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Short Communication:
The Present Value of Human Lives Lost Due to COVID-19 in the United Kingdom

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ABSTRACT

Introduction: Approximately 43906 human lives were lost to COVID-19 by July 2, 2020, in the United Kingdom (UK). This study estimated the total present value of human lives lost due to COVID-19 in the UK as of July 2, 2020.

Background: The ongoing global COVID-19 pandemic has disrupted external trade and negatively impacted on all the socioeconomic sectors in the UK.

Objectives: The objective of this study was to estimate the total present value of human lives lost due to COVID-19 n the UK as of July 2, 2020.

Methods: The human capital approach was employed to value human lives lost into money, assuming a 3% discount rate and an average life expectancy of 81.8 years in the UK. The economic model was re-estimated using (a) 5% and 10% discount rates, and (b) the average world life expectancy of 72 years, and (c) the world's highest life expectancy of 88.1 years to test the robustness of the total present value of human lives lost.

Results: The human lives lost had a total present value of the international dollar (Int$) of 9883426226 and an average present value per human life of Int$ 225104. Approximately 76.2% of the total present value was sustained by those aged 30 and 79 years. Re-estimation of the model with discount rates of 5% and 10% instead of 3% reduced the total present value by Int$ 1158424570 (11.7%), and Int$ 3058724257 (31.0%), respectively.

Conclusion: The average present value per human life was almost five-fold the UK's GDP per person in 2020. The presented evidence could be used to advocate for increased investments into the British National Health Service and other health-related systems to optimize Universal Health Coverage, International Health Regulations capacities, and secondary education coverage to better mitigate economic and human suffering during future pandemics.

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1. Introduction

The United Kingdom (UK) has an estimated population of 67.255 million. The country has a total gross domestic product (GDP) of Int$ 3239.6 billion, and a GDP per capita of Int$ 48168.9 in 2020 [1]. The UK has an inequality-adjusted human development index (IHDI) of 0.835, and a Gini coefficient of 33.2% in 2018 [2].

As of July 2, 2020, the world had notified 10819595 cases of coronavirus disease 2019 (COVID-19), which resulted in 519265 deaths and 6040304 recovered cases [3]. The United Kingdom (UK) had notified a total of 313483 cases, including 43906 deaths [4]. Approximately 0% of human lives lost from COVID-19 were under 10 years old; 0.02% were 10-19 years old; 0.15% were 20-29 years old; 0.41% were 30-39 years old; 1.37% were 40-49 years old; 4.54% were 50-59 years old; 9.69% were 60-69 years old; 22.48% were 60-69 years old; and 61.34% were 80 years or older [5].

Why have the COVID-19 cases grown exponentially in the UK? The UK had a Universal Health Coverage (UHC) Index of about 87%, meaning a gap of approximately 13% in coverage of essential health services [6]. The population with household expenditures on the health of greater than 25% of total household expenditure or income was 0.5% [6]; signifying that 336275 had a high risk of catastrophic health-related spending. The average of 13 International Health Regulations (IHR) core capacity score was 93% in 2018 [6], denoting a gap of 7%. The proportions of the population using safely managed drinking water and sanitation services were 99% and 98% [6], respectively. The water and sanitation services coverage implies that 672550 (1%) and 1345100 (2%) of the UK's population did not have access; and thus, would have difficulty practicing safe hand hygiene to prevent the spread of COVID-19.

Many people have hailed the National Health Service (NHS) as Britain's single greatest achievement [7]. In 2013, the British Medical Association expressed concerns regarding cuts in the budget of the NHS [8]. Evidence from the monetary value of human lives lost from a disease could be useful in making a case for sustained investments into health development. As Card and Mooney [9] argued:

"The resources available to the health service are limited and so the amount the NHS can spend on saving human life is also limited. Rational allocation of resources requires a decision theory model, which in turn demands some monetary valuation of human life" (p.1627).

In the UK, some studies have attempted to estimate the impact of COVID-19 on various economic sectors [10]. A knowledge gap exists in the total monetary value of human lives lost due to COVID-19 in the UK. The specific objective of this study was to estimate the total present value of human lives lost due to COVID-19 in the UK as of July 2, 2020.

2. Materials and Methods

Analytical framework

This study applied the human capital approach to estimate the total present value of human lives lost due to COVID-19 in the UK. The approach was proposed initially by Petty [11], and subsequently, refined by Weisbrod [12], who clarified that:

"The present value of a man at any given age may be defined operationally as his discounted expected future earnings stream (net of his consumption if the net concept is used)" (p.427).

The current study replicates the methodology applied in estimating the monetary value of human life losses associated with COVID-19 in China [13] and the USA [14]. The total present value (TPV) of human lives lost from COVID-19 in the UK (TPVUK) was estimated using the following Formula 1:

$$1.\ TPV_{UK}=\sum_{k=1}^{k=9} PV_k$$

where $\sum_{k=1}^{k=9}$ is the summation of present values of human lives lost from COVID-19 in age groups 1 (0-9 years old), 2 (10-19 years old), 3 (20-29 years old), 4 (30-39 years old), 5 (40-49 years old), 6 (50-59 years), 7 (60-69 years old), 8 (70-79 years old), 9 (80 years and older), and NPVk is the present value for the kth age group.The PVk was estimated using the Formula 2 quation [13, 14]:

$$2.\ PV_k=\sum_{t=1}^{t=n}\{(1/(((1+r)^k)\times(PCGDP_{UK}-PCCHE_{UK})\times(ALE_{UK}-AAD_k)\times(TCOVD_{UK}\times P_k)\}$$

where $\sum_{t=1}^{t=n}$ 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 refers to the discount rate, i.e. 3% in the current study; $PCGDP_{UK}$ denotes the GDP per capita for the UK; $PCCHE_{UK}$ represents the per capita current health expenditure in the UK; ALE^{UK} is the average life expectancy in the UK; AAD_k is the average age at death in kth age group; $TCOVD_{UK}$ refers to the total number of

Table 1. Data and the sources

Variables	Data	Sources
Discount rate	3%, 5%, 10%	Kirigia and Muthuri [13, 14]
Gross domestic product per capita in the UK	Int$ 48168.9	International Monetary Fund (IMF), the World Economic Outlook Database [1]
Current health expenditure per capita in the UK	Int$ 4338	World Health Organization (WHO), Global Health Expenditure Database [15]
Average life expectancy at birth	The UK=81.8 years [16]; Global=72 years [6]; Japanese Females (world's highest)=88.1 years [17]	WHO world health statistics report 2019 [6], Worldometer United Kingdom demographics [16]. Worldometer United Kingdom demographics [17].
COVID-19 deaths in the UK by July 2, 2020	43906	Worldometer United Kingdom Coronavirus Cases [4].
Proportion of COVID-19 deaths per age group	0-9 years=0; 10-19 years=0.000229; 20-29 years=0.001485; 30-39 years=0.004136; 40-49 years =0.013665; 50-59 years=0.045427; 60-69 years=0.096908; 70-79 years=0.224756; and 80 years and older=0.613395	United Kingdom Office for National Statistics [5].

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human lives lost in the UK as of July 2, 2020; Pk is the proportion of COVID-19 deaths borne by age group k. The base year for the calculations was 2020. The equations (1) and (2) were estimated using the Microsoft Excel software.

Data and data sources

The data analyzed in this paper and the sources are in Table 1.

3. Results

Findings by assuming the UK's both sexes life expectancy of 81.8 years and a 3% discount rate

Table 2 portrays the age group distribution of the present value of the human lives lost from COVID-19 by 2 July 2020 in the UK.

Table 2. Present value of human lives lost from COVID-19 in the UK in 2020 (Int$)

Age group in years	The Present Value of Human Lives Lost at a 3% Discount Rate (Int$)	Average Present Value per Human Life Lost in an Age Group (Int$)
0-9*	0	0
10-19	12635106	1259395
20-29	77606006	1190050
30-39	199179559	1096855
40-49	582921258	971610
50-59	1602159250	803290
60-69	2455405401	577083
70-79	2694780939	273079
80 & older	2258738707	83869
TOTAL	9883426226	225104

* Present value for 0-9 years old was nil as there were no COVID-19 deaths.

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The 43906 COVID-19 human lives lost had a TPVUK of Int$ 9883426226, and an average of Int$ 225104 per human life. The 0-9 years old sustained 0%; 10-19 years old sustained 0.1%, 20-29 years old sustained 0.8%, 30-39 years old sustained 2.0%, 40-49 years old sustained 5.9%, 50-59 years old sustained 16.2%, 60-69 years old sustained 24.8%, 70-79 years old sustained 27.3%, and 80 years old and above sustained 22.9% of the TPVUK. Approximately 76.2% of the TPVUK was sustained by those aged between 30 and 79 years. The average present value per human life in the age group 10-19 was 15 fold the value of a life lost in the age group 80 years and older. Each life lost between ages 10 and 39 had a present value of above one million international dollars.

The sensitivity of TNPV to 5% and 10% discount rates holding life expectancy constant

Application of a discount rate of 5% instead of 3% reduced the TPVUK of human lives lost due to COVID-19 by Int$ 1158424570 (11.7%), and the average NPV per human life diminished by Int$ 26384. Consecutively, the use of a discount rate of 10% instead of 3% eroded the TPVUK by Int$ 3058724257 (31%), and the average decreased by Int$ 69665 per human life.

Table 3 shows the results of the reanalysis of the economic model in turn with discount rates of 5% and 10% to test the robustness of the estimated TPV_{UK}.

The sensitivity of TNPV to changes in average life expectancy holding discount rate constant at 3%

The model was recalculated alternately with the average global life expectancy of 72 years and the world's highest life expectancy of 88.1 years (i.e. the life expectancy of Japanese females). Table 4 presents the results of the reanalysis.

The substitution of the UK's life expectancy of 78.6 years with the global average life expectancy of 72 years in the economic model decreased the TPV_{UK} by Int$ 6615259954 (67%). Application of the world's highest life expectancy of 88.1 years, instead of the UK life expectancy of 78.6 years, led to a growth in the TPV_{UK} of Int$ 9237796343 (93%).

4. Discussion

Key findings and implications

The 43906 human lives lost due to COVID-19 by July 2, 2020, in the UK had a total present value of Int$ 9883426226, which was equivalent to 0.31% of the total UK's GDP in 2020. The average present value per human life lost in the UK of Int$ 225104 was lower than that of China of Int$ 356203 [13] and the USA of Int$ 292889 [14]. A possible reason why the average value of human life lost in China is higher than that of the UK could be because of the fact that 61.34% of the COV-

Table 3. Present value of human life losses from COVID-19 in the UK applying 5% and 10% discount rates in 2020 (Int$)

Age Group in Years	Present value of human life lost at a 5% discount rate (Int$)	Present value of human life lost at a 10% discount rate (Int$)
0-9	-	-
10-19	8460210	4390001
20-29	53623527	28458232
30-39	143116587	78690718
40-49	439448783	255231875
50-59	1280102115	807523168
60-69	2102548539	1495973575
70-79	2502776977	2105734575
80 & above	2194924917	2048699825
TOTAL	8725001656	6824701969
Present value per human life	198720	155439

Table 4. Present value of human lives lost from COVID-19 assuming UK's, global, and world's highest life expectancies in 2020 (Int $ or Purchasing Power Parity [PPP])

Age Group in Years	Present value of human life lost at a 3% discount rate and mean global life expectancy of 72 years (Int $)	Present value of human life lost at a 3% discount rate and the world highest life expectancy of 88.1 years (Int $)
0-9	-	0
10-19	12018570	13013210
20-29	72220280	80908914
30-39	179024611	211540000
40-49	493430839	637803117
50-59	1202339737	1847356875
60-69	1309132236	3158381241
70-79	-	4885884446
80 & above	-	8286334767
TOTAL	3268166272	19121222569
Present value per human life	74436	435504

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ID-19 deaths in the UK occurred at the age of 80 years and above, where the years of life lost are relatively few.

Comparison of G-7 countries COVID-19 morbidity and mortality and attributes of health systems, social determinants of health, and environment

Table 5 compares the COVID-19 morbidity and mortality in the UK against those of the other six major advanced economies or G-7 countries.

The UK has the second-highest total number of COVID-19 cases per million population after the USA [3, 4]. Also, the country has the most significant number of COVID-19 deaths per million population. The UK's deaths per million population are 2.8-fold, 1.4-fold, 6-fold, 1.1-fold, and 81-fold those of Canada, France, Germany, Italy, and Japan, respectively. Why does the UK have a higher ratio of COVID-19 cases and deaths than the other six G-7 countries? The answers might be related to four factors: less resourced and weaker health system; gaps in social determinants of health; IHR capacity gaps; and delayed national leadership decisions and actions to prevent the spread of COVID-19.

Table 5. Comparison of major advanced economies (G-7) COVID-19 morbidity and mortality as of July 2, 2020

COVID-19	Canada	France	Germany	Italy	Japan	UK	USA
Total cases	104271	165719	196324	240760	18723	313483	2779953
Deaths	8615	29861	9061	34788	974	43906	130798
Recovered cases	67744	76539	179800	190717	16731	N/A	1164680
Active cases	27912	59319	7463	15255	1018	N/A	1484475
Total cases per million population	2763	2539	2343	3952	148	4618	8398
Deaths per million population	228	457	108	575	8	647	395
Tests per million population	73396	21213	70103	90066	3696	142325	105302

Source: Worldometer.

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Table 6. Comparison of major advanced economies (G-7 countries) health systems, social determinants of health, and environmental characteristics/attributes

Health system, social determinants of health, and air pollution characteristics		UK	Canada	France	Germany	Italy	Japan	USA
Density of medical doctors (per 10000 population) [6]		28.1	23.1	32.7	42.5	39.8	24.1	26.1
Density of nursing and midwifery personnel (per 10000 population) [6]		81.7	99.4	114.7	132.4	57.4	121.5	145.5
Density of dentists (per 10000 population) [6]		5.2	6.4	6.7	8.5	8.2	8.0	5.8
Density of pharmacists (per 10000 population) [6]		8.9	11.2	10.6	6.5	10.9	18.0	9.2
Hospital beds (per 10000 population) [18]		27.58	27	64.77	82.78	34.22	134	29
Radiotherapy units per million population [19]		5.0	8.1	7.5	6.4	6.4	7.2	12.4
Domestic general government health expenditure (GGHE-D) as percentage of general government expenditure (GGE) (%) [15]		18.7	19.3	15.5	19.9	13.4	23.6	22.5
Current health expenditure (CHE) per capita in Purchasing Power Parity (PPP) [15]		4338	4929	5011	5923	3620	4563	10246
Universal Health Coverage Index [6]		87	89	78	83	82	83	84
Proportion of population using safely-managed drinking-water services (%) [6]		>99	99	98	>99	95	98	>99
Proportion of population using safely-managed sanitation services (%) [6]		98	82	88	97	96	99	90
Population with at least some secondary education (% ages 25 and older) [2]	Female	82.9	100	81.0	96.0	76.6	95.2	95.7
	Male	85.7	100	86.3	96.6	83.0	92.2	95.5
Proportion of population with primary reliance on clean fuels and technology (%) [6]		>95	>95	>95	>95	>95	>95	>95
Annual mean concentrations of fine particulate matter (PM2.5) in urban areas (μg/m3) [6]		10.6	6.7	12.4	11.9	15.7	11.8	7.6

Source: UNDP [2], WHO [6, 15, 18, 19].

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Table 6 contrasts the UK's health system, social determinants of health, and environmental characteristics/attributes with those of the other six G-7 countries.

In terms of the health workforce, the UK's density of medical doctors (per 10000 population) is lower than those of France, Germany, and Italy but higher than those of Canada, Japan, and the USA. The UK's density of nursing and midwifery personnel (per 10000 population) is lower than those of Canada, France, Germany, Japan, and the USA [6].

Concerning health infrastructure and diagnostic devices, the number of hospital beds per 10000 population in the UK was lower than those of all the G-7 countries, except Canada [18, 19]. The number of radiotherapy units per million population in the UK was the lowest among the G-7 countries. Besides, the current health expenditure per capita of the UK is lower than those of Canada, France, Germany, Japan, and the USA. The lower health system resource levels might partially account for the relatively high number of COVID-19 deaths per million population in the UK. According to Scally, Jacobson, and Abbasi [20], COVID-19 has exposed the "the disempowered and fragmented infrastructures of its public health system" (p.3).

Regarding social determinants of health, the UK's both sexes population with at least some secondary education (% ages 25 and older) was 15.7, 12.0, 9.4, and 11.0 percentage points lower than those of Canada, Germany, Japan, and the USA [2]. The proportions of the population in the UK using safely-managed drinking-water and sanitation are almost 100% and relatively comparable to those of most G-7 countries [6]. Furthermore, the proportion of the population with primary reliance on clean fuels and technology, and the annual mean concentrations of fine particulate matter in urban areas are relatively similar to most G-7 countries [6]. Air pollution levels and population coverage of safely-managed water

Table 7. Comparison of advanced economies (G-7) countries International Health Regulations (IHR) core capacities

IHR Core Capacities	Canada	France	Germany	Italy	Japan	UK	USA
1. Legislation and financing (2019)	100	100	100	100	100	100	100
2. Coordination and national focal point functions	100	100	100	100	100	100	100
3. Laboratory	100	100	100	100	100	100	100
4. Surveillance	100	100	100	100	100	100	100
5. Human resources	100	80	80	80	80	100	60
6. National emergency framework	100	100	100	100	100	100	100
7. Health service provision	100	100	100	100	100	100	100
8. Risk communication	100	80	60	60	60	100	100
9. Points of entry	100	40	60	80	100	40	100
10. Food safety	100	80	80	80	100	100	100
11. Zoonotic events and the human-animal interface	100	80	100	100	100	100	80
12. Chemical events	100	100	80	60	100	80	80
13. Radiation emergencies	100	100	100	80	100	100	80
Average of 13 International Health Regulations core capacity scores [6]	99	82	88	85	95	93	92

Source: WHO.

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and sanitation do not seem to contribute to accounting for the difference in the ratios of COVID-19 deaths.

Grossman [21, 22] human capital model of demand for health predicts that educated persons are more efficient producers of own health, i.e. they can produce more stock of health from a given amount of inputs, e.g. health services, diet, physical exercise, self-protective behaviors such as non-consumption of tobacco, avoidance of substance abuse, and in the current context of COVID-19, physical distancing, handwashing with soap, voluntary testing, self-isolation, and quarantine. Hahn and Truman [23] reviews evidence which supports Grossman's prediction that academic achievement is significantly associated with health risk avoidance and protective behaviors, high income, access to health-related resources, lower rates of non-communicable diseases (cardiovascular diseases, diabetes, liver disease), psychological symptoms (hopelessness, worthlessness, and sadness), and mortality from many diseases. Therefore, the UK's percentage of the population with at least some secondary education might contribute partly to explaining the higher number of total COVID-19 cases and deaths per million population compared to Canada, Germany, and Japan.

Table 7 compares advanced economies (G-7) countries International Health Regulations (IHR) core capacities in 2019.

The average IHR core capacity score for the UK is smaller than those of both Canada and Japan but higher than those of France, Germany, Italy, and the USA [24]. The UK's IHR core capacities of legislation and financing, coordination and national focal point functions, laboratory, surveillance, human resources, national emergency framework, health service provision, risk communication, food safety, radiation emergencies, and zoonotic events and the human-animal interface were assessed by government as 100, i.e. the optimal value. The 40 score for points of entry was equal to that of France but lower than those of Canada, Germany, Italy, Japan, and the USA. The 60-point gap in the points of entry (POE) capacity in the UK might partially account for the disproportionately large number of total COVID-19 cases and deaths per million population. What does the POE gap mean?

WHO [25] defines POE as designated airports, ports, and ground crossings "for international entry or exit of travelers, baggage, cargo, containers, conveyances,

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goods, and postal parcels as well as agencies and areas providing services to them on entry or exit" (p.7). The consequences of gaps in POE capacities for public health emergencies surveillance, response, coordination, and communication are reflected in the importation and rapid spread of COVID-19; poor IHR coordination and risk communication [20, 26]; ineffective procurement and delivery of testing resources [17, 23]; lack of strategy for case finding, testing, contact tracing, and isolation [17, 23]; shortage of personal protective equipment (including eye protection, gloves, surgical masks, and particulate respirators) and mechanical ventilators [20, 26]; and the delayed, inadequate, flawed, and lethargic response to the pandemic in the UK [20, 26].

Study limitations

This study had some limitations. First, the GDP per person was one of the variables used in the valuation of human life. Some economists have criticized GDP for not capturing non-market production, economic inequalities, and externality effects of production processes, e.g. air and water pollution [27]. Second, the study did not quantify the negative impact of COVID-19 on the various socio-economic sectors, e.g. agriculture, education, insurance, and finance (including stock markets), manufacturing, real estate, logistic, professional and technical services, transport (road, rail, and air), construction, and tourism [10]. Third, the study omitted the NHS resources used in the implementation of preventive interventions (e.g. hand washing, sanitizing, physical distancing, lockdown, and information, education, and communication); testing, contact tracing, and isolation; treatment of COVID-19 cases, and related mental disorders; and interment of the dead. Fourth, it did not take into account the intangible cost of stress, anxiety, fear, physical and psychological pain, and stigma associated with COVID-19 [28].

5. Conclusions

The study revealed that each human life lost from COVID-19 has a present value which is 5.64-fold the GDP per capita for the UK. The UK's higher COVID-19 cases and deaths per million population compared to some of the other G-7 countries may be attributed to lower health system resource levels [15, 18, 19]; a higher percentage of the population without secondary education [2]; and delays in operationalizing International Health Regulations (IHR) standard operating procedures [20, 26]. Increased investments into the National Health Service (especially public health services) and other related systems to optimize Universal Health Coverage [29, 30], IHR capacities [24, 25], safely managed water and sanitation services coverage [6], and secondary education coverage [2] could mitigate further economic and human life losses during the current and future pandemics. Whereas the kind of evidence reported in this paper is essential for use in advocacy, there is a need for economic evaluations (cost-effectiveness, cost-utility, and cost-benefit analyses) of preventive and curative interventions to aid decision-making [31, 32].

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

All authors equally contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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