC_{COVID-19} + TOOPS_{COVID-19}) \quad (10)$$

Under ideal COVID-19-free conditions, estimating equation nine would have entailed conducting detailed costing surveys at the household (community level) and COVID-19 testing (diagnostic) and treatment centers to collect primary data on quantities and prices of various inputs. However, due to the ongoing community circulation of COVID-19 (at the time of the study) and a limited research budget compared to the expected considerable cost of conducting household and health-facility-based surveys in all African countries, it was not feasible to collect primary data.

Therefore, in the absence of primary cost data, researchers estimated the total direct cost associated with prevention, diagnosis, contact tracing, isolation/quarantine, management, and rehabilitation of COVID-19 ( $TDC_{COVID-19}$ ) through the multiplication of the total number of reported COVID-19 cases per country ( $TCOVIDCASES_j$ ) by the total current expenditure on health per capita per country ( $CEHPC_j$ ). According to the [Organisation for Economic Co-operation and Development \[OECD\] \(2000\)](#), the CEHPC includes expenditures on personal health care services and goods (services of curative care, services of rehabilitative care, services of long-term nursing care, ancillary services to health care, medical goods dispensed to out-patients), prevention and public health services (health promotion, epidemiological surveillance, blood-bank operation, public health service laboratories, and population planning services), and health administration and health insurance (includes activities performed by private insurers and national and local authorities plus social security funds).

Algebraically, we have the following:

$$TDC_{COVID-19} = (TCOVIDCASES_j \times CEHPC_j) \quad (11)$$

For illustration, in Algeria,  $TCOVIDCASES_{Algeria}$  equals 139,229 total cases reported as of 30 June 2021, and  $CEHPC_{Algeria}$  equals Int\$940 in 2021. Thus,

$$TDC_{Algeria} = (139229 \times 940) = \text{Int\$}130,934,190.$$

The estimation of Equation (10) is based on three assumptions:

- CEHPC is a good proxy for the value of all health-related systems inputs used in prevention (including policing of travel bans), diagnosis, contact tracing, isolation/quarantine, management, and rehabilitation of COVID-19 cases;

- CEHPC is efficiently utilized in each country to manage COVID cases, ensuring no wastage in the allocation and use of resources;
- All COVID-19 patients have an equal quantity (and value) of resources spent on them, irrespective of whether the cases are asymptomatic, mild, moderate, severe, or critical.

Our estimation of total direct cost using Equation (10) has two shortcomings: (a). Capital formation of healthcare provider institutions was not included due to the unavailability of data per country in the WHO Global Health Expenditure Database (WHO, 2019a). (b). The equation does not include the COVID-19 laboratory test cost among negative cases. If the data on the average cost per COVID-19 test ( $ALTESTC_j$ ) were available in the  $j$ th country, the total laboratory test cost for negative cases would have been equal to  $TCOVIDNEG_j \times ALTESTC_j$ , where  $TCOVIDNEG_j$  is the total number of cases that tested negative for COVID-19 per country, i.e., the total number of cases tested for COVID per  $j$ th country minus the total number of cases that tested positive.

#### 2.4.3. Total Intangible Cost Algorithm

The intangible cost refers to the adverse effect on social welfare (mental health and psychosocial wellbeing) of those who test positive for COVID-19 and their loved ones (Geirdal et al., 2021). How? First, people who test positive for COVID-19 are expected to self-isolate to minimize the risk of spreading the infection to family, friends, workmates, and the public. According to Cesare (2020), such people may experience shame and guilt about the possibility of transmitting the infection to others.

Second, people with moderate to severe COVID-19 disease may be quarantined (confined) in treatment centers where family and friends are not allowed to visit them. As a result, according to Dubey et al. (2020), this group of patients may experience loneliness, anxiety, depression, and increased substance dependence.

Third, studies have revealed that people who test positive for COVID-19 (Bhanot et al., 2021; Gronholm et al., 2021) and healthcare providers experience some form of stigma and hence, avoidance by communities for fear of infection (Mostafa et al., 2020). Fourth, according to Cabarkapa et al. (2020), family, friends and workmates may experience psychological stress witnessing the pain and suffering and ensuing decrease in the health of those infected by COVID.

The abovementioned psychosocial consequences of COVID-19 on patients, family and healthcare providers are somewhat difficult to measure and value monetarily. However, as demonstrated in the study on osteoarthritis by Cross et al. (2000), arthritis by Slothuus and Brooks (2000), malaria by Jimoh et al. (2007), and HIV/AIDS by Adekunjo et al. (2020), decrements in health status due to various forms of pain and suffering can potentially be measured using the willingness-to-pay (contingent valuation) (WTP) approach. In the context of COVID-19, the WTP approach has been applied in the valuation of the installation of an early warning system for infectious diseases (Himmeler et al., 2022), and COVID-19 vaccine (Cerdeira & García, 2021) in Europe, WTP per DALY saved through early implementation of movement restriction policies (MRPs) (Zhao et al., 2021) and COVID-19 vaccine demand (Lin et al., 2020) in China, WTP for prospective COVID-19 vaccine in Nigeria (Ilesanmi et al., 2021), and WTP for a hypothetical COVID-19 Vaccine in Italy, Spain, UK, and USA by Catma and Varol (2021) and Costa-Font et al. (2021).

Therefore, erosion in health status is associated with increased anxiety, depression, insomnia, loneliness, self-harm, and stigma/discrimination, and substance abuse (Kumar & Nayar, 2021) associated with COVID-19 infection can be quantified and valued through the WTP approach. It would involve using survey methods, presenting respondents with hypothetical scenarios to reveal the maximum they would be willing to pay for a

COVID-19 intervention that reduces the probability of experiencing negative psychosocial consequences of COVID-19 infection.

The intangible cost of COVID-19 can be derived using the following formula:

$$TIC_{COVID-19} = T_{COVIDCASES_j} \times AWTP_j \quad (12)$$

where,

$T_{COVIDCASES_j}$ , as previously defined, is the total number of reported COVID-19 cases per  $j$ th country and  $AWTP_j$  is the average amount of money a person would be willing to pay to finance an intervention to prevent COVID-19 infection and, hence, avert the associated negative psychosocial consequences. Given the limited budget and scope of the current study, it was not feasible to conduct a contingent valuation study to elicit willingness to pay for an intervention that would reduce the probability of COVID-19 infection and, hence, avert associated intangible consequences. It is worth clarifying that the WTP here would only be used for payment to avoid intangible welfare loss.

### 2.5. Estimation of Potential Savings Assuming a 100% Vaccine Target Population Coverage

Our study estimates the potential savings from COVID-19 vaccination, assuming 100% coverage, rather than the prevailing coverage levels in Africa, which are currently very low. The potential monetary savings associated with vaccination equal total direct cost savings plus indirect cost savings.

#### 2.5.1. Expected Savings in Total Direct Costs Due to COVID-19 Vaccinations

The expected total direct cost savings per country due to vaccination with the Oxford–AstraZeneca vaccine were estimated in seven steps.

Step 1: The 2021 population estimates for each of the 54 African countries were obtained from [Worldometer \(2021\)](#).

Step 2: A search in the PubMed.com database for the Oxford–AstraZeneca vaccine effectiveness revealed an article by [Voysey et al. \(2021\)](#) that reported a pooled analysis of four randomized trials (Brazil, South Africa, and the UK) with 8597 participants receiving the ChAdOx1 nCoV-19 (Oxford–AstraZeneca vaccine) and 8581 receiving a control vaccine or saline. The study found an “Overall vaccine efficacy more than 14 days after the second dose was 66.7% (95% CI 57.4–74.0), with 84 (1.0%) cases in the 8597 participants in the ChAdOx1 nCoV-19 group and 248 (2.9%) in the 8581 participants in the control group (p. 881)”.

Step 3: Use the evidence in Step 2 to estimate the COVID-19 infection risk without ( $IR_{Control}$ ) and with Oxford–AstraZeneca ( $IR_{AZ}$ ) in the [Voysey et al. \(2021\)](#) pooled analysis of randomized trials in Brazil, South Africa, and the UK. The infection risk in a group equals the number of infected people divided by the group size (see Table 3).

**Table 3.** COVID-19 infection risk among control group and the vaccinated group.

Group	(A) Group Size	(B) No. Infected	(C) Infection Risk [C = (B/A)]	(D) Infection Risk (%) [D = C × 100]
Control	8581	248	0.02890106	2.890106048
ChAdOx1 nCov-19 (AZ)	8597	84	0.00977085	0.97708503

Source: [Voysey et al. \(2021\)](#). Note: Vaccine efficacy (VE) = ((risk for the control group – risk for the vaccinated group)/risk for the placebo group) × 100 = ((2.89010604824613 – 0.97708502966151)/2.89010604824613) × 100 = 66.19207%.

Step 4: Estimate the number of people in the  $j$ th country that would be expected to contract COVID-19 without vaccination ( $PoPI_{without}$ ). The number of people in each of the 54 African countries expected to contract COVID-19 without vaccination was obtained by multiplying the respective country's population ( $PoP_j$ ) by the  $IR_{Control}$  of 0.02890106 (See Supplementary Table S8). In Algeria, for example, the number of people expected to contract COVID-19 without vaccination equals 44,634,463 persons times 0.02890106, i.e.,  $PoPI_{without} = PoP_{Algeria} \times IR_{Control} = 44,634,463 \times 0.02890106 = 1,289,983$ .

Step 5: Estimate the number of people in the  $j$ th country that would be expected to contract COVID-19 with the Oxford–AstraZeneca vaccination ( $PoPI_{with}$ ). The number of people in each of the 54 African countries expected to contract COVID-19 with vaccination was obtained by multiplying the respective  $PoP_j$  by  $IR_{AZ}$  of 0.00977085 (See Supplementary Table S8). In Algeria, for instance, the number of people expected to contract COVID-19 with vaccination equals 44,634,463 persons times 0.00977085, i.e.,  $PoPI_{with} = PoP_{Algeria} \times IR_{AS} = 44,634,463 \times 0.00977085 = 436,117$ .

Step 6: The number of infections averted, assuming 100% population coverage, equals the difference between the number of people expected to contract COVID-19 without and with vaccination, i.e.,  $PoPI_{without} - PoPI_{with}$ . In the case of Algeria, the infections averted through 100% vaccination coverage with Oxford–AstraZeneca equals 853,867, which is 1,289,983 (from Step 4) minus 436,117 (from Step 5).

Step 7: The total direct cost savings expected by the  $j$ th country from vaccination equals the number of infections averted (from Step 6) multiplied by the total current health expenditure per capita. For instance, the expected savings in Algeria equal Int\$802,996,067, i.e., 853,867 infections averted (from Step 6) times CEHPC of Int\$940.423260222453.

Step 8: The total direct cost savings for Continental Africa were calculated by summing the savings for each country, as obtained in Step 7, across the 54 countries in the continent.

#### 2.5.2. Expected Savings in Total Indirect Costs Due to COVID-19 Vaccination

We estimated the expected savings in total indirect costs resulting from COVID-19 vaccination in each of the 54 countries by following the eight steps below.

Step 1: A search in the PubMed.com database for COVID-19 vaccine effectiveness in reducing the risk of death revealed an article by Bernal et al. (2021), which attempted “To estimate the real-world effectiveness of the Pfizer-BioNTech BNT162b2 and Oxford–AstraZeneca ChAdOx1-S vaccines against confirmed COVID-19 symptoms, admissions to hospital, and deaths” (p. 1).

Step 2: Utilize the evidence in Step 1 to calculate the risk of COVID-19 resulting in death among the unvaccinated ( $DR_{unvaccinated}$ ) and those vaccinated with the Pfizer-BioNTech BNT162b2 ( $DR_{PB}$ ). The risk of death in a group equals the number of deaths from COVID-19 in an age group divided by the total number of cases in the group (see Table 4).

**Table 4.** The risk of death from COVID-19 among the unvaccinated and the vaccinated.

Group	(A) Total No of Cases *	(B) No. of Deaths *	(C) Death Risk [C = (B/A)] **	(D) Death Risk (%) [D = C × 100] **
Unvaccinated	8091	1063	0.131380546	13.13805463
≥14 days after vaccination	750	51	0.068	6.8
Vaccine efficacy (VE)			48.24195673	

Source: \* Bernal et al. (2021). \*\* Author's calculation.



Step 3: Estimate the number of people infected in the  $j$ th country expected to die from COVID-19 without vaccination ( $PoPD_{without}$ ). The number of people in each of the 54 African countries expected to die from COVID-19 without vaccination was obtained by multiplying the respective country's  $PoPI_{without}$  by the  $DR_{unvaccinated}$  of 0.131380546 (See Supplementary Table S9). In Algeria, for example, the number of COVID-19-positive people expected to die without vaccination equals 1,289,983 times 0.131380546, i.e.,  $PoPD_{without} = PoPI_{without} \times DR_{unvaccinated} = 1,289,983 \times 0.131380546 = 169,479$ .

Step 4: Estimate the number of people in the  $j$ th country that would be expected to die from COVID-19 even though vaccinated with Pfizer-BioNTech BNT162b2 ( $PoPD_{with}$ ) through the multiplication of the number of people expected to contract COVID-19, even after being vaccinated ( $PoPI_{with}$ ) (from Step 5 of Section 2.5.1) by the probability of death in a vaccinated group ( $DR_{PB}$ ) of 0.068 (See Supplementary Table S9). In Algeria, for instance, the  $PoPI_{with}$  equals 436,117 persons times  $DR_{PB}$  of 0.068, i.e.,  $PoPD_{with} = PoPI_{with} \times DR_{PB} = 436,117 \times 0.068 = 29,656$ .

Step 5: The number of COVID-19-associated deaths prevented ( $COVID-19D_{Prevented}$ ) across all age groups, assuming that 100% of the population's vaccine coverage equals the difference between the number of people expected to die from COVID-19 without and with vaccination, i.e.,  $PoPD_{without} - PoPD_{with}$ . In the Algeria example, the number of deaths in all age groups prevented through 100% vaccination coverage equals 139,823, i.e., 169,479 (from Step 3 in Section 2.5.2) minus 29,656 (from Step 5 in Section 2.5.2).

Step 6: The number of COVID-19 deaths prevented within the productive age group 15–64 years equals  $COVID-19D_{Prevented}$  times the proportion of deaths in that age group (i.e., 0.184401193351328). In Algeria, for instance, the projected total number of deaths prevented in the 15–64 age group equals 25,783.5, i.e., 139,823 (from Step 5 Section 2.5.2) times 0.184401193351328.

Step 7: The indirect cost savings expected by the  $j$ th country from deaths prevented by vaccination equals the number of deaths prevented in the age group 15–64 years ( $COVID-19D_{Prevented}$ ) (from Step 6 in Section 2.5.2) times the average indirect cost per COVID-19 death in country  $j$  ( $ATIC_j$ ) (from Section 2.4.1 Equation (9)). For instance, the expected savings from COVID-19-associated deaths prevented in Algeria equals Int\$1,909,014,416, i.e., 25,783.5 deaths prevented times the indirect cost per death from COVID-19 of Int\$74,040.2. The indirect cost savings for the remaining 53 countries were estimated in a similar manner.

Step 8: Continental Africa indirect cost savings were obtained by summing the indirect cost savings for each country, as calculated in Step 7, across the 54 countries.

### 3. Results

#### 3.1. Discounted Monetary Value of Human Life Losses Associated with COVID-19

Monetary Value of Human Life Losses at a 3% Discount Rate and National Life Expectancies at Birth

Table 5 shows that as of 30 June 2021, Africa had incurred 142,171 human life losses due to COVID-19, with an estimated discounted total monetary value (TMV) of Int\$6,684,101,196. Twenty countries (37.04%) of all the 54 countries had TMV of less than Int\$1 million; 16 (29.63%) countries had between Int\$1 million and Int\$10 million; and 18 (33.3%) countries had Int\$11 million and above.

**Table 5.** The discounted monetary value of actual human life losses from COVID-19 in Africa as of 30 June 2021 (in 2021 Int\$ or PPP).

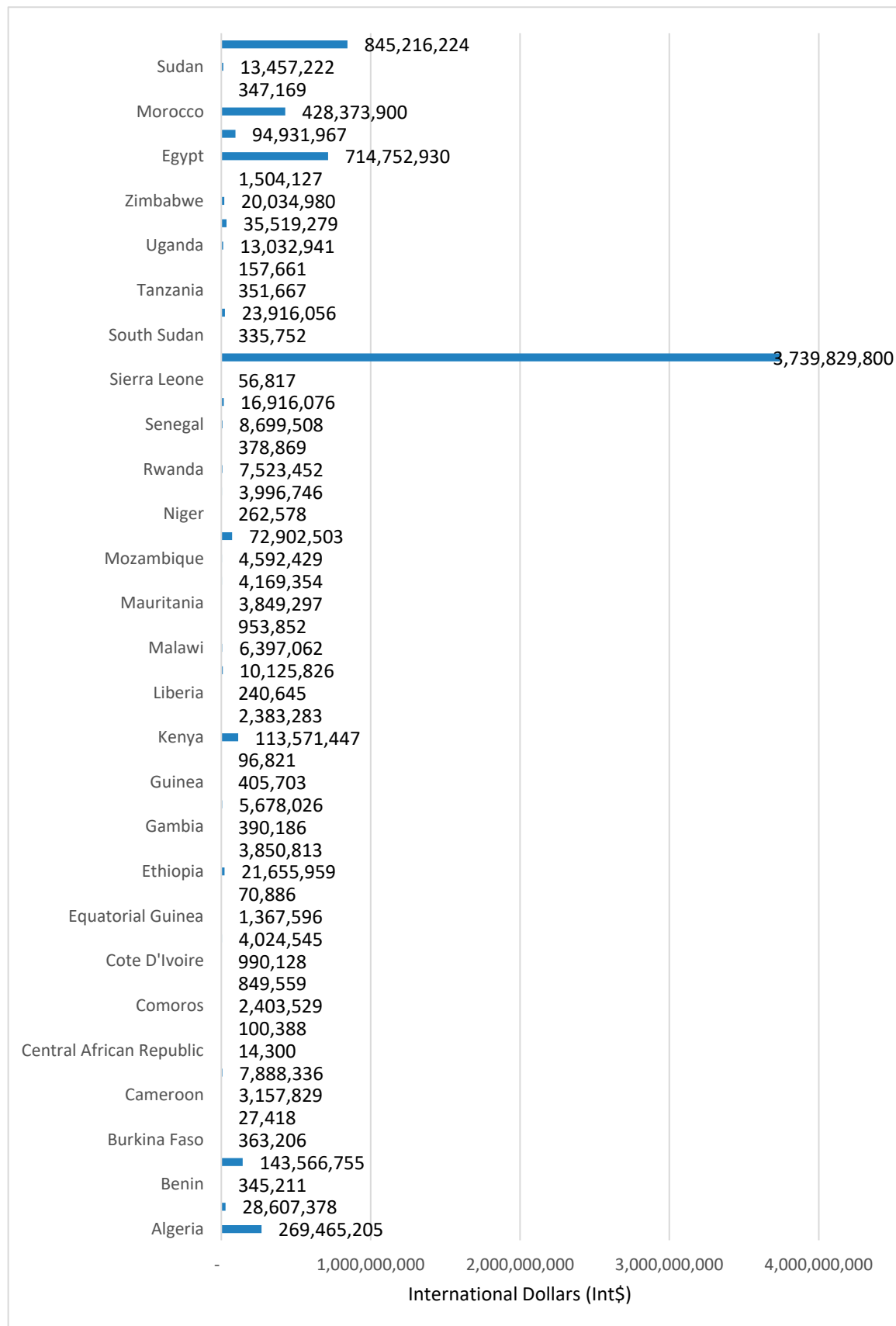
Country	Population in 2021 * (A)	COVID-19 Deaths as of 30 June 2021 * (B)	Total Discounted Monetary Value of Human Lives Lost (Int\$) [C] **	Discounted Monetary Value per Human Life Lost (Int\$) [D = C/B] **	The Discounted Monetary Value of Human Life Lost per Person in the Population (Int\$) [E = C/A] **
Algeria	44,634,463	3708	269,465,205	72,671	6.04
Angola	33,874,015	894	28,607,378	31,999	0.84
Benin	12,436,641	104	345,211	3319	0.03
Botswana	2,398,576	1125	143,566,755	127,615	59.85
Burkina Faso	21,468,861	168	363,206	2162	0.02
Burundi	12,239,994	8	27,418	3427	0.00
Cameroon	27,198,364	1324	3,157,829	2385	0.12
Cape Verde	561,973	286	7,888,336	27,582	14.04
Central African Republic	4,912,863	98	14,300	146	0.00
Chad	16,890,785	174	100,388	577	0.01
Comoros	887,911	146	2,403,529	16,463	2.71
Congo, Republic of	5,652,216	165	849,559	5149	0.15
Cote d'Ivoire	27,023,309	313	990,128	3163	0.04
Congo, Democratic Republic of	92,245,852	924	4,024,545	4356	0.04
Equatorial Guinea	1,448,396	121	1,367,596	11,302	0.94
Eritrea	3,595,038	23	70,886	3082	0.02
Ethiopia	117,775,639	4320	21,655,959	5013	0.18
Gabon	2,277,613	159	3,850,813	24,219	1.69
Gambia, The	2,483,649	181	390,186	2156	0.16
Ghana	31,714,153	795	5,678,026	7142	0.18
Guinea	13,484,325	169	405,703	2401	0.03
Guinea-Bissau	2,013,948	69	96,821	1403	0.05
Kenya	54,941,831	3621	113,571,447	31,365	2.07
Lesotho	2,159,095	329	2,383,283	7244	1.10
Liberia	5,175,111	127	240,645	1895	0.05
Madagascar	28,393,805	911	10,125,826	11,115	0.36
Malawi	19,617,945	1194	6,397,062	5358	0.33
Mali	20,826,158	525	953,852	1817	0.05
Mauritania	4,770,294	487	3,849,297	7904	0.81

Table 5. Cont.

Country	Population in 2021 * (A)	COVID-19 Deaths as of 30 June 2021 * (B)	Total Discounted Monetary Value of Human Lives Lost (Int\$) [C] **	Discounted Monetary Value per Human Life Lost (Int\$) [D = C/B] **	The Discounted Monetary Value of Human Life Lost per Person in the Population (Int\$) [E = C/A] **
Mauritius	1,273,865	18	4,169,354	231,631	3.27
Mozambique	32,119,351	872	4,592,429	5267	0.14
Namibia	2,586,431	1445	72,902,503	50,452	28.19
Niger	25,069,087	193	262,578	1361	0.01
Nigeria	211,184,869	2120	3,996,746	1885	0.02
Rwanda	13,269,271	431	7,523,452	17,456	0.57
São Tomé and Príncipe	223,185	37	378,869	10,240	1.70
Senegal	17,179,451	1166	8,699,508	7461	0.51
Seychelles	98,951	68	16,916,076	248,766	170.95
Sierra Leone	8,137,375	98	56,817	580	0.01
South Africa	60,049,601	60,264	3,739,829,800	62,057	62.28
South Sudan	11,323,788	117	335,752	2870	0.03
Swaziland	1,172,073	678	23,916,056	35,274	20.40
Tanzania	61,412,589	21	351,667	16,746	0.01
Togo	8,470,400	129	157,661	1222	0.02
Uganda	47,164,701	989	13,032,941	13,178	0.28
Zambia	18,891,903	2138	35,519,279	16,613	1.88
Zimbabwe	15,077,192	1761	20,034,980	11,377	1.33
Djibouti	1,002,228	155	1,504,127	9704	1.50
Egypt	104,243,582	16,148	714,752,930	44,263	6.86
Libya	6,963,848	3191	94,931,967	29,750	13.63
Morocco	37,344,128	9292	428,373,900	46,101	11.47
Somalia	16,330,692	775	347,169	448	0.02
Sudan	44,860,676	2754	13,457,222	4886	0.30
Tunisia	11,941,219	14,843	845,216,224	56,944	70.78
TOTAL	1,370,493,279	142,171	6,684,101,196	47,015	4.88

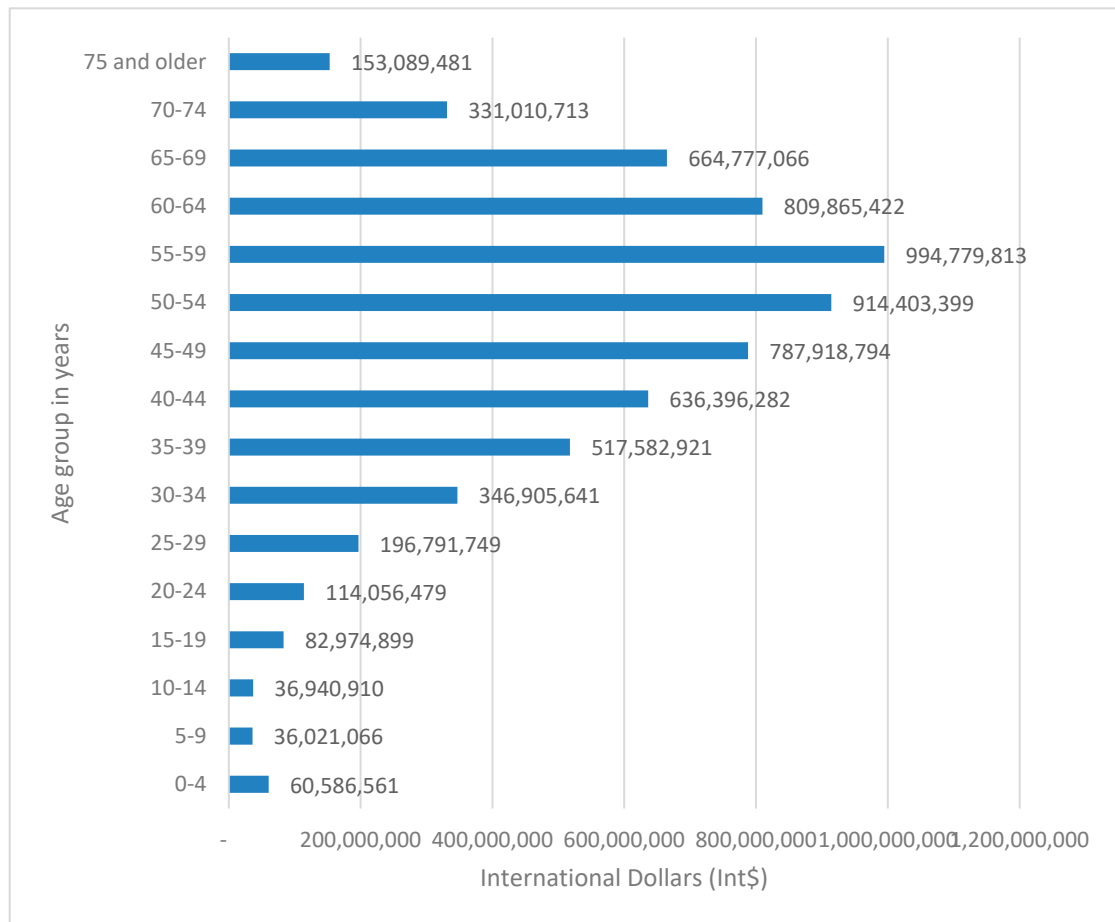
Sources: \* [Worldometer \(2021\)](#); \*\* Authors' estimates.

As depicted in Figure 1, the TMV varied widely from a minimum of Int\$14,300 in the Central African Republic to a maximum of Int\$3,739,829,800 in South Africa.



**Figure 1.** Discounted total monetary value of human life losses associated with COVID-19 in Africa by 30 June 2021 (in International Dollars).

Figure 2 portrays the distribution of TMV across the 16 age groups. About Int\$133,548,537 (2.0%) accrued to 0–14-year-olds; Int\$4,591,809,977 (68.7%) to 15–59-year-olds; and Int\$1,958,742,682 (29.3%) to 60-year-olds and above.



**Figure 2.** Discounted monetary value of human life losses from COVID-19 by age group in Africa (Int\$).

About Int\$133,548,537 (2.0%) accrued to 0–14-year-olds; Int\$4,591,809,977 (68.7%) to 15–59-year-olds; and Int\$1,958,742,682 (29.3%) to 60-year-olds and above. Thus, most of the monetary value of lives lost to COVID-19 accrued to the most socioeconomically productive age bracket, i.e., 15–59-year-olds.

The average monetary value was Int\$47,015 per human life lost, and the monetary value of human life lost per person in the population was Int\$4.88. The average TMV per COVID-19 death varied widely from a minimum of Int\$146 in the Central African Republic to a maximum of Int\$248,766 in Seychelles.

The five countries with the highest average TMV per human life included Algeria with Int\$72,671, Botswana with Int\$127,615, Mauritius with Int\$231,631, Seychelles with Int\$248,766, and South Africa with Int\$62,057.

### 3.2. Economic Cost of COVID-19 in Africa

As explained earlier in Section 2.4 of the methods, the estimates of the total economic cost of COVID-19 ( $TC_{COVID-19}$ ) reported in this paper encompass only total indirect costs (TIC) and total direct costs (TDC).

## 3.2.1. Indirect Cost of COVID-19 in Africa

Table 6 presents the total and average indirect costs (productivity losses) incurred per country as of 30 June 2021, due to COVID-19.

**Table 6.** Total and average indirect cost among 15–64 years old by country in Africa (in 2021 Int\$ or PPP).

Country	(A). COVID-19 Deaths 2021 *	(B). Total Monetary Value of Lives Lost to COVID-19 (Int\$) ***	(C). Labor Force Participation Rate for Ages 15–64 (%) **	(D). To Indirect Cost (Int\$) [D = Bx(C/100)] ***	(E). Average Indirect Cost [E = (D/A)] ***
Algeria	684	109,107,102	46.4	50,625,695	74,040
Angola	486	27,554,096	77.9	21,464,641	44,176
Benin	19	342,422	71.7	245,517	12,802
Botswana	611	133,347,604	73.0	97,343,751	159,205
Burkina Faso	31	360,381	67.8	244,338	7887
Burundi	4	26,455	80.0	21,164	4868
Cameroon	244	3,121,502	76.9	2,400,435	9832
Cape Verde	53	4,694,663	63.9	2,999,890	56,882
Central African Rep	18	13,977	72.3	10,106	559
Chad	32	98,344	70.7	69,529	2167
Comoros	79	2,329,866	46.6	1,085,718	13,682
Congo	30	844,274	70.3	593,524	19,507
Cote d'Ivoire	58	977,392	54.6	533,656	9246
DRC	502	3,871,323	64.1	2,481,518	4941
Equatorial Guinea	22	1,351,863	63.2	854,378	38,291
Eritrea	4	62,991	81.3	51,212	12,075
Ethiopia	797	19,419,954	81.3	15,788,423	19,819
Gabon	29	3,831,028	54.7	2,095,572	71,473
Gambia The	33	387,034	60.5	234,155	7016
Ghana	147	5,642,699	69.2	3,904,748	26,636
Guinea	31	402,426	63.0	253,528	8135
Guinea Bissau	13	95,658	72.9	69,735	5481
Kenya	1968	110,454,961	74.6	82,399,401	41,869
Lesotho	179	2,244,799	69.9	1,569,114	8775
Liberia	23	239,148	77.1	184,383	7873
Madagascar	495	9,675,527	87.2	8,437,060	17,040
Malawi	649	6,212,044	77.3	4,801,910	7400
Mali	97	944,317	71.3	673,298	6955
Mauritania	90	3,827,676	46.5	1,779,869	19,820
Mauritius	10	3,467,754	66.2	2,295,653	234,657
Mozambique	474	4,422,875	78.3	3,463,111	7307
Namibia	785	70,668,214	60.6	42,824,938	54,529
Niger	36	260,749	73.4	191,390	5378
Nigeria	391	3,922,315	56.7	2,223,953	5689



Table 6. Cont.

Country	(A). COVID-19 Deaths 2021 *	(B). Total Monetary Value of Lives Lost to COVID-19 (Int\$) ***	(C). Labor Force Participation Rate for Ages 15–64 (%) **	(D). To Indirect Cost (Int\$) [D = Bx(C/100)] ***	(E). Average Indirect Cost [E = (D/A)] ***
South Sudan	64	320,264	73.8	236,355	3717
Rwanda	234	6,987,929	84.1	5,876,849	25,088
Sao Tome et Principe	7	281,197	59.9	168,437	24,687
Senegal	215	7,213,397	47.1	3,397,510	15,802
Seychelles	37	14,790,765	66.6	9,849,170	266,496
Sierra Leone	18	55,759	58.8	32,786	1814
South Africa	32,753	3,625,212,884	60.1	2,178,752,943	66,520
Swaziland (Eswatini)	368	22,951,859	54.7	12,554,667	34,070
Tanzania	11	341,496	84.5	288,564	25,283
Togo	24	156,146	58.5	91,346	3840
Uganda	538	12,607,006	70.9	8,938,367	16,629
Zambia	1162	34,430,697	75.1	25,857,454	22,252
Zimbabwe	957	19,295,282	84.0	16,208,037	16,934
Djibouti	29	1,348,824	63.7	859,201	30,061
Egypt	2978	460,883,696	47.9	220,763,290	74,139
Libya	588	61,213,594	52.8	32,320,778	54,928
Morocco	1713	188,853,193	48.7	91,971,505	53,676
Somalia	143	342,073	49.4	168,984	1182
Sudan	508	13,381,636	49.7	6,650,673	13,096
Tunisia	2737	396,784,269	51.5	204,343,899	74,658
TOTAL (Int\$)	54,210	5,401,675,398		3,173,546,125	58,542

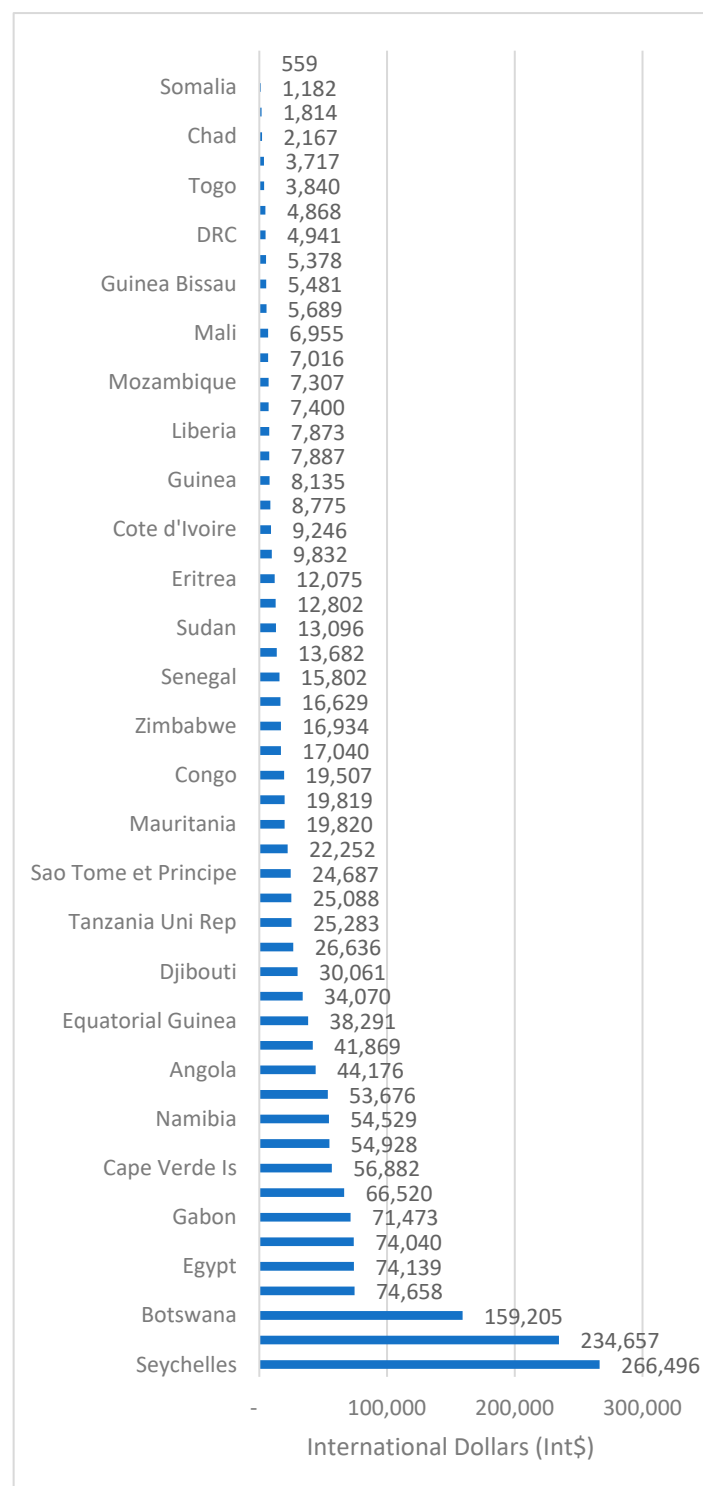
Sources: \* [Worldometer \(2021\)](#), \*\* [International Monetary Fund \(IMF\) \(2021\)](#), \*\*\* Authors' estimates.

Approximately 54,210 of the persons who died of COVID-19 in Africa were aged 15–64 years. Those lives had a monetary value of Int\$5.402 billion. Adjustment for labor force participation rate yielded a Continental total indirect cost of Int\$3,173,546,125 and an average of Int\$58,542 per life lost in the 15–64 years bracket. Twenty-two countries (40.7%) had a total indirect cost of less than Int\$1 million; 18 countries (33.3%) had an indirect cost of Int\$1 million to Int\$10 million; and 14 countries (26.0%) had an indirect cost of Int\$11 million and above. Figure 3 illustrates that the total indirect cost varied widely, ranging from Int\$10,106 in the Central African Republic to a maximum of Int\$2,178,752,943 in South Africa.

Figure 4 presents the average indirect cost of COVID-19 in Africa. The five countries with the highest average indirect cost per life lost were Seychelles, with Int\$266,496; Mauritius, with Int\$234,657; Botswana, with Int\$159,205; Tunisia, with Int\$74,658; and Egypt, with Int\$74,139. The average indirect cost per COVID-19 death varied from a minimum of Int\$559 in the Central African Republic to a maximum of Int\$266,496 in Seychelles. One (1.9%) country had less than Int\$1000 per life lost; 20 (37.0%) countries had between Int\$1000 and Int\$10,000; 11 (20.4%) countries had between Int\$11,000 and Int\$20,000; 6 (11.1%) countries had between Int\$21,000 and Int\$30,000; 16 (29.6%) countries had Int\$31,000 and above.



**Figure 3.** Total indirect cost of COVID-19 by country in Africa (in 2021 Int\$ or PPP).



**Figure 4.** Average indirect cost of COVID-19 by country in Africa (in 2021 Int\$ or PPP).

### 3.2.2. Direct Cost of COVID-19 in Africa

As depicted in Table 7, the total direct health system cost of preventing and managing COVID-19 cases in Africa is estimated at Int\$3,981,927,049. Five countries (Algeria, Egypt, Morocco, Tunisia, and South Africa) alone bore 86.7% (Int\$3.45 billion) of the Continent's total direct cost.

**Table 7.** Estimated direct cost of preventing and managing COVID-19 cases as of 30 June 2021.

Country	(A) Total COVID-19 Cases *	(B) Current Health Expenditure per Capita in 2021 (Int\$) **	(C) Direct Cost (Int\$) [C = A × B] ***
Algeria	139,229	940	130,934,190
Angola	38,682	115	4,448,923
Benin	8199	85	700,219
Botswana	69,680	1082	75,380,140
Burkina Faso	13,479	73	977,779
Burundi	5428	89	485,399
Cabo Verde	32,457	481	15,617,354
Cameroon	80,858	154	12,492,030
Central African Republic	7141	540	3,855,622
Chad	4951	62	306,781
Comoros	3912	144	562,929
Congo	12,596	51	643,920
Djibouti	11,602	136	1,580,972
DRC	40,836	18	720,805
Egypt	281,031	491	138,124,544
Equatorial Guinea	8734	585	5,105,836
Eritrea	5936	139	823,562
Eswatini	19,084	659	12,581,054
Ethiopia	276,037	70	19,349,040
Gabon	24,984	482	12,034,455
Gambia	6079	76	464,312
Ghana	95,642	244	23,291,505
Guinea	23,753	138	3,272,720
Guinea-Bissau	3853	137	529,337
Cote d'Ivoire (Ivory Coast)	48,242	181	8,746,361
Kenya	183,603	263	48,349,428
Lesotho	11,344	399	4,529,139
Liberia	3900	59	230,223
Libya	193,238	8	1,559,041
Madagascar	42,207	60	2,518,105
Malawi	35,897	115	4,133,405
Mali	14,422	87	1,248,415
Mauritania	20,747	219	4,553,581
Mauritius	1833	1741	3,190,929
Morocco	530,585	560	297,383,335
Mozambique	75,828	143	10,815,752

Table 7. Cont.

Country	(A) Total COVID-19 Cases *	(B) Current Health Expenditure per Capita in 2021 (Int\$) **	(C) Direct Cost (Int\$) [C = A × B] ***
Namibia	86,649	778	67,442,498
Niger	5488	79	434,235
Nigeria	167,543	273	45,673,668
Rwanda	38,198	279	10,639,375
São Tomé and Príncipe	2366	215	507,569
Senegal	42,957	156	6,702,574
Seychelles	15,579	1922	29,950,243
Sierra Leone	5495	264	1,447,951
Somalia	14,933	30	447,990
South Africa	1,954,466	1256	2,454,780,059
South Sudan	10,834	52	561,673
Sudan	36,658	243	8,922,926
Tanzania	509	123	62,703
Togo	13,881	137	1,899,448
Tunisia	414,182	1036	429,152,254
Uganda	79,434	163	12,932,700
Zambia	152,056	324	49,332,595
Zimbabwe	48,533	196	9,495,444
TOTAL	5,465,790		3,981,927,049

Source: \* [Worldometer \(2021\)](#), \*\* Authors' projections using data from [WHO \(2019a\)](#), \*\*\* Authors' estimates.

Figure 5 shows that the direct costs of preventing and managing COVID-19 infections vary widely from a minimum of Int\$62,703 in Tanzania to a maximum of Int\$2,454,780,059 in South Africa.

Sixteen (30%) of the countries had a total direct cost of under Int\$1 million, 18 (33%) countries had between Int\$1 million and Int\$10 million, and the remaining 20 (37%) countries had a total direct cost of Int\$11 million and above. The main direct cost drivers are the size of per capita current health expenditure, and the number of COVID-19 cases identified through laboratory testing per country. The latter depends on the proportion of the population tested and the number of those who are reported positive. There is evidence that the population coverage of COVID-19 testing is very low in most African countries. Therefore, the direct cost estimates reported in this paper could be underestimated.



**Figure 5.** Estimated direct cost of preventing and managing COVID-19 cases in Africa (2021 Int\$ or PPP).



### 3.2.3. Total Cost of COVID-19 in Africa

As depicted in Table 8, the total cost (direct plus indirect) associated with COVID-19 cases reported in Africa as of June 30, 2021, is approximately Int\$7,155,473,174.

**Table 8.** Total costs associated with COVID-19 cases reported as of 30 June 2021 in Africa (in 2021 Int\$ or PPP).

Country	Total Cost	Total Cost per COVID-19 Case (Int\$)	Total Cost per Person in Population (Int\$)
Algeria	181,559,885	1304	4.07
Angola	25,913,564	670	0.76
Benin	945,736	115	0.08
Botswana	172,723,891	2479	72.01
Burkina Faso	1,222,117	91	0.06
Burundi	506,563	93	0.04
Cameroon	14,892,465	184	0.55
Cape Verde	18,617,243	574	33.13
Central African Republic	3,865,727	541	0.79
Chad	376,311	76	0.02
Comoros	1,648,647	421	1.86
Congo, Republic of	1,237,444	98	0.22
Cote d'Ivoire	9,280,016	192	0.34
Congo, Democratic Republic of	3,202,323	78	0.03
Equatorial Guinea	5,960,214	682	4.12
Eritrea	874,774	147	0.24
Ethiopia	35,137,463	127	0.30
Gabon	14,130,028	566	6.20
Gambia, The	698,467	115	0.28
Ghana	27,196,253	284	0.86
Guinea	3,526,248	148	0.26
Guinea-Bissau	599,072	155	0.30
Kenya	130,748,829	712	2.38
Lesotho	6,098,253	538	2.82
Liberia	414,606	106	0.08
Madagascar	10,955,165	260	0.39
Malawi	8,935,316	249	0.46
Mali	1,921,713	133	0.09
Mauritania	6,333,451	305	1.33
Mauritius	5,486,582	2993	4.31
Mozambique	14,278,863	188	0.44
Namibia	110,267,435	1273	42.63
Niger	625,625	114	0.02
Nigeria	47,897,621	286	0.23
Rwanda	16,516,224	432	1.24

Table 8. *Cont.*

Country	Total Cost	Total Cost per COVID-19 Case (Int\$)	Total Cost per Person in Population (Int\$)
Sao Tome and Principe	676,006	286	3.03
Senegal	10,100,085	235	0.59
Seychelles	39,799,413	2555	402.21
Sierra Leone	1,480,738	269	0.18
South Africa	4,633,533,002	2371	77.16
South Sudan	798,028	74	0.07
Swaziland	25,135,720	1317	21.45
Tanzania	351,267	690	0.01
Togo	1,990,794	143	0.24
Uganda	21,871,067	275	0.46
Zambia	75,190,049	494	3.98
Zimbabwe	25,703,481	530	1.70
Djibouti	2,440,173	210	2.43
Egypt	358,887,834	1277	3.44
Libya	33,879,818	175	4.87
Morocco	389,354,840	734	10.43
Somalia	616,974	41	0.04
Sudan	15,573,599	425	0.35
Tunisia	633,496,153	1530	53.05
TOTAL (Int\$)	7,155,473,174	1309	5.22

The five countries with the highest total cost of COVID-19 are South Africa, with Int\$4.634 billion; Tunisia, with Int\$633.5 million; Morocco, with Int\$389.4 million; Egypt, with Int\$358.9 million; and Algeria, with Int\$181.6 million. Those five countries account for Int\$6,196,831,716 (86.6%) of the Continental total cost of COVID-19.

The total cost of COVID-19 was less than Int\$1 million in 12 (22.2%) countries, between Int\$1 million and Int\$10 million in 17 (31.5%) countries, and over Int\$11 million in 25 (46.3%) countries. As depicted in Figure 6, the estimated total cost of COVID-19 varies significantly across countries, ranging from a minimum of Int\$351,267 in Tanzania to a maximum of Int\$4,633,533,002 in South Africa.

The average total cost (ATC) per COVID-19 case is Int\$1309, i.e., Int\$7,155,473,174, divided by the total number of COVID-19 cases aged 15–64 years, which is 5,465,790. The top five countries with the highest average total cost per COVID-19 case were Mauritius, with an average of Int\$2993; Seychelles, with an average of Int\$2555; Botswana, with an average of Int\$2479; South Africa, with an average of Int\$2371; and Tunisia, with an average of Int\$1530. As depicted in Figure 7, the average total cost varied widely from Int\$41 in Somalia to Int\$2993 in Mauritius. Seven (13%) countries had an ATC of less than Int\$100 per case; 28 (52%) countries had between Int\$100 and Int\$500 per case; 10 (18%) countries had between Int\$501 and Int\$900 per case; nine (17%) countries had an ATC of Int\$1000 and above per case.

On the other hand, the average total cost per person in the population is Int\$5.22, i.e., Int\$7,155,473,174 divided by the continental population of 1,370,493,279. As demonstrated in Figure 7, the total cost associated with COVID-19 per person in the population ranged from Int\$0.01 in Tanzania to Int\$402.21 in Seychelles.



**Figure 6.** Total costs associated with COVID-19 in Africa (in 2021 Int\$ or PPP).



**Figure 7.** Average total cost associated with COVID-19 per person in population in Africa (in 2021 Int\$ or PPP).

Seychelles had Int\$402.21, South Africa had Int\$77.16, Botswana had Int\$72.01, Tunisia had Int\$53.05, and Namibia had Int\$42.63 per person. The cost per person was less than Int\$1 in 31 countries, between Int\$1 and Int\$9 in 15 countries, and Int\$10 and above in eight countries.

### 3.3. Savings in Potential Direct and Indirect Costs of COVID-19 in Africa Expected from COVID-19 Vaccination

Section 3.3.1 reports the potential savings in direct costs of COVID-19 in Africa that can be expected from vaccination. Section 3.3.2 reports the potential savings in indirect costs associated with COVID-19 in Africa that are expected from vaccination. Section 3.3.3 reports on total savings in the projected direct plus indirect costs of COVID-19 in Africa expected from vaccination. The estimates in the three subsections use the projected number of COVID-19 cases, rather than the actual reported cases. A 100% vaccine coverage is assumed. Therefore, these are estimates of the most optimistic scenario.

#### 3.3.1. Savings in Potential Direct Costs of COVID-19 in Africa Expected from COVID-19 Vaccination

The potential direct cost savings equals the difference between the direct cost without vaccine (among controls) and the direct cost with vaccine (among treatments). The direct cost of the control group equals the product of the country's population and the infection risk in the control group, multiplied by the current health expenditure per capita. The vaccine group's direct cost equals the product of the country's population and the infection risk in the AZ vaccine group, multiplied by the current health expenditure per capita.

Table 9 compares the total direct cost without and with the COVID-19 Oxford–AstraZeneca vaccine per African country.

**Table 9.** Total direct costs without and with the COVID-19 Oxford–AstraZeneca vaccine in Africa (in 2021 Int\$ or PPP).

Country	Control Group Direct Cost (Int\$)	Vaccine Group Direct Cost (Int\$)
Algeria	1,213,130,315	410,134,248
Angola	112,596,891	38,066,678
Benin	30,696,569	10,377,875
Botswana	74,992,194	25,353,308
Burkina Faso	45,009,650	15,216,831
Burundi	31,634,010	10,694,804
Cameroon	121,441,348	41,056,806
Cape Verde	7,814,988	2,642,086
Central African Republic	76,662,647	25,918,054
Chad	30,248,209	10,226,293
Comoros	3,692,648	1,248,408
Congo, Republic of	8,350,869	2,823,256
Cote d'Ivoire	141,597,107	47,871,051
Congo, Democratic Republic of	47,058,206	15,909,405
Equatorial Guinea	24,471,172	8,273,197
Eritrea	14,415,171	4,873,471
Ethiopia	238,595,019	80,664,037

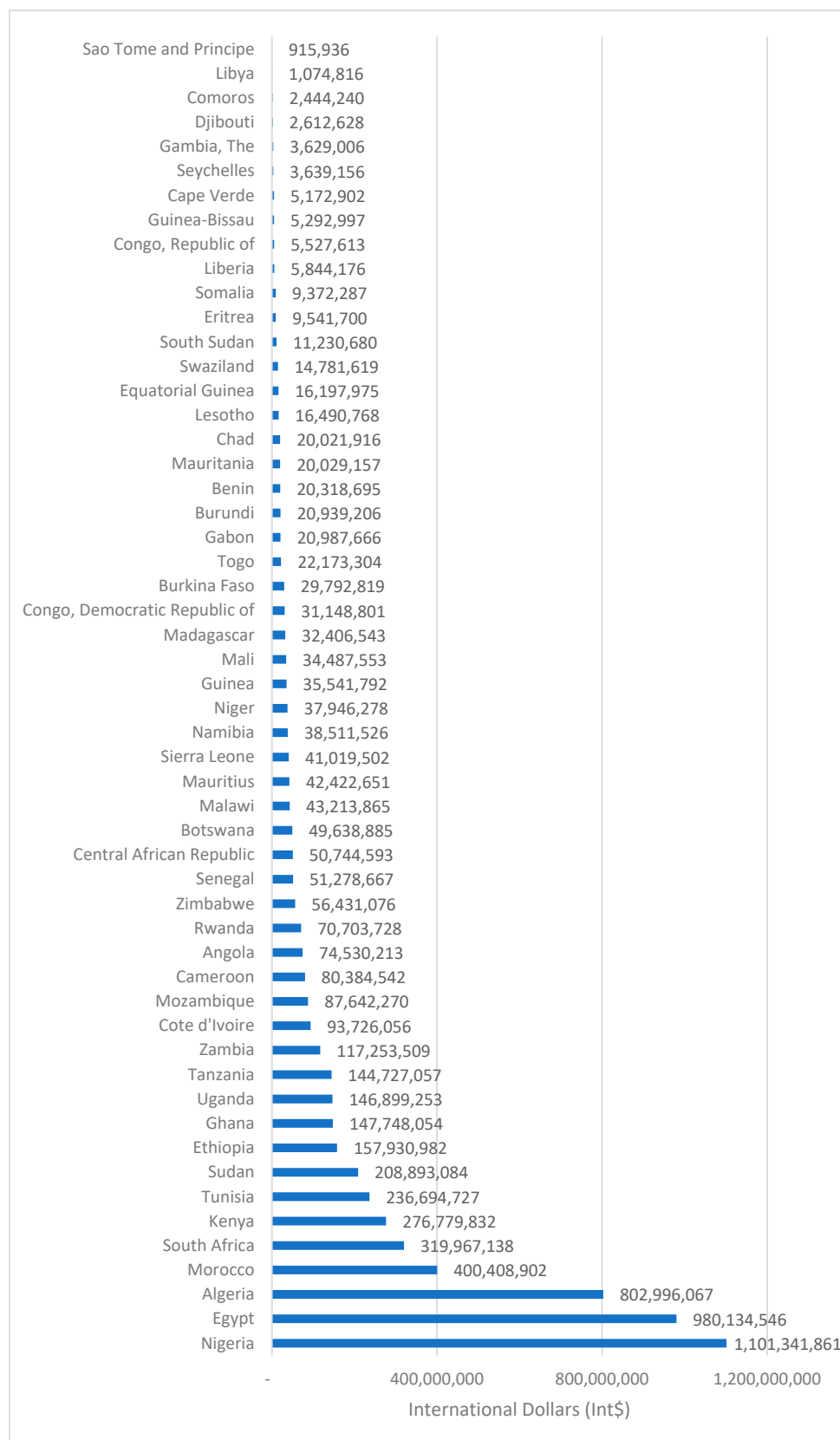
Table 9. *Cont.*

Country	Control Group Direct Cost (Int\$)	Vaccine Group Direct Cost (Int\$)
Gabon	31,707,221	10,719,555
Gambia, The	5,482,538	1,853,533
Ghana	223,211,109	75,463,056
Guinea	53,694,939	18,153,147
Guinea-Bissau	7,996,421	2,703,424
Kenya	418,146,512	141,366,680
Lesotho	24,913,510	8,422,742
Liberia	8,829,117	2,984,942
Madagascar	48,958,347	16,551,804
Malawi	65,285,562	22,071,697
Mali	52,102,243	17,614,690
Mauritania	30,259,150	10,229,992
Mauritius	64,090,232	21,667,581
Mozambique	132,405,996	44,763,727
Namibia	58,181,480	19,669,954
Niger	57,327,529	19,381,251
Nigeria	1,663,857,712	562,515,851
Rwanda	106,816,010	36,112,282
Sao Tome and Principe	1,383,754	467,819
Senegal	77,469,502	26,190,835
Seychelles	5,497,873	1,858,717
Sierra Leone	61,970,418	20,950,916
South Africa	483,391,950	163,424,812
South Sudan	16,966,806	5,736,126
Swaziland	22,331,405	7,549,786
Tanzania	218,647,124	73,920,067
Togo	33,498,430	11,325,126
Uganda	221,928,779	75,029,526
Zambia	177,141,323	59,887,815
Zimbabwe	85,253,530	28,822,454
Djibouti	3,947,041	1,334,413
Egypt	1,480,743,156	500,608,610
Libya	1,623,783	548,967
Morocco	604,919,747	204,510,845
Somalia	14,159,230	4,786,942
Sudan	315,586,269	106,693,185
Tunisia	357,587,739	120,893,013

If the unit cost per COVID-19 case managed equals the respective country's per capita current health expenditure, the continental total direct cost without vaccination is Int\$9,459,720,500. Contrastingly, the total continental direct cost of the Oxford–AstraZeneca vaccination is estimated at Int\$3,198,135,685.



Figure 8 shows that COVID-19 vaccination could potentially save Africa at least Int\$6,261,584,816 in direct health systems costs.



**Figure 8.** Total direct cost savings with COVID-19 Oxford–AstraZeneca vaccination in Africa (in 2021 Int\$ or PPP).

The direct cost savings due to the Oxford–AstraZeneca vaccine range from a minimum of Int\$915,936 in São Tomé and Príncipe to a maximum of Int\$1,101,341,861. About 12 (22.2%) countries are expected to make direct cost savings of less than Int\$10 million; 21 (38.9%) countries between Int\$10 million and Int\$50 million; 8 (14.8%) countries between Int\$51 million and Int\$100 million; and 13 (24.1%) countries with savings of Int\$101 million and above.

### 3.3.2. Savings in Potential Indirect Costs of COVID-19 in Africa Expected from COVID-19 Vaccination

Applying the risk of death reported by Bernal et al. (2021), it is estimated that 1,656,615 unvaccinated persons aged 15–64 years would die from COVID-19 compared to 289,880 deaths among those vaccinated. We estimate that the total indirect cost in Africa is Int\$42,863,554,186 among unvaccinated persons aged 15–64 years and Int\$7,500,403,177 among those vaccinated. Thus, the total indirect cost saving from vaccination is approximately Int\$35,363,151,009 in Africa.

Figure 9 shows that the total indirect cost savings from the COVID-19 Oxford–AstraZeneca vaccination in Africa range from Int\$1,587,020 in the Central African Republic to Int\$6,800,921,734 in South Africa.

Four (7%) countries had indirect cost savings of less than Int\$10 million; 12 (22%) countries had between Int\$10 million and Int\$50 million; 10 (19%) countries had between Int\$50 million and Int\$100 million; and 28 (52%) countries had savings of Int\$101 million or more.

### 3.3.3. Savings in Potential Total Costs of COVID-19 in Africa Expected from COVID-19 Vaccination

It is estimated that the vaccination of 100% of the eligible population in Africa with the Oxford–AstraZeneca vaccine would potentially prevent 26.22 million COVID-19 infections and avert 4,293,234 deaths. Almost 32.4% of the latter would be among those aged 15–64.

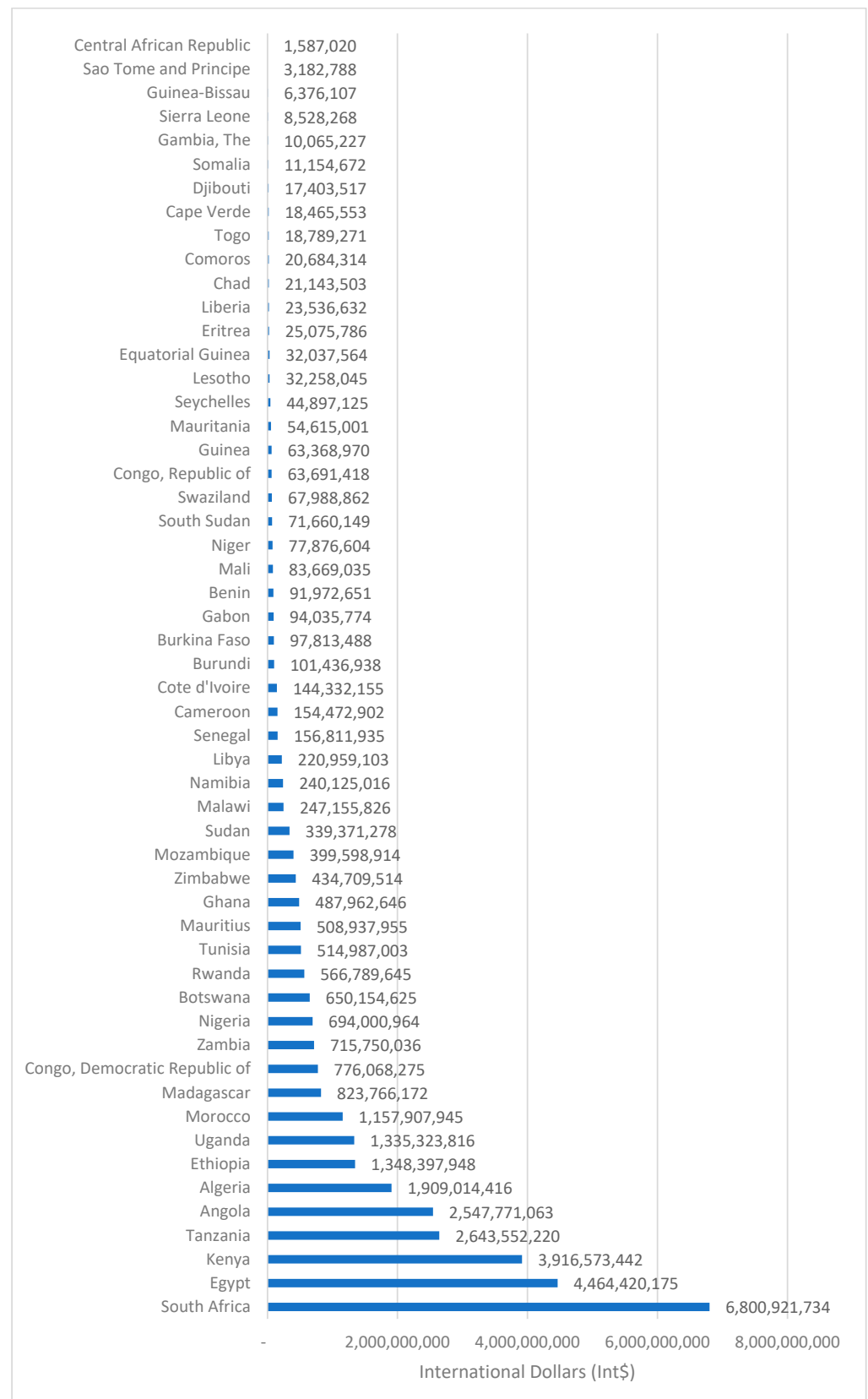
As depicted in Table 10, vaccinating all eligible people would save the continent approximately Int\$41,624,735,824. Out of these, Int\$6.262 billion (15.0%) represents a direct cost savings, and Int\$35.363 billion (85.0%) represents an indirect cost savings.

**Table 10.** Savings in potential total costs of COVID-19 expected from COVID-19 vaccination in Africa (in 2021 Int\$ or PPP).

Country	Direct Cost Savings (Int\$)	Indirect Cost Savings (Int\$)	Total Cost Savings (Int\$)
Algeria	802,996,067	1,909,014,416	2,712,010,483
Angola	74,530,213	2,547,771,063	2,622,301,276
Benin	20,318,695	91,972,651	112,291,346
Botswana	49,638,885	650,154,625	699,793,511
Burkina Faso	29,792,819	97,813,488	127,606,307
Burundi	20,939,206	101,436,938	122,376,144
Cameroon	80,384,542	154,472,902	234,857,444
Cape Verde	5,172,902	18,465,553	23,638,455
Central African Republic	50,744,593	1,587,020	52,331,613
Chad	20,021,916	21,143,503	41,165,418
Comoros	2,444,240	20,684,314	23,128,555
Congo, Republic of	5,527,613	63,691,418	69,219,031
Cote d'Ivoire	93,726,056	144,332,155	238,058,211
Democratic Republic of Congo	31,148,801	776,068,275	807,217,076
Equatorial Guinea	16,197,975	32,037,564	48,235,539

Table 10. Cont.

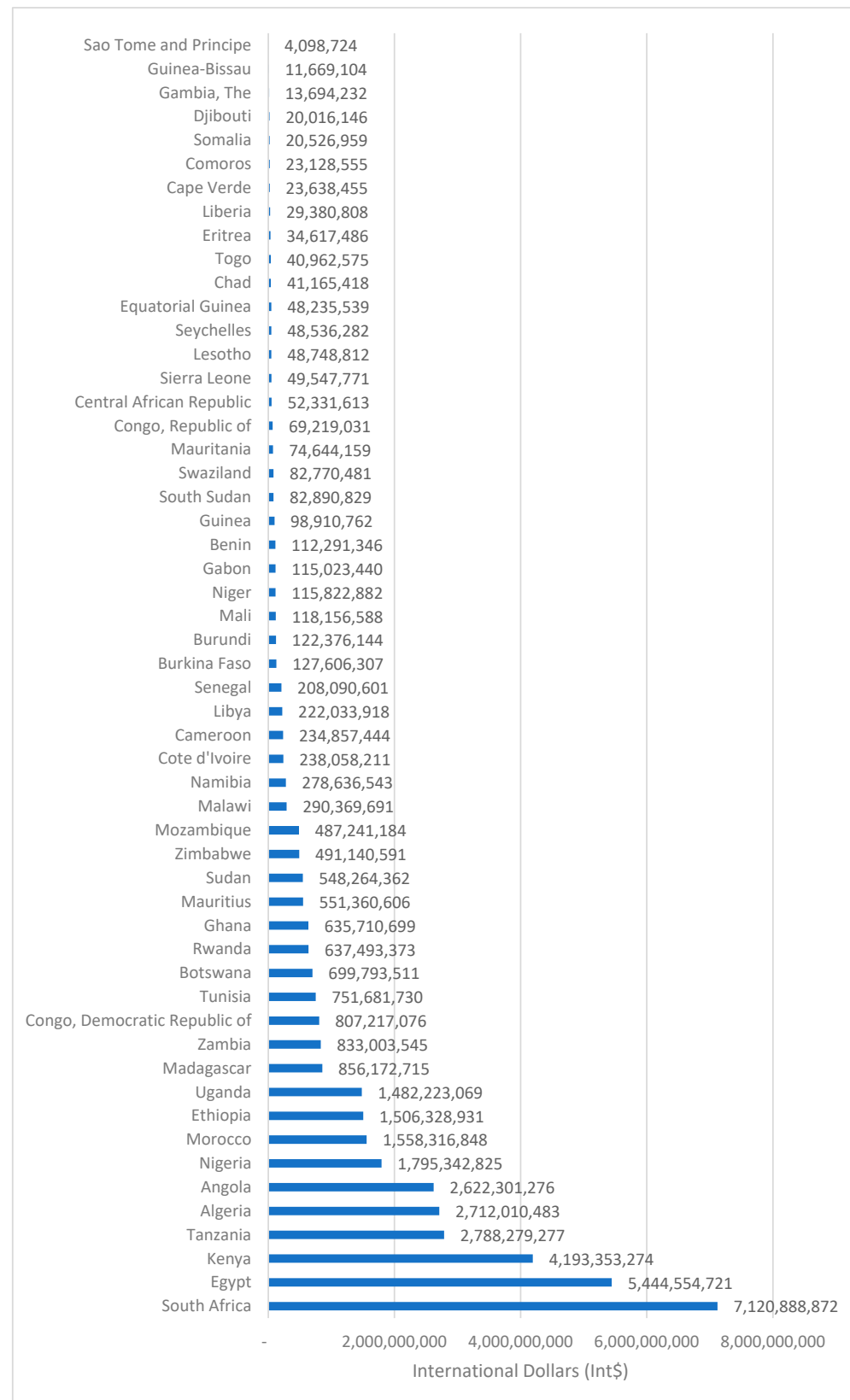
Country	Direct Cost Savings (Int\$)	Indirect Cost Savings (Int\$)	Total Cost Savings (Int\$)
Eritrea	9,541,700	25,075,786	34,617,486
Ethiopia	157,930,982	1,348,397,948	1,506,328,931
Gabon	20,987,666	94,035,774	115,023,440
Gambia	3,629,006	10,065,227	13,694,232
Ghana	147,748,054	487,962,646	635,710,699
Guinea	35,541,792	63,368,970	98,910,762
Guinea-Bissau	5,292,997	6,376,107	11,669,104
Kenya	276,779,832	3,916,573,442	4,193,353,274
Lesotho	16,490,768	32,258,045	48,748,812
Liberia	5,844,176	23,536,632	29,380,808
Madagascar	32,406,543	823,766,172	856,172,715
Malawi	43,213,865	247,155,826	290,369,691
Mali	34,487,553	83,669,035	118,156,588
Mauritania	20,029,157	54,615,001	74,644,159
Mauritius	42,422,651	508,937,955	551,360,606
Mozambique	87,642,270	399,598,914	487,241,184
Namibia	38,511,526	240,125,016	278,636,543
Niger	37,946,278	77,876,604	115,822,882
Nigeria	1,101,341,861	694,000,964	1,795,342,825
Rwanda	70,703,728	566,789,645	637,493,373
São Tomé and Príncipe	915,936	3,182,788	4,098,724
Senegal	51,278,667	156,811,935	208,090,601
Seychelles	3,639,156	44,897,125	48,536,282
Sierra Leone	41,019,502	8,528,268	49,547,771
South Africa	319,967,138	6,800,921,734	7,120,888,872
South Sudan	11,230,680	71,660,149	82,890,829
Swaziland	14,781,619	67,988,862	82,770,481
Tanzania	144,727,057	2,643,552,220	2,788,279,277
Togo	22,173,304	18,789,271	40,962,575
Uganda	146,899,253	1,335,323,816	1,482,223,069
Zambia	117,253,509	715,750,036	833,003,545
Zimbabwe	56,431,076	434,709,514	491,140,591
Djibouti	2,612,628	17,403,517	20,016,146
Egypt	980,134,546	4,464,420,175	5,444,554,721
Libya	1,074,816	220,959,103	222,033,918
Morocco	400,408,902	1,157,907,945	1,558,316,848
Somalia	9,372,287	11,154,672	20,526,959
Sudan	208,893,084	339,371,278	548,264,362
Tunisia	236,694,727	514,987,003	751,681,730
TOTAL	6,261,584,816	35,363,151,009	41,624,735,824



**Figure 9.** Total indirect cost savings from COVID-19 Oxford–AstraZeneca vaccination in Africa (in 2021 Int\$ or PPP).

Figure 10 demonstrates that the total cost savings expected from the COVID-19 AstraZeneca vaccination vary from Int\$4,098,724 in São Tomé and Príncipe to Int\$7,120,888,872

in South Africa. Twenty-one (39%) countries had a total cost saving of below Int\$100 million; 14 (26%) countries had between Int\$100 million and Int\$499 million; 9 (17%) countries had between Int\$500 and Int\$999 million; and 10 (18%) countries had Int\$1 billion and above.



**Figure 10.** Total cost saving expected from COVID-19 Oxford–AstraZeneca vaccine in Africa (in 2021 Int\$ or PPP).

The longer the COVID-19 pandemic persists, the more people develop coping mechanisms that reduce disruptions to activities of daily living (including work), productivity losses, and hence expected savings. Additionally, as the COVID-19 mutation level continues to evolve and milder variants emerge, stability is likely to be achieved, where infection does not result in complete immobility and incapacity in those infected. All these considerations may influence the magnitudes of projected savings from vaccination.

### 3.4. Sensitivity Analysis

First, a re-run of the human capital model with a discount rate of 5% instead of 3%, holding all other variables (deaths, GDPPC, CEHPC, average life expectancy at birth) constant reduced the continental: (i) Total monetary value of reported lives lost to COVID-19 by Int\$947,265,868 (14.17%), and the average monetary value per death from Int\$47,015 to Int\$40,352. (ii) Total productivity loss (total indirect cost) among 15–64-year-olds from Int\$3,173,546,125 to Int\$2,687,145,189, which is a Int\$486,400,935 (15.3%) decrease. (iii) Reported cases total cost (total direct cost plus total indirect cost) from Int\$7,155,473,174 to Int\$6,669,072,238, which is a reduction of Int\$486,400,935 (6.8%). (iv) Projected total savings from COVID-19 vaccination decreases by Int\$ 5,340,467,285 (12.83%).

Second, a re-estimation of the economic model with a discount rate of 10% instead of 3%, holding all other variables (deaths, GDPPC, CEHPC, average life expectancy at birth) constant, reduced the following in Africa: (i) Total monetary value of reported lives lost to COVID-19 by Int\$2,455,027,232 (36.73%), and the average monetary value per death from Int\$47,015 to Int\$29,746. (ii). Total productivity loss (total indirect cost) from Int\$3,173,546,125 to Int\$1,919,633,288, which is an Int\$1,253,912,837 (39.5%) decrease. (iii) Reported case's total cost (total direct cost plus total indirect cost) from Int\$7,155,473,174 to Int\$5,901,560,337, which is a reduction of Int\$1,253,912,837 (17.5%). (iv) Projected total savings from COVID-19 vaccination decreases by Int\$13,814,723,812 (33.2%).

Third, a re-calculation of the model with the world's highest average life expectancy (ALE) of 88 years (in Hong Kong) instead of individual country's national ALE, holding all other variable constant (deaths, GDPPC, CEHPC, discount rate at 3%), grew the following in Africa: (i) Total monetary value of reported lives lost to COVID-19 by Int\$13,982,454,402 (209.2%); (ii) total productivity loss (total indirect cost) by Int\$3,238,491,270 (102%), i.e., from Int\$3,173,546,125 (with national ALE) to Int\$6,412,037,395 (with world highest ALE); (iii) total cost of reported cases increased from Int\$7,155,473,174 (with national ALE) to Int\$10,393,964,444 (with the world's highest ALE), representing a growth of Int\$3,238,491,270 (45.3%). (iv) Total cost savings due to vaccination from Int\$41,624,735,824 to Int\$85,097,353,802, i.e., a 104.4% growth.

Fourth, a re-estimation of the model with Africa's highest average life expectancy (ALE) of 77.5 years (in Algeria) instead of the individual country's national ALE, holding all other variables constant (deaths, GDPPC, CEHPC, discount rate at 3%), augmented the following in Africa: (i) total monetary value of reported lives lost to COVID-19 by Int\$6,074,005,112 (90.9%), i.e., from Int\$6,684,101,196 (at national ALE) to Int\$12,758,106,309 at Africa's highest ALE. (ii) The total indirect cost grew from Int\$3,173,546,125 (with national ALE) to Int\$5,149,685,439 (with Africa's highest ALE), representing an increase of Int\$1,976,139,314 (62.3%). (iii) The total cost of reported cases increased from Int\$7,155,473,174 (with national ALE) to Int\$9,131,612,487 (with Africa's highest ALE), which is a growth of Int\$1,976,139,314 (27.6%). (iv) Projected total cost savings from COVID-19 vaccination increased from Int\$41,624,735,824 to Int\$69,119,995,455, which is an Int\$27,495,259,631 (66.1%) increase.

## 4. Discussion

### 4.1. Key Findings

#### 4.1.1. Value of Human Life Losses, Indirect Costs, and Direct Costs Associated with Actual Reported COVID-19 Cases

This study estimates the following:

- (a) The total discounted monetary value of human life losses associated with 142,171 COVID-19 deaths reported in Africa as of 30 June 2021 at Int\$6,684,101,196.
- (b) The discounted monetary value per human life lost was Int\$47,015, and the monetary value of human life lost per person in the population was Int\$4.88.
- (c) Approximately 54,210 of 15–64-year-old persons reported dead from COVID-19 in Africa had a total indirect cost of Int\$3,173,546,125 (i.e., after adjustment for labor participation rate), and an average of Int\$58,542 per life lost (productivity losses).
- (d) As of 30 June 2021, the 5,514,709 COVID-19 cases reported in Africa had an estimated total direct cost (TDC) of Int\$3,981,927,049. Dividing the estimated TDC by the total number of COVID-19 cases reported in Africa yields an average direct cost of Int\$722.06 (US\$289.53) per case managed.
- (e) The total cost (direct plus indirect) associated with the actual 5,514,709 COVID-19 cases reported in Africa as of 30 June 2021, was approximately Int\$7,155,473,174. The average total cost per COVID-19 case was Int\$1309 and Int\$5.22 per person in the population.

#### 4.1.2. Savings in Potential/Projected Total Costs of COVID-19 in Africa Expected from COVID-19 Vaccination Findings

- (a) How many people in the population would be infected with COVID-19 without and with vaccination? Utilizing the risk rates of infection from [Voysey et al. \(2021\)](#), it is projected that approximately 39,608,709 people would be infected by COVID-19 without vaccination (Control Group) compared to 13,390,885 people with vaccination (Treatment Group). Thus, 100% vaccination coverage of eligible persons would potentially avert an estimated 26,217,824 COVID-19 infections in Africa.
- (b) How many people in the population would die from COVID-19 without and with vaccination? Applying the risk of death reported by [Bernal et al. \(2021\)](#), it is estimated that 5,203,814 people would die without vaccination, vis-à-vis 910,580 deaths with vaccination.
- (c) How many deaths would be averted by COVID-19 vaccination? An estimated 4,293,234 deaths from COVID-19 would be prevented by vaccination, i.e., 5,203,814 minus 910,580.
- (d) How many averted COVID-19 deaths would be within the productive age bracket of 15–64 years? Applying the risk of death reported by [Bernal et al. \(2021\)](#), it is estimated that 1,656,615 people in the 15–64 years age bracket would die without vaccination compared to 289,880 with vaccination. Thus, 1,366,735 deaths in the 15–64-year age bracket would be saved with COVID-19 vaccination, i.e., 1,656,615 minus 289,880.
- (e) We estimate that vaccinating all eligible people in the population would save the African continent approximately Int\$41,624,735,824 (i.e., equivalent to 0.61% of Africa's total GDP in 2021). That total saving consists of Int\$6.262 billion (15.0%) in direct cost savings and Int\$35.363 billion (85.0%) in indirect cost savings.
- (f) The benefit–cost ratio of COVID-19 vaccination is 5.8, implying that Africa reaps \$6 in return for every \$1 spent on COVID-19 vaccination.
- (g) The average total saving per person in the population is approximately Int\$30.4.

### 4.2. Comparison with Other Studies

#### 4.2.1. A Comparison of Our Estimates with Results from Similar Studies

The average discounted monetary value per human life in Africa, at Int\$47,015, was lower than in China, at Int\$356,203, by a factor of 8, and in Spain, at Int\$470,798, by a factor of 10



(Kirigia & Muthuri, 2020a, 2020b). The differences could be attributed to Africa's significantly lower GDP per capita compared to that of China and Spain. Differences in demographic structures are also known to have had a significant role, according to Thorbecke (2022).

#### 4.2.2. Comparison of Estimates from Direct and Indirect Cost Studies

In Africa, there is a paucity of research into direct and indirect costs associated with COVID-19. Barasa et al. (2021) estimated the direct unit cost for COVID-19 case management for patients at different stages (asymptomatic, mild/moderate, severe, and critical) in Kenya. These authors' findings were as follows. First, managing asymptomatic COVID-19 at home costs US\$226.71 per patient, whereas managing it at a hospital (and isolation) center costs US\$764.16 per patient (Barasa et al., 2021). Second, managing mild to moderate COVID-19 at home-based care costs US\$226.96, while hospital or isolation center care costs US\$764.41 per patient (Barasa et al., 2021). Third, managing severe COVID-19 in the general hospital ward costs US\$1494.38 per patient (Barasa et al., 2021). Fourth, managing critical COVID-19 cases in the hospital intensive care unit costs US\$7194.07 per patient (Barasa et al., 2021).

Ismaila et al. (2021) estimated the cost of clinical management of COVID-19 infection by disease severity level and treatment setting in Ghana. The authors estimated the total direct cost of home management COVID-19 case at US\$282; institutional care for a mild case at US\$5707; institutional care for a moderate case at US\$9952; institutional care for a severe case at US\$20,305; and institutional care for a critical case at US\$23,382 (Ismaila et al., 2021). The average total cost per COVID-19 case was US\$11,925 (Ismaila et al., 2021). The estimates of unit costs in Ghana by Ismaila et al. (2021) are higher than those of Barasa et al. (2021) in Kenya because of the former calculated costs according to the Ministry of Health's COVID-19 clinical management protocol.

Our study estimated that the average direct cost per case managed is Int\$722.06 (US\$289.53), which is roughly comparable to Barasa et al.'s (2021) unit cost of US\$226 per asymptomatic and mildly to moderately ill COVID-19 patient managed using home-based care. However, our estimated direct cost per COVID-19 case-managed of US\$289.53 is 3-fold, 3-fold, 5-fold, and 25-fold lower than Barasa et al.'s (2021) unit cost per asymptomatic, mild-to-moderate, severe, and critical COVID-19 disease case managed at hospital/isolation center, hospital general inpatient ward, and hospital intensive care unit, respectively.

Similarly, whereas our estimated direct cost per COVID-19 case of US\$289.53 is comparable to Ismaila et al.'s (2021) total direct cost of home management per COVID-19 case of US\$282, it is 41-fold lower than their average total direct cost per COVID-19 case of US\$11,925. Comparison with the average total direct costs from Ghana and Kenya implies that our finding may be a gross underestimate and, thus, should be viewed as a lower limit.

#### Limitations of the Study

First, like other HCA studies, we used GDP per capita to monetarily value human life losses associated with the COVID-19 pandemic in Africa. GDP per capita suffers several limitations: (a) does not capture home non-marketed production; (b) does not reflect extant inequalities in wellbeing, income, and wealth; (c) omits negative externalities of economic production activities, e.g., environmental pollution, global warming, soil erosion, deforestation, inter-community fights over dwindling water resources (especially in arid and semi-arid areas), depletion of natural resources (and hence accompanying long-term wellbeing sustainability consequences); (d) not an accurate measure of societal happiness and quality of life (Stiglitz et al., 2010). Thus, our calculation yields the lower bound of the monetary value of a life lost to COVID-19.

Second, the standard HCA has some perceived shortcomings. One, Landefeld and Seskin (1982) posit that HCA "... is implicitly based upon the maximization of society's

present and future production” (p. 556). Thus, the approach assumes that the only reason society invests, for example, in preventing premature deaths from COVID-19 is to maximize economic production (or GDP). However, as [Mooney \(1977\)](#) argues, there are other reasons, e.g., human life (or health) has intrinsic value (valued for its own sake), society values the life (or health) of its members (productive or not), being alive enables individuals to enjoy leisure. Two, standard HCA attaches zero value for people without income, e.g., retired, children below legal working age, severely handicapped, and homemakers. Three, according to [Landefeld and Seskin \(1982\)](#) application of HCA entails “... choice of an appropriate social discount rate to convert future earnings into present values”, which is contentious ([Claxton et al., 2011](#); [Odum et al., 2020](#)).

Third, the COVID-19 pandemic may have had broad adverse economic effects on labor markets, corporate investment, and other aspects of the macroeconomy ([Campello et al., 2024](#); [Eichenbaum et al., 2021](#)). The economic policies (e.g., cash infusions) implemented by national governments may have contributed partly to mitigating economic losses ([Cortes et al., 2022](#)) and stemming the burden of non-fatal disability and fatalities associated with the pandemic. It was beyond the scope of the current study to estimate and incorporate additional costs related to economic policy interventions. The magnitude of additional costs would depend on the labor market effects and labor allocation effects.

Concerning labor market effects, the premature deaths from COVID-19 naturally reduce the labor supply. In an environment of reduced labor demand due to pandemic uncertainty ([Campello et al., 2024](#)), this results in lower output, revenues, and corporate investment. However, when fiscal and monetary policies support aggregate demand, it may lead to elevated inflation, as evidenced by the recent 2021 wave ([Govindarajan et al., 2022](#)). Elevated inflation is a direct economic cost, insofar as it reduces individuals’ real income. In this case, the cost is directly attributed to life losses, resulting in a mismatch between aggregate labor supply and aggregate demand.

Regarding labor allocation effects, the pandemic did not affect every African country equally; thus, its impact on labor supply is inherently heterogeneous. In theory, the potential adverse effects of COVID-19 on labor supply could be mitigated by increased labor mobility, which would suggest migratory patterns from countries (or local geographical regions) with relatively low labor shortages to those with relatively high labor shortages. However, the COVID-19-related restrictions, compounded by a growing wave of anti-immigration sentiment, may have prevented the ideal labor relocation ([Funke et al., 2023](#)).

Fourth, our study utilized the number of COVID-19 cases and deaths reported by individual African countries in estimating the discounted monetary value of human life losses associated with COVID-19 (Section 3.1) and the economic cost of COVID-19 in Africa (Section 3.2). These statistics are likely to be grossly underestimated due to the inadequacy of national health information systems ([WHO/AFRO, 2012](#)); 6% completeness of cause-of-death primary data in the WHO African Region (compared to 97% in the European Region and 94% in the Region of the Americas) ([WHO, 2019b](#)); and a 52% gap in International Health Regulations core capacities ([WHO, 2020, 2021c](#)).

[Msemburi et al. \(2023\)](#) estimated that between January 2020 and December 2021, the total COVID-19 death toll in the African Region was eight-fold higher than the officially reported number of COVID-19-related deaths. Thus, by relying on the cumulative number of COVID-19-related deaths reported by national governments, we may have underestimated the total monetary value of human life losses (in Section 3.1) and the associated indirect costs (in Section 3.1) by almost eight-fold. We chose to use the official national COVID-19-related deaths reported by individual WHO Member States, rather than the WHO excess mortality estimates published by Msemburi et al., to increase the likelihood of uptake of the study’s results in public health advocacy by Ministries of Health on the continent.

However, as explained in Section 3.3, to mitigate the underestimation of expected benefits from COVID-19 vaccination, the estimates of savings in potential direct and indirect costs of COVID-19 in Africa from COVID-19 vaccination that are reported in sub-Section 3.3 use the projected number of COVID-19 cases and not the actual reported cases (see Supplementary Tables S8 and S9).

Fifth, due to the availability of pertinent epidemiological evidence on the Oxford–AstraZeneca COVID-19 vaccine from randomized trials in Brazil, South Africa, and the UK, the estimations of “Savings in Potential Direct and Indirect Costs of COVID-19 in Africa Expected from COVID-19 Vaccination” reported in Section 3.3 assumed only Oxford–AstraZeneca and Pfizer vaccinations in Africa. Similar published epidemiological information for Moderna vaccine was not available at the time of our study. We acknowledge that, at the time, there was a significant international effort also to make the Moderna vaccine available to certain countries in Africa. Since different vaccines have varying success rates (efficacy) and expense levels, we are uncertain how much our cost savings estimates would have changed if pertinent epidemiological evidence were available at the time of our study and the international push to supply significant quantities of Moderna vaccine to Africa had been more successful.

Sixth, our estimates of indirect and direct costs of COVID-19 were derived using a cost-of-illness (COI) approach. We concur with Shiell et al. (1987) that COI estimates, such as those reported in this paper, are purely for raising public awareness of the economic burden of a public health problem and should not be used as a guide for decision-making regarding the prevention, diagnosis, and treatment of, for example, COVID-19. Setting COVID-19 control priorities requires evidence of the costs and consequences of alternative preventive, diagnostic, treatment, and rehabilitative interventions (Drummond et al., 2015).

Seventh, this study utilized current health expenditure (CHE) for each of the 54 African countries as a proxy for the direct health system costs associated with each COVID-19 case. The average cost of institutional management of a COVID-19 case in Ghana, at US\$11,925, was 153 times the country’s per capita CHE of Int\$78. Kenya’s total institutional cost per COVID-19 patient was US\$3151, 36-fold the country’s per capita CHE. Therefore, there is a high likelihood that by using CHE per capita, we underestimated the value of health systems (and other intersectoral) resources used to prevent, diagnose, treat (manage), and rehabilitate COVID-19 cases.

### Suggestions for Further Economic Research

In our view, there is a need for further economic studies in Africa for the following:

- (1) Undertake a sub-national analysis of the monetary value of human life losses, direct health system costs, indirect costs, and potential savings from COVID-19 vaccination using an adapted version of the analytical framework developed in the current study.
- (2) Conduct simulations assuming different COVID-19 infection and death rates in countries as the pandemic evolves.
- (3) Collect primary data to allow valuation of human life loss risk reductions associated with COVID-19 using the willingness-to-pay approach (Robinson et al., 2019).
- (4) Use cost-effectiveness analysis, cost-utility analysis, and cost-benefit analysis of mass vaccination against COVID-19 to guide decision-making concerning the choice between the three vaccines, i.e., Pfizer-BioNTech, Moderna, and Oxford–AstraZeneca. An example of such a study is the economic evaluation for mass vaccination against COVID-19 in Taiwan by Wang et al. (2021).
- (5) Compute the cost of public health interventions required to (i) prevent the spread of COVID-19, (ii) cover the cost of COVID-19 testing, and (iii) the cost of clinical management of COVID-19 by severity per country. Ismaila et al. (2021) and Barasa

et al. (2021) are examples of studies that attempted to estimate unit costs of COVID-19 infection management by level of severity in Ghana and Kenya, respectively.

- (6) Calculate and compare the economic welfare loss due to the COVID-19 pandemic relative to a counterfactual scenario. Possible scenarios could include an economy without a pandemic (baseline); an economy with a pandemic but no government response, i.e., a passive government that adopts a laissez-faire approach; an economy with a pandemic but with a government implementing economic policies to mitigate the effects of a pandemic (Benmelech & Tzur-Ilan, 2020; Cortes et al., 2022).

## 5. Conclusions

Despite the limitations, the estimates reported in this paper demonstrate that COVID-19-associated mortality imposed a sizable economic burden on countries in continental Africa. The pandemic did not affect every country equally; thus, the estimated monetary value of human lives lost, the direct and indirect costs, and the savings in potential direct and indirect costs of COVID-19 in Africa, expected from COVID-19 vaccination, are inherently heterogeneous.

This study projected that 100% coverage with the COVID-19 vaccine could potentially save the continent a total of Int\$41.6 billion (i.e., equivalent to 0.61% of Africa's total GDP in 2021). The benefit–cost ratio of COVID-19 vaccination is 5.8, implying that Africa reaps \$6 in return for every \$1 spent on COVID-19 vaccination.

A significant number of COVID-19-related deaths and the associated economic losses could have been averted if (a) the countries had fully implemented the IHR core capacities to enhance effectiveness and efficiency of national pandemic prevention, preparedness and response; (b) there was efficient cross-border collaboration in implementing coordinated/synchronized public policy measures for pandemic prevention, preparedness, and response; (c) there was more effective coordinated global solidarity and collaboration to bolster global health architecture aimed at assuring equitable and timely production, distribution, and access to effective vaccines and other related public health commodities (therapeutics and diagnostics) to combat pandemics that have “public bad” attributes of non-excludability (impossible or challenging to prevent individuals from getting infected) and non-rivalrous (infection of one person does not deplete chances of other persons getting infected).

Once again, we caution readers that the economic burden of COVID-19 evidence presented in this paper is intended for advocacy purposes, aiming to raise public awareness and increase investments in health-related systems for effective preparedness and response to public health emergencies. It is not a guide for decision-making regarding the prevention, diagnosis, and treatment of COVID-19. Setting COVID-19 control priorities requires evidence of the costs and consequences of alternative preventive, diagnostic, therapeutic, and rehabilitative public health policy interventions.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/economics13080241/s1>, Supplementary Table S1. List of names and population of 54 sovereign countries in Africa. Supplementary Table S2. Africa's COVID-19 recovered cases, active cases, and deaths reported by 30 June 2021. Supplementary Table S3. African countries' gross domestic product (GDP) per capita in purchasing power parity (PPP) or international dollars (Int\$), 2021. Supplementary Table S4. Forecast of current health expenditure (CHE) per capita for each African country (2021 PPP). Supplementary Table S5. Average life expectancy at birth per country in Africa. Supplementary Table S6. African countries' number of COVID-19 deaths per age group as of 30 June 2021. Supplementary Table S7. African countries' labor force participation rate for ages 15–64 in 2019. Supplementary Table S8. Number of people projected to contract COVID-19 without and with vaccination in Africa. Supplementary Table S9. Projected deaths from COVID-19 without and with Oxford–AstraZeneca vaccination in Africa.

**Author Contributions:** J.M.K. and G.M. designed the study, extracted the data on per capita GDP from the IMF database, current health expenditure per person from the WHO Global Health Expenditure database, number of COVID-19 deaths in the 54 African Sovereign States from the Worldometer database, ages of onset of death from the Worldometer database, developed the human capital approach model on Excel software, and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** The authors declare that they have no conflicts of interest.

## Abbreviations

AAD <sub>i</sub>	Average age at onset of death in the <i>i</i> th age group
AERC	African Economic Research Consortium
ALE <sub>j</sub>	Average life expectancy in country <i>j</i>
ALTESTC <sub>j</sub>	Average cost per COVID-19 test
AMU	Arab Maghreb Union
ATIC <sub>j</sub>	Average indirect cost per COVID-19 death in country <i>j</i>
AU	African Union
AWTP <sub>j</sub>	Average willingness-to-pay
ECA	East African Community
CEHPC <sub>j</sub>	Current expenditure on health per capita in the <i>j</i> th country in 2021
CEMAC	Central African Economic and Monetary Community
COVID-19	Coronavirus disease 2019
COVID – 19D <sub>Prevented</sub>	Number of COVID-19-associated deaths prevented
DR <sub>PB</sub>	Risk of COVID-19 resulting in death among those vaccinated with the Pfizer-BioNTech BNT162b2
DR <sub>unvaccinated</sub>	Risk of COVID-19 resulting in death among the unvaccinated
DYLL	Discounted years of life lost
ECOWAS	Economic Community of West African States
GDP	Gross domestic product
GDPPC <sub>j</sub>	GDP per capita for the <i>j</i> th country in 2021
HCA	Human capital approach

HIV/AIDS	Human immunodeficiency virus infection and acquired immune deficiency syndrome
IMF	International Monetary Fund
INT\$	International Dollars or Purchasing Power Parity (PPP)
$IR_{AZ}$	COVID-19 infection risk with Oxford–AstraZeneca
$IR_{Control}$	COVID-19 infection risk without
IVA	Implied values approach
$MV_i$	Monetary value of a life lost for the $i$ th age group
NAC	Number of active COVID-19 cases
NAP	Average number of working-age family members and friends accompanying and visiting COVID-19 patients
$NDD_A$	Number of disability days per active COVID-19 case
$NDD_R$	Number of disability days per recovered person
NHGPPC	Non-health GDP per capita
NHRS	National health research system
NHS	National health systems
NRC	Number of persons that recovered from COVID-19 infection in country $j$
NV	Number of COVID-19 laboratory-diagnosed cases in country $j$
NVD	Average number of days visited by a family/friend per COVID-19 patient
OOPs	Direct out-of-pocket payments (OOPs)
$P_i$	Proportion of COVID-19 deaths borne by age group $i$
$PoP_j$	Number of country $j$ 's population
$PoPD_{with}$	Number of people in the $j$ th country that would be expected to die from COVID-19 even though vaccinated
$PoPD_{with}$	Number of people infected in the $j$ th country expected to die from COVID-19 without vaccination
$PoPD_{without}$	Number of people in the population infected by COVID-19 without vaccination
$PoPI_{without}$	Number of people in the population infected by COVID-19 without vaccination
$PoPI_{without}$	Discount rate
$r$	Discount rate
SADC	Southern African Development Community
SDH	Social determinants of health
$TC_{COVID-19}$	Total economic cost of COVID-19
$TCOVD_j$	Total number of human lives lost from COVID-19 in the $j$ th country
$TCOVIDCASES_j$	Total number of reported COVID-19 cases per country
$TCOVIDNEG_j$	Total number of cases that tested negative for COVID-19 per country
$TDC_{COVID-19}$	Total direct costs of COVID-19
$TIC_{COVID-19}$	Total indirect costs of COVID-19
$TMV_{Africa}$	African continent's total monetary value of human life
$TMV_{j=1,...,54}$	Country $j$ total monetary value
$TNHSC_{COVID-19}$	Transport of persons with COVID-19 symptoms to testing and treatment centers, and transport of accompanying family persons
$TOOPS_{COVID-19}$	Total out-of-pocket payments related to COVID-19 testing, isolation, treatment, health workers' consultation, medicines, and bribes
$TOSC_{COVID-19}$	Monetary value of quantities of inputs borne by other sectors involved in combating the community spread of COVID-19 infections
$TPC_{COVID-19}$	Psychic/intangible costs
UDYLL	Undiscounted years of life lost
VE	Vaccine efficacy
VFTL	Value of work time lost among all family members (and friends) of working-age accompanying and/or visiting patients.
$VPYLL_{COVID-19}$	Value of potentially productive years of life lost among 15–64-year-olds
$VPTL_{NFL}$	Value of productive time lost among non-fatal COVID-19 cases in a specific working-age bracket



WD	Wage per day
WHO	World Health Organization
WTP	Willingness to pay
YLL	Year of life lost

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