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RESEARCH ARTICLE

The impact of carbon pricing, climate financing, and financial literacy on COVID-19 cases: go-for-green healthcare policies

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Abstract

Climate finance and carbon pricing are regarded as sustainable policy mechanisms for mitigating negative environmental externalities via the development of green financing projects and the imposition of taxes on carbon pollution generation. Financial literacy indicates that it is beneficial to invest in cleaner technology to advance the environmental sustainability goal. The current wave of the COVID-19 epidemic has had a detrimental effect on the world economies' health and income. The pandemic crisis dwarfs previous global financial crises in terms of scope and severity, collapsing global financial markets. The study's primary contribution is constructing a climate funding index (CFI) based on four critical factors: inbound foreign direct investment, renewable energy usage, research and development spending, and carbon damages. In a cross-sectional panel of 43 nations, the research evaluates the effect of climate funding, financial literacy, and carbon pricing in lowering exposure to coronavirus cases. The study utilized Newton–Raphson and Marquardt steps to estimate the current parameter estimates while evaluating the COVID-19 prediction model with level regressors using the robust least squares regression model (S-estimator). Additionally, the innovation accounting matrix predicts estimations over a specific period. The findings indicate that climate finance significantly reduces coronavirus exposure by introducing green financing initiatives that benefit human health, which eventually strengthens the immune system's ability to fight infectious illnesses. Financial literacy and carbon pricing, on the other hand, are ineffectual in controlling coronavirus infections due to rising economic activity and densely inhabited areas that enable the transmission of coronavirus cases across countries. Similar findings were obtained using the alternative regression apparatus. The COVID-19 predicted variable was used as a "response variable," and climate financing was shown to have a favorable impact on containing coronavirus exposure. As shown by the innovation accounting matrix, carbon pricing would drastically decrease coronavirus cases' exposure over a time horizon. The study concludes that climate finance and carbon pricing were critical in improving air quality indicators, which improved countries' health and wealth, allowing them to reduce coronavirus infections via sustainable healthcare reforms.

Keywords Climate financing · Carbon pricing · COVID-19 cases · Financial literacy · Population density · Generalized linear model

Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the virus strain that causes coronavirus disease (COVID-19). The virus first identified in the city of Wuhan, China, exacerbates the infection rate in a shorter time all over the world. The WHO declared a healthcare emergency on 30th January 2020, while it declared a global pandemic on 11th March 2020 (Hua and Shaw 2020). The COVID-19 pandemic confined its impact on deteriorating human health while its negative effect on economic and financial activities (Anser et al. 2021a, b). The US economy has a highest COVID-19 infected cases, followed by India, Brazil, Russia, and the UK, with a value of 28,381,220; 10,937,320; 9,921,981; 4,099,323; and 4,058,468, respectively (Worldometer 2021). Besides that, the US economy spent an enormous amount of R&D activities, i.e., 2.840% of GDP, limiting carbon emissions

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up to 0.834% of GNI in the current year. The Indian economy spent huge money on renewable energy consumption, i.e., 36.021% of total energy consumption, which attracts inbound FDI up to 1.764% of GDP. Brazil's economy spent 1.264% of its R&D expenditures to maintain its per capita income up to US$11,121.74, fueled by high green energy consumption, i.e., 43.790%, and inbound FDI, i.e., 3.995% of GDP. The Russian economy confined its population density up to 8.822 people per square km of land area, which maintains an inflation rate of 4.470%. Finally, UK reduced carbon damages up to 0.443% of GNI, which helps to reduce average inflation of 1.738% that enables a country to improve its per capita income up to US$43,711.71 in the current years. Climate financing is considered a vital factor to improve the environmental quality level. The four main factors remain actively visible in the earlier studies that can be combined to form climate financing index (CFI), i.e., FDI inflows (Zubair et al. 2020), R&D expenditures (Fragkiadakis et al. 2020), renewable energy consumption (Anser et al. 2020a), and carbon damages (Hong et al. 2020). The study's main contribution is to amalgamate the stated factors to form a relative weighted index across countries. Figure 1 shows information about the climate financing index that has a range between – 1.784 and 4.657. The data illustration spikes show that 13 countries have a positive spike and have a positive value while the remaining 30 countries have a negative index value. The positive value shows that the countries spent an enormous amount to protect the natural environment through green financing. In contrast, the negative values show that countries keep struggling to use environmental sustainability policies to devote an adequate sum of money to climate protection. The study assumes that climate financing is helpful to contain coronavirus cases through smart and sustainable financing. The greening projects improve environmental air quality while it improves individual's health that developed the resistance against any contagious disease, which reduces healthcare sufferings. The green healthcare policies are desirable to mitigate carbon pollution and coronavirus cases with a caution to use sustainable financing.

The sizeable research is available on the impact of environmental pollutants on COVID-19 cases, while little work on climate financing and its positive impact on the environmental quality reduce coronavirus cases globally. Hepburn et al. (2020) argued that during the COVID-19 pandemic, different fiscal packages introduce subsidizing financial and economic activities that create cleaner production and healthcare sustainability agendas globally. The climate change agenda is highly prioritized in developed countries, while rural support programs are vital for low- and middle-income countries to restore economic activities in pandemic crises. Obergassel et al. (2020) concluded that climate governance played a vital role in improving environmental quality that is equally important to tackle pandemic crisis during the exacerbation of high infected cases, which deprived the global economies. The world introduced different recovery packages to minimize coronavirus cases; however, these packages affected the Paris agreement on carbon control, which faced the commercialized market's forefront challenges. Fuentes et al. (2020) discussed the vulnerability of coronavirus cases and climate change together. Both have a different scale of disasters and covered a wide range of international territories that need uniform economic and environmental solutions to tackle them. Barbier and Burgees (2020) proposed a sustainable policy framework after COVID-19 to achieve different sustainable development goals, including promotion of clean energy investment and reduced fossil fuel dependency; improved pure drinking water, water supply, sanitation facilities, and make a wastewater infrastructure; and introduced a carbon pricing mechanisms to fund climate solutions. Brown and Susskind (2020) emphasized the need to integrate global economies to increase their cooperation to reduce coronavirus cases by improving through providing healthcare facilities. Mintz-Woo et al. (2020) argued that introducing carbon pricing in the COVID-19 pandemic is the optimal solution to combat environmental issues and reducing healthcare sufferings. Malliet et al. (2020) found that strict lockdown substantially decreases the economic output of 5% of France's GDP. However, its positive effect associated with air quality improvement is far greater than the country's losses. Although it is foresighted that both the effects are temporary, once the pandemic issue has settled down, the country's economic growth exacerbates that negatively affects the country's environmental sustainability agenda. The greater need is to devise a sustainable environmental policy that helps both in the short- and long-term reduce coronavirus cases and tackle environmental issues, which lead to the countries toward green transformation. Khurshid and Khan (2021) simulated the impacts of the COVID-19 pandemic on Pakistan's energy and environment and found that COVID-19 will negatively affect its economic growth while quarantine situation and energy consumption improves environmental quality in the coming years. Thus, the need to sustain a country's economic growth through sustainable environmental policies helps a country move forward toward green development. Fujiki (2021) concluded that financial literacy improves financial services during a pandemic crisis, as peoples were more aware of the dealing of payment in cashless mode and increasing demand for non-face-to-face financial activities. Thus, it helps to reduce the incidence of coronavirus cases in commercialized activities.

Bhattacharyya (2022) stressed the need to regulate green financing choices to address challenges of the

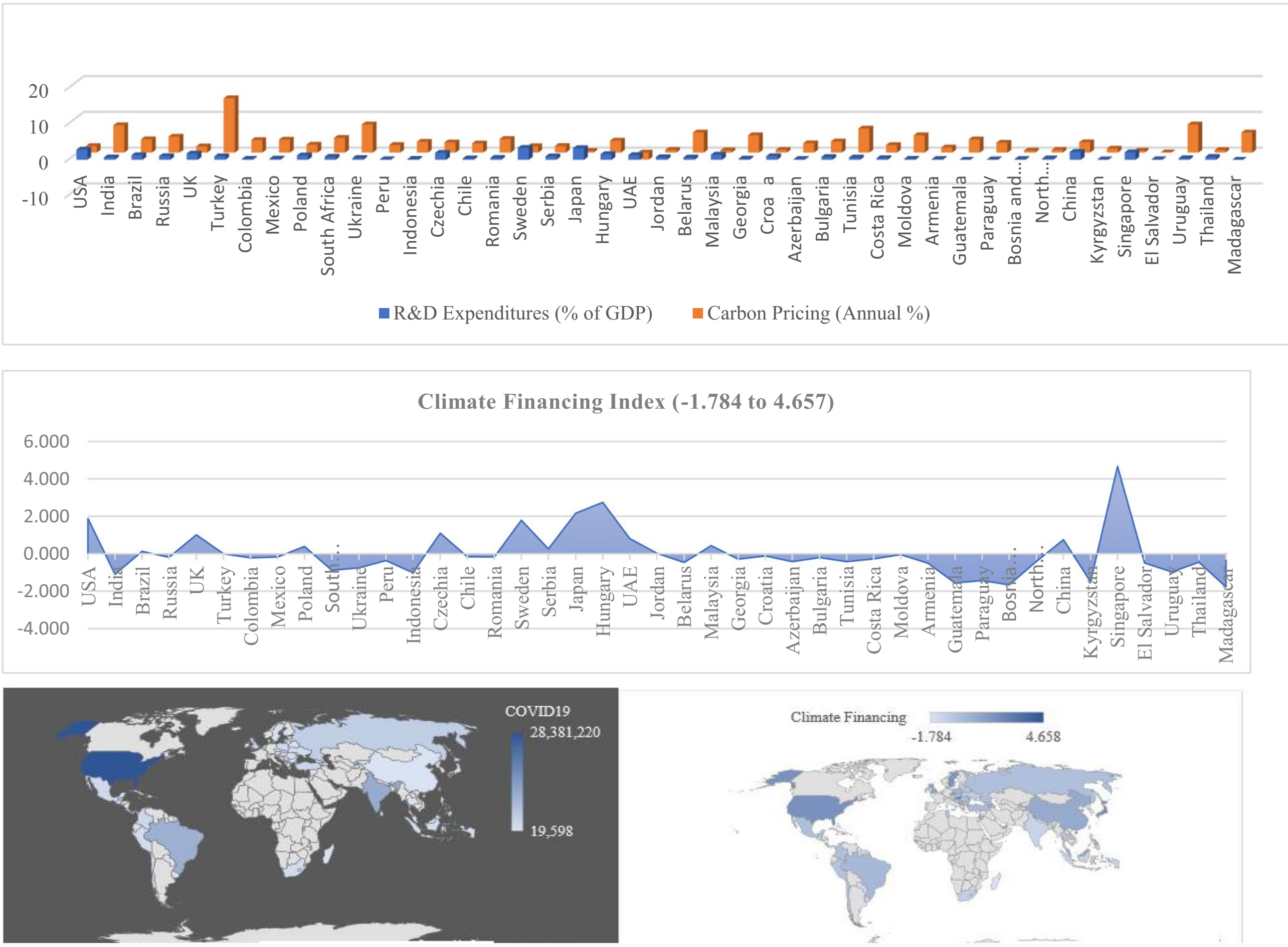

Fig. 1 Trend values of COVID-19 cases, R&D expenditures, carbon pricing, and climate financing index. Source: Worldometer (2021), World Bank (2021), and author's estimate. Note: Dark blue region shows the high intensity of COVID-19 cases and greater climate financing while light blue region shows a less number of COVID-19 cases and lower climate financing

energy transition, climate sensitivity, and sustainable development. Financial investors and regulators must tighten financial disclosure requirements to pave the way for green projects. Newell (2022) favors public–private financial distributions that reduce social inequalities, including poverty and income inequality; additionally, they contribute to the achievement of the healthcare sustainability agenda, which has accelerated in recent years to the COVID-19 pandemic. Thus, effective financial management and community engagement are necessary to reap the benefits of long-term investment that contributes to reducing social inequalities. Gholipour et al. (2022) conducted a study of a broad panel of high- and low-income countries to assess the effect of green finance in lowering GHG emissions from 2012 to 2018. The findings indicate that green construction finance is a feasible policy tool for enhancing environmental quality, with a stronger positive effect in developing nations. Thus, measures aimed at sustaining green property finance should be implemented to accelerate the transition to cleaner development. Mavlutova et al. (2022) examined the potential for sustained financial well-being in Latvia. They found that financial development and literacy were critical in mitigating socioeconomic, environmental, and governance challenges that predominated during the COVID-19 pandemic. Green and clean funding enables the allocation of additional resources to enhance people's livelihoods by creating a social comfort zone and resolving economic concerns, contributing to the achievement of the healthcare sustainability goal. Martínez et al. (2022) discovered that healthcare personnel are disproportionately affected by the COVID-19 pandemic. They were exposed to the coronavirus at a higher rate than the general population. The findings were found from a large sample of Spanish healthcare professionals who observed increased healthcare issues, such as poor health and psychosocial dangers. The increased requirement for healthcare worker prevention ensures that they work productively and take care of their health via concrete policy measures and psychotherapy. Adetunji et al. (2022) stated that information and communication technology would aid in monitoring, delivering, and managing sustainable healthcare services that contribute to the global reduction of coronavirus infections.

The study's contribution is to construct a comprehensive climate financing index, including four vital socio-environmental factors, including inbound FDI, green energy consumption, R&D expenditures, and carbon damages. The earlier literature mostly used the stated factors in relation with the climate financing as regressors that impact the carbon emissions; however, they are not making a weighted contribution of the stated factors to form an index (Nawaz et al. 2021; Sarkodie et al. 2020; Muhammad et al. 2021). Another contribution of the study is to use carbon pricing as a mediator that supports the climate financing agenda to reduce negative environmental externalities that ultimately improve the countries' health and wealth. About the COVID-19 factor, the study believes that this is the first study that used both the sustainable policy instruments in infectious healthcare modeling to reduce contagious diseases likely. The earlier studies used different financing coping factors to reduce the incidence of coronavirus cases globally; for instance, Yoshino et al. (2021) used portfolio investment to reduce coronavirus cases by investing in sustainable development goals. Klioutchnikov and Kliuchnikov (2021) considered renewable energy and energy efficiency investment opportunities to create a healthy living environment that tackles COVID-19 cases. Smith et al. (2021) used carbon pricing to mitigate fossil fuel combustion that needs to be more focused on the pandemic crisis for sustainable growth. Finally, the study used financial literacy in the healthcare modeling framework that supports climate financing and carbon pricing objectives to improve environmental and healthcare infrastructure.

Based on the study's contribution, the study formulated the following research questions to help move forward for achieving healthcare sustainability. First, does climate financing helps to reduce the exposure of COVID-19 cases through achieving healthcare sustainability? This question implies that climate financing has an indirect impact on reducing the exposure of coronavirus cases. It helps mitigate negative environmental externalities by initiating green financing projects, which improve air quality indicators and human health that support reducing contagious diseases. Second, to what extent carbon pricing improves environmental and healthcare quality? This question argued that taxes imposition on dirty production is desirable for mitigating carbon emissions and achieving energy efficiency leading to sustainable healthcare financing. Finally, does financial literacy helps to increase knowledge spillover to reduce coronavirus cases? The advancement in cleaner technologies is not limited to achieving green development agendas while improving economic efficiency and healthcare sustainability to reduce the exposure of coronavirus cases globally.

The study's contribution and research questions help to make the research objectives of the study, i.e.,

i) To examine the role of climate financing in reducing the exposure of coronavirus cases across countries,
ii) To determine the impact of carbon pricing and financial literacy on reducing COVID-19 cases, and
iii) To analyze the inter-temporal relationship between climate financing and coronavirus cases over a time horizon.

These objectives need to be analyzed using statistical techniques to get sound parameter inferences, which helps to propose sustainable long-term policies for achieving healthcare sustainability.

Materials and methods

The study used COVID-19 cases as a response variable, while climate financing, carbon pricing, financial literacy, the country's per capita income, and population density served as regressors. The COVID-19 cases are taken from Worldometer (2021), while the stated variables' remaining data are taken from World Bank (2021) database. The study constructs a relative weighted index for climate financing by combing four key factors, including inbound FDI (% of GDP), renewable energy consumption (% of total energy demand), R&D expenditures (% of GDP), and carbon damages (% of GNI). The formulation of climate financing index (denoted by CFI) is made by principal component analysis (PCA) to get eigenvalues and eigenvectors loadings, which form a unique CFI data containing all the properties of the used variables to represent the index value efficiently. Table 1 shows the construction of CFI by PCA matrix.

The estimation shows four main variables used in the formulation of CFI that have a relative contribution of 1.480, 1.313, 0.806, and 0.399, respectively. Out of four eigenvalues, the first two eigenvalues surpassed the unit's threshold that confirmed the importance of the variables in forming CFI value. The proportional variance shows that the first and second factors contribute 37.02% and 32.83%, respectively, which have a cumulative sum of 69.85%, while the remaining two factors constitute 20.01% and 0.099%. The eigenvectors loadings confirmed that the principal component-4 (PC 4) matrix has a greater sum of values that help make an efficient index of climate financing. Figure 2 shows the scree plot, eigenvalue differences, and cumulative eigenvalue proportion for ready reference.

Table 1 PCA matrix for climate financing index (CFI)

Eigenvalues (sum = 4, average = 1)					
Number	Value	Difference	Proportion	Cumulative value	Cumulative proportion
1	1.480789	0.167690	0.3702	1.480789	0.3702
2	1.313099	0.506225	0.3283	2.793888	0.6985
3	0.806874	0.407636	0.2017	3.600762	0.9002
4	0.399238	–	0.0998	4.000000	1.0000
Eigenvectors (loadings)					
Variable	PC 1	PC 2	PC 3	PC 4	
FDI	0.559561	0.046895	0.798807	0.215870	
REC	−0.392148	0.687882	0.070359	0.606702	
R&D	0.652314	0.009111	−0.587026	0.479378	
CARDAM	−0.328020	−0.724248	0.111165	0.596246	

FDI shows foreign direct investment inflows, REC shows renewable energy consumption, R&D shows research and development expenditures, and CARDAM shows carbon damages.

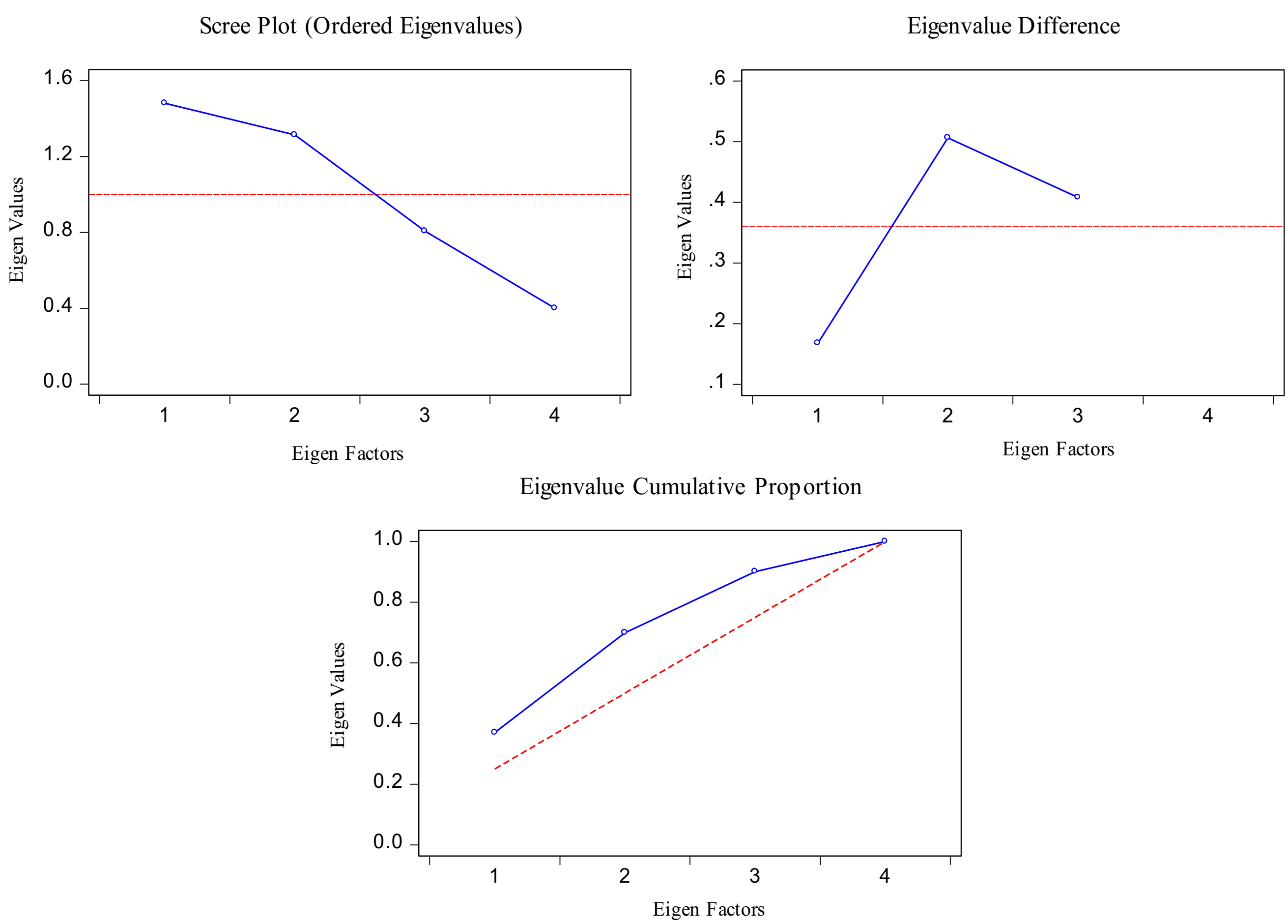

Fig. 2 Eigenvectors loadings. Note: Blue line shows eigenvalue estimates while the red line shows the critical region

Figure 3 shows the eigenvalue vectors loadings that confirmed the greater proportion of component matrix in the formation of orthonormal loadings. The first component has a higher share of CFI formation with a value of 37% than the second component that has a respective value of 32.8%. The rest of the variations have been found by the

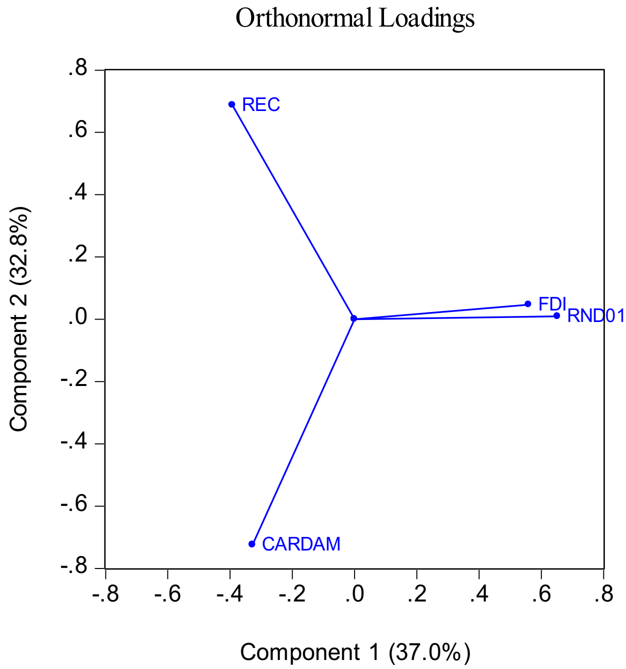

Fig. 3 Factor loadings. Note: Blue line shows factor loadings. RND01 shows research and development expenditures, REC shows renewable energy consumption, CARDAM shows carbon damages, and FDI shows inbound FDI

other two factors that have a combined response of 30.2%. These loadings help form a reliable CFI matrix for using a separate variable in the regression apparatus to get policy insights.

The study constructs an index of climate financing based on the PCA matrix, which has a range value of minimum to − 1.784 and a maximum value of 4.657. The study used a cross-sectional panel of 43 countries that fall in the prescribed range of CFI. Out of 43 countries, only 13 countries have a positive CIF value, while the remaining countries exhibit a negative CFI value. Further, out of 13 countries, there are only three countries with a more than 2 CFI value (high frequency), while four countries have a value of more than one but less than the CFI value 2 (medium frequency). The rest of the six countries have CFI values greater than

Table 2 CFI trended values

Total number of countries	CFI range values (− 1.784 to 0)	CFI range values (> 0 and < 1) [low frequency]	CFI range values (1 to < 2) [medium frequency]	CFI range values (2 to > 4) [high frequency]
N = 43	*N* = 30	*N* = 6	*N* = 4	*N* = 3

Source: Author's estimation. CFI shows climate financing index.

zero but less than one (low frequency). Table 2 shows the complete picture of CFI values for ready reference.

The other regressors include carbon pricing (denoted by CPRICE), financial literacy (denoted by FLIT), the country's per capita income (denoted by GDPPC), and population density (dented by POPDEN) used in the study for robust inferences. The following variable's definitions used in this study are as follows:

i) COVID-19: The study used the number count of registered coronavirus cases on 18th February 2021 in a cross-sectional panel of 43 countries at one point on time. The study evaluated different economic and environmental factors that could impact COVID-19 cases that formulate broad-based global policies. The COVID-19 cases served as the primary regressand variable in this study that was influenced by several factors. The study used a wide variety of positive and negative factors that influenced COVID-19 cases across countries.
ii) Climate financing index (CFI): The study constructed a relative weighted index of climate financing by PCA matrix. The main factors used in the construction of CFI are FDI inflows, renewable energy consumption, R&D expenditures, and carbon damages. The stated factor served as a regressor that likely to influence COVID-19 cases across countries. The index value corresponds to both negative and positive values based on the stated variables' actual data. The study used the latest available data on the World Bank database of the corresponding variables for analysis.
iii) Carbon pricing (CPRICE): Carbon pricing is considered a policy instrument for a green economy. It is a viable factor that helps to attain green resources globally. The study used carbon tax as a pricing substitute in this study to improve environmental quality. The study assumes that carbon tax should be optimal and flexible that limits dirty production globally. Thus, there is a greater need to use a uniform tax value equally applicable to all countries. The study assumed that carbon tax should impose an equal proportion of price level changes across countries. Based on this assumption, this study used the consumer price index (inflations, annual %) as a proxy for carbon pricing.
iv) Financial literacy (FLIT): Finance literacy is essential for trading goods in the stock market. It is essential to absorb the price volatility and other exogenous shocks that possible only when an adequate base of financial knowledge has been inhabited. The broad money supply (% of GDP) gives a substantial knowledge about the liquidity of money in circulation. The study assumed that higher literacy about the transaction of money sup-

ply in the economy leads to a more absorbing financial risk capacity due to other exogenous shocks. Based on this assumption, the study used money supply as a proxy variable of financial literacy that absorbs financial crisis in the pandemic era.

v) Economic growth (GDPPC): The continued economic growth sustains economic activities that absorb any exogenous shocks that could prevail during the pandemic era. The rise and fall in economic activities are mostly visible during the time of the COVID-19 pandemic; hence, the study used GDP per capita in constant 2020 US$ as a variable factor that influenced coronavirus cases across countries.

vi) Population density (POPDEN): During the COVID-19 pandemic, the World Bank and other healthcare agencies mainly provoked the need to maintain the adequate distance between the individuals to avoid the exposure of coronavirus cases. The study assumed that high dense population has a greater susceptibility rate of coronavirus cases than the less dense population area. Hence, the study used population density (people per square km of land area) used as a control variable to analyze its impact on COVID-19 cases across countries.

Theoretical underpinning

Sandberg (2018) articulated the theory of sustainable finance effectively, arguing that the financial sector has failed to meet the societal perspective of the welfare economy, staying obsessed with neoclassical economic theories with a self-centered aim of increasing corporate payoffs. Climate financing is mostly being explored about worsened COVID-19 cases, which are expected to spread through environmental toxins (Shamsi et al. 2021). Anser et al. (2021a, b) proposed a theory of healthcare signaling. Government and healthcare professionals warned the general population to avoid contagious diseases through different communication channels and trained them to prevent them via comprehensive standardized operating procedures. Consequently, it reduces societal costs and expands access to preventive treatment. Preventative interventions in healthcare, such as the logistical supply of protective equipment and improved corporate social responsibility, may help minimize sensitive COVID-19 cases (Sasmoko et al. 2021). Healthcare supply chain management contributes to pandemic containment by implementing sustainable business strategies (Sriyanto et al. 2021). By implementing a green healthcare system within the context of climate financing, we may mitigate economic and environmental complexity during the COVID-19 pandemic (Jia et al. 2021).

Based on the sustainable financing and healthcare theories, the study extended the scholarly work of Yu et al. (2021) and Anser et al. (2020b) that comprehensively discussed the vulnerability of COVID-19 cases that leads economies into the global depression. The study included climate financing, carbon pricing, and financial literacy in the response of COVID-19 that is less explored in the exiting work, which gives new insights and directions to contain coronavirus cases across countries possibly. The following empirical equations are used to explore the interlinkages between climate financing and COVID-19 cases in a cross-sectional panel of countries, i.e.,

$$COVID19 = \beta_0 + \beta_1 CFI + \beta_2 CPRICE + \beta_3 FLIT + \beta_4 GDPPC + \beta_5 POPDEN + \varepsilon$$
$$\therefore \frac{\partial(COVID19)}{\partial(CFI)} < 0, \frac{\partial(COVID19)}{\partial(CPRICE)} < 0, \frac{\partial(COVID19)}{\partial(FLIT)} < 0, \frac{\partial(COVID19)}{\partial(GDPPC)} > 0, \frac{\partial(COVID19)}{\partial(POPDEN)} > 0 \quad (1)$$

$$COVID19\_F = \beta_0 + \beta_1 CFI + \beta_2 CPRICE + \beta_3 FLIT + \beta_4 GDPPC + \beta_5 POPDEN + \varepsilon$$
$$\therefore \frac{\partial(COVID19\_F)}{\partial(CFI)} < 0, \frac{\partial(COVID19\_F)}{\partial(CPRICE)} < 0, \frac{\partial(COVID19\_F)}{\partial(FLIT)} < 0, \frac{\partial(COVID19\_F)}{\partial(GDPPC)} > 0, \frac{\partial(COVID19\_F)}{\partial(POPDEN)} > 0 \quad (2)$$

where COVID19 shows coronavirus cases, COVID19_F shows the forecasted value of coronavirus cases, CFI shows climate financing index, CPRICE shows carbon pricing, FLIT shows financial literacy, GDPPC shows GDP per capita, POPDEN shows population density, and ε shows error term.

Equation (1) shows that climate financing, carbon pricing, and financial literacy will likely reduce coronavirus cases, whereas continued economic growth and population density will increase the exposure of coronavirus cases in a cross-sectional panel of countries. On the other hand, Eq. (2) shows that climate financing, carbon pricing, and financial literacy assume to impact positively to minimize the incidence of future increase in coronavirus cases. On the other hand, GDP per capita and population density will likely increase more coronavirus cases in the future due to high population density and resuming economic activities across countries. Figure 4 shows the research framework of the study.

Figure 4 illustrates that climate financing index, carbon tax, and knowledge spillover will likely have a positive impact on reducing coronavirus cases' exposure. In contrast, population density and the country's per capita income will likely increase coronavirus cases' susceptibility due to increased commercialization and socialization activities across economies. The following tentative statements have checked the possibilities in a given situation, i.e.,

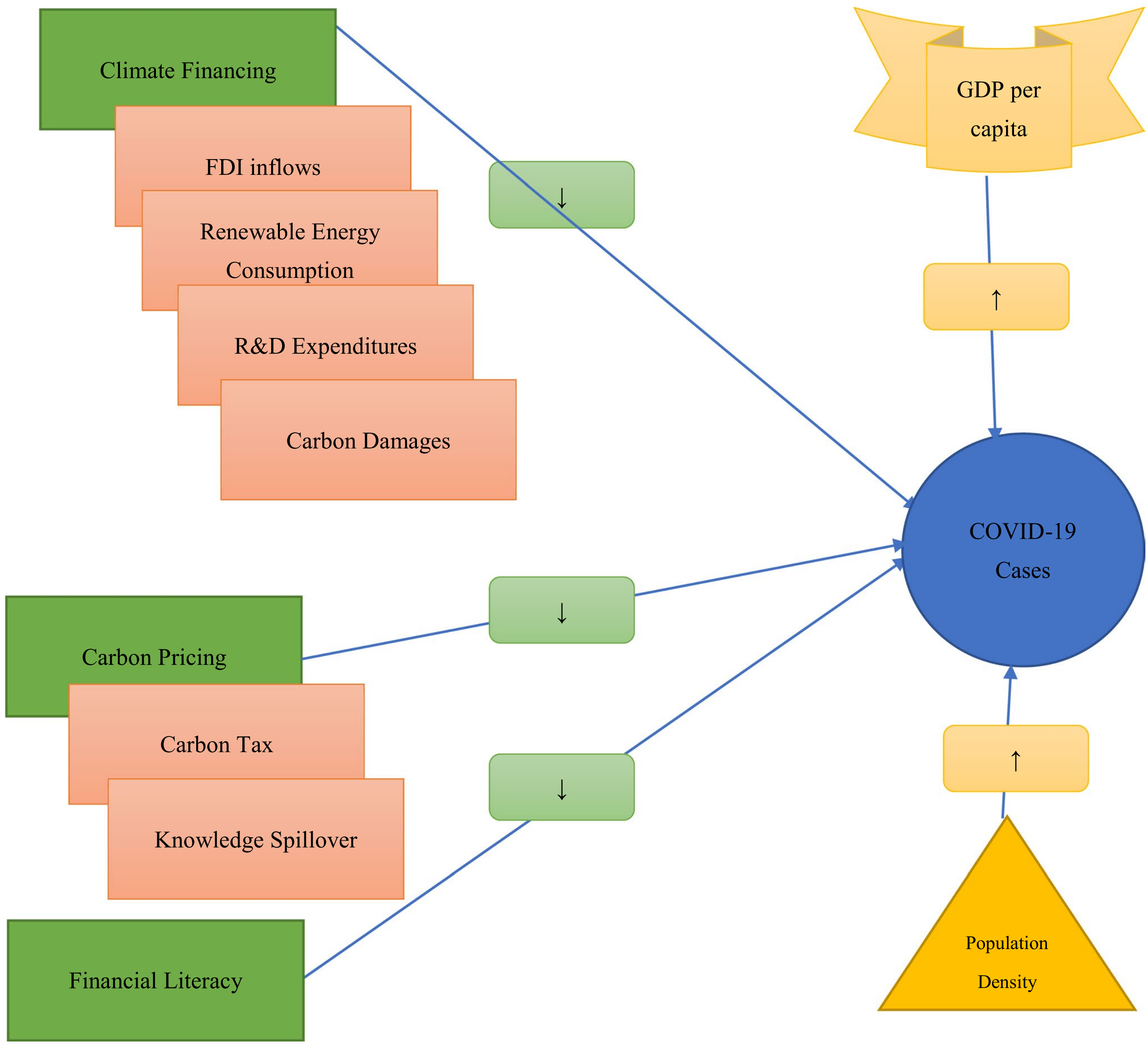

Fig. 4 Research framework of the study. Source: Author's extract. ↓ shows decrease and ↑ shows an increase

H1: Climate financing will be likely to reduce the exposure of coronavirus cases through sustainable healthcare financing.
H2: Carbon pricing will likely reduce the susceptibility rate of increasing the coronavirus cases through mitigating carbon emissions.
H3: Financial literacy will likely absorb the adverse pandemic shocks through smart production.

These hypotheses need to be checked by sophisticated statistical techniques, including generalized least square (GLS) regression, robust least square (RLS) regression, and innovation accounting matrix (IAM). The GLS regression approach is more efficient than the simple least squares regression and weights regression to handle the possible correlation between the stochastic term and regressors in the specified model. The estimates of GLS are considered efficient, asymptomatically normal, consistent, and unbiased, which gives unique linear transformation for model predictions. Further, the study used the RLS regression approach to find out the impact of the climate finance index and other potential regressors on the forecasted COVID-19 cases. The RLS regression approach evaluates Eq. (2) through S-estimator. The S-estimator absorbs the possible outliers from the regressors that help get the robust parameter estimates from the regression.

Finally, the study used a variance decomposition analysis (VDA) approach to analyze the inter-temporal relationship between the coronavirus cases and its possible determinants across countries. The VDA decomposition can be seen in Eqs. (3) and (4), i.e.,

$$\begin{gathered} Var(\sigma(COVID19, CFI) = Var(E[\sigma \perp CFI]) + E[Var(\sigma \perp CFI)] \\ \Rightarrow Var(E[\sigma \perp CFI]) \leq Var(\sigma[COVID19, CFI)] \\ Var(\sigma(COVID19, CPRICE) = Var(E[\sigma \perp CPRICE]) + E[Var(\sigma \perp CPRICE)] \\ \Rightarrow Var(E[\sigma \perp CPRICE]) \leq Var(\sigma[COVID19, CPRICE)] \\ Var(\sigma(COVID19, FLIT) = Var(E[\sigma \perp FLIT]) + E[Var(\sigma \perp FLIT)] \\ \Rightarrow Var(E[\sigma \perp FLIT]) \leq Var(\sigma[COVID19, FLIT)] \\ Var(\sigma(COVID19, GDPPC) = Var(E[\sigma \perp GDPPC]) + E[Var(\sigma \perp GDPPC)] \\ \Rightarrow Var(E[\sigma \perp GDPPC]) \leq Var(\sigma[COVID19, GDPPC)] \\ Var(\sigma(COVID19, POPDEN) = Var(E[\sigma \perp POPDEN]) + E[Var(\sigma \perp POPDEN)] \\ \Rightarrow Var(E[\sigma \perp POPDEN]) \leq Var(\sigma[COVID19, POPDEN)] \end{gathered} \tag{3}$$

Equation (4) shows the mean square error term of the respective candidate variables, i.e.,

$$\begin{gathered} MSE_{\mu} = E_{CFI}[MSE_{\mu}(CFI)] \\ MSE_{\mu} = E_{CPRICE}[MSE_{\mu}(CPRICE)] \\ MSE_{\mu} = E_{FLIT}[MSE_{\mu}(FLIT)] \\ MSE_{\mu} = E_{GDPPC}[MSE_{\mu}(GDPPC)] \\ MSE_{\mu} = E_{POPDEN}[MSE_{\mu}(POPDEN)] \end{gathered} \tag{4}$$

where MSE shows mean square error.

Table 3 Descriptive statistics for climate financing indicators

Methods	FDI	REC	RND01	CARDAM
Mean	3.711	22.851	0.881	1.930
Maximum	28.346	70.174	3.339	5.233
Minimum	0.731	0.137	0.015	0.259
Std. Dev	4.894	18.134	0.850	1.274
Skewness	3.876	0.999	1.427	0.878
Kurtosis	18.405	3.245	4.416	2.963

FDI shows foreign direct investment, REC shows renewable energy consumption, RND01 shows research and development expenditures, and CARDAM shows carbon damages.

Results

Table 3 and Table 4 show the descriptive statistics for climate financing indicators and other potential determinants of COVID-19 cases in a cross-sectional panel of countries. Table 3 shows that inbound FDI has a minimum value of 0.731% of GDP and a maximum value of 28.346% of GDP with a mean value of 3.711% of GDP. The mean value of renewable energy consumption, R&D expenditures, and carbon damages is 22.851% of total energy demand, 0.881% of GDP, and 1.930% of GNI. These factors were used to construct a composite index of climate financing in the study.

Table 4 shows that the average number count of COVID-19 cases reached 1,848,278 with a maximum of 28,381,220 and a minimum value of 19,598. The climate financing index fall is in the range of − 1.784 to 4.657. Financial literacy is checked by money supply across countries, showing an average value of 74.271% of GDP. The carbon pricing is, on average, suggested to impose 3.163% on dirty production. The average value of per capita income and population density is US$14,363.16 and 285.839 people per square km of land area, respectively.

Table 5 shows the GLS and RLS estimates of coefficient parameters and found that climate financing is the only statistically significant contributor that minimizes the exposure of coronavirus cases at the initial and forecast level. Other variables, including financial literacy, carbon pricing, GDP per capita, and population density, unable to contain the susceptibility of coronavirus cases across countries.

The result implies that climate financing improves air quality indicators that ultimately achieve the healthcare sustainability agenda. On the other hand, carbon pricing and financial literacy are expected to join hands with climate financing to minimize the chances to spread coronavirus cases. However, due to inadequate financial literacy and ease in environmental regulations, these factors cannot explain their positive impact on achieving healthcare policy agendas. Continued economic growth leads to increased coronavirus cases due to increased commercialization activities, while the high population density area remains a risk to spread

Table 4 Descriptive statistics of the key determinants of COVID-19 cases

Methods	COVID19	CFI	FLIT	CPRICE	GDPPC	POPDEN
Mean	1,848,278	− 4.13E − 17	74.271	3.163	14,363.16	285.839
Maximum	28,381,220	4.657	255.017	15.176	58,829.64	7952.998
Minimum	19,598	− 1.784	24.613	− 1.931	500.402	8.822
Std. Dev	4,729,054	1.231	44.091	2.877	16,007.60	1200.504
Skewness	4.522	1.573	2.202	1.827	1.807	6.270
Kurtosis	24.707	6.500	8.758	8.3914	5.001	40.556

COVID19 shows COVID-19 cases, CFI shows climate financing index, CPRICE shows carbon pricing, GDPPC shows GDP per capita, and POPDEN shows population density.

Table 5 Generalized linear model and robust least squares regression estimates

Variables	GLM[a] approach - dependent variable: COVID19	RLS estimator - dependent variable: COVID19_F
CFI	−4.858*	−15,412.52*
FLIT	0.028*	88.245*
CPRICE	0.568*	1886.765*
GDPPC	0.0004*	0.964*
POPDEN	0.001*	11.883*
Constant	–	−18,658.49*
Statistical tests		
Mean dependent variable	1,848,278	1,426,206
Deviance statistic	13,286,082	92,362,402
Pearson statistic	9.21E+10	–
Rn-squared statistic	–	659.6199
Prob(Rn-squared stat.)	–	0.000

* indicates 99% confidence interval. CFI shows climate financing index, CPRICE shows carbon pricing, POPDEN shows population density, and superscript “a” shows z-statistics estimated values.

contagious disease across countries. Domínguez-Amarillo et al. (2020) argued that indoor air quality levels should be green and clean to reduce healthcare sufferings, ultimately minimizing the risk of spreading coronavirus cases. Bashir et al. (2020) concluded that environmental pollutants directly linked with the spread of the COVID-19 pandemic need a greater amount of sustainable healthcare financing to reduce coronavirus cases and environmental pollutants simultaneously. Rupani et al. (2020) confirmed the significant drop down in carbon pollution during COVID-19 due to strict measures adopted to contain coronavirus cases. Thus, it clearly shows that healthcare reforms are directly linked with environmental sustainability to minimize healthcare sufferings and improve air quality levels that need stringent environmental regulations to achieve the stated goals. Ye et al. (2020) point out that the hospital environment is probably a great source of human-to-human transmission of coronavirus cases due to contaminated hospital environment. It is essential to pay urgent attention to cleaning the environment, hospital wards and giving training to prevent infectious disease to healthcare workers and the public to prevent it from contagious diseases. Rume and Islam (2020) discussed both the positive and negative arguments of environmental sustainability and healthcare reforms during the pandemic era and argued that although the pandemic era reduces GHG emissions and restores ecological diversity by adopting strict measures of reducing coronavirus cases, however, it increases national healthcare bills that lead to the severe loss of economic output. The proper implementation for achieving healthcare sustainability is pivotal for reducing healthcare sufferings and improving economic development.

Table 6 shows the VDA estimates of COVID-19 cases and found that carbon pricing will exert a more significant share to influence COVID-19 cases with a variance of 9.083%, followed by per capita income, financial literacy, population density, and climate financing with a variance of 6.400%, 3.245%, 1.821%, and 1.710%, respectively, over a time horizon.

Conclusions

The purpose of this study is to explore the impact of climate finance in advancing the healthcare sustainability agenda by assisting nations in controlling coronavirus cases through carbon pricing and financial literacy in a cross-sectional panel of 43 countries. Along with carbon pricing and financial literacy, the study developed the climate finance index, which functioned as the primary explanatory factor for COVID-19 cases at the initial and projected levels. In comparison, economic growth and population density were moderators of the link between the abovementioned variables. The findings indicate that climate financing has a beneficial

Table 6 Variance decomposition analysis of COVID-19

Month	S.E	COVID19	CFI	FLIT	CPRICE	GDPPC	POPDEN
August 2021	313,200.3	91.148	0.076	1.687	5.778	1.114	0.194
September 2021	372,532.8	84.757	0.133	2.228	9.051	2.021	1.807
October 2021	387,676.2	81.981	0.716	2.057	9.562	3.888	1.792
November 2021	401,369.9	79.636	0.862	3.114	9.240	5.434	1.711
December 2021	405,490.1	78.655	1.258	3.197	9.105	6.094	1.689
January 2022	407,365.5	78.344	1.504	3.177	9.121	6.152	1.699
February 2022	408,542.1	77.962	1.600	3.228	9.105	6.363	1.740
March 2022	409,003.2	77.823	1.674	3.247	9.089	6.372	1.791
April 2022	409,273.3	77.738	1.710	3.245	9.083	6.400	1.821

S.E. shows standard error, COVID19 shows COVID-19 cases, CFI shows climate financing index, CPRICE shows carbon pricing, and POPDEN shows population density.

effect on lowering coronavirus exposure at both the initial and projected levels. Carbon pricing and financial literacy, on the other hand, are impotent to advance healthcare sustainability objectives as a result of greater socializing and commercialization activities after the global relaxation of the lockdown situation. The variance decomposition study indicates that carbon pricing would be critical in reducing carbon emissions and eventually strengthening nations' health and wealth systems to limit worldwide coronavirus infections. According to the study's findings, the following three policy implications are desired for reducing coronavirus exposure across countries, i.e.,

i) Climate financing is a green effort for air pollution reduction. Carbon emissions are the primary cause of environmental degradation, which has a detrimental effect on human health. Unhealthy individuals are more prone to infection by infectious illnesses, including COVID-19. Therefore, there is a more considerable need to enhance climate finance to explore green energy sources and improve energy efficiency. Renewable energy sources are considered environmentally and humane, advancing the global sustainability agenda for healthcare.
ii) Imposing a tax on polluting output is deemed beneficial to enhance environmental quality via carbon reduction. Carbon pricing is a regulation choice made by the government to rein in pollution levels, which ultimately improves the healthcare agenda. Coronavirus is a fatal illness likely to spread by photochemical smog and fuel combustion; thus, it is critical to improving air quality standards to avoid infectious diseases.
iii) Financial literacy acts as a knowledge spillover, allowing for the development of policies to broaden the base of climate finance and the application of carbon taxes on polluting industries. Making the appropriate investment in cleaner production technologies is only achievable with knowledge of green finance instruments that help attain the healthcare sustainability goal. It is desirable to invest in sustainable healthcare technology in order to limit coronavirus cases on a worldwide scale.

Climate funding is critical to fulfilling the healthcare sustainability goal desired for economic growth. Economic progress is impossible without human development; hence, it is critical to invest in human health to protect from communicable illnesses that hinder people from participating in economic output.

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Author contribution HURK: conceptualization, methodology, writing—reviewing and editing. BU: software, formal analysis, writing—reviewing and editing. KZ: methodology, software, formal analysis, writing—reviewing and editing. AAN: supervision, resources, writing—reviewing and editing. MH: formal analysis, resources, validation. GM: resources, visualization, formal analysis.

Data availability The data is freely available at Worldometer (2021) at https://www.worldometers.info/coronavirus/ and World Development Indicators published by World Bank (2021) at https://databank.worldbank.org/source/world-development-indicators.

Declarations

Ethics approval Not applicable.

Consent to participate The study was conducted with equal participation by all authors.

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