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RESEARCH ARTICLE

The impact of coal combustion, nitrous oxide emissions, and traffic emissions on COVID-19 cases: a Markov-switching approach

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Abstract

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) spread to more than 200 countries with a current case fatality ratio (CFR) of more than 2% globally. The concentration of air pollutants is considered a critical factor responsible for transmitting coronavirus disease among the masses. The photochemical process and coal combustions create respiratory disorders that lead to coronavirus disease. Based on the crucial fact, the study evaluated the impact of nitrous oxide (N_2O) emissions, coal combustion, and traffic emissions on COVID-19 cases in a panel of 39 most affected countries of the world. These three air pollution factors are considered to form a lethal smog that negatively affects the patient's respiratory system, leading to increased susceptibility to coronavirus worldwide. The study used the Markov two-step switching regime regression model for obtaining parameter estimates. In contrast, an innovation accounting matrix is used to assess smog factors' intensity on possibly increasing coronavirus cases over time. The results show that N_2O emissions, coal combustion, and traffic emissions increase COVID-19 cases in regime-1. On the other hand, N2O emissions significantly increase coronavirus cases in regime-2. The innovation accounting matrix shows that N2O emissions would likely have a more significant share of increasing coronavirus cases with a variance of 33.902%, followed by coal combustion (i.e., 6.643%) and traffic emissions (i.e., 2.008%) over the time horizon. The study concludes that air quality levels should be maintained through stringent environmental policies, such as carbon pricing, sustainable urban planning, green technology advancement, renewable fuels, and pollution less accessible vehicles. All these measures would likely decrease coronavirus cases worldwide.

Keywords Coal combustion · Nitrous oxide emissions · Traffic emissions · Smog · COVID-19 cases · Switching regression

Introduction

The enormous increase in global average temperature puts high pressure on implementing green and clean environmental policies, which need to attain 'industrial ecology.' This is the newly emerging concept that allows interactive human actions with growth sustainable opportunities to reduce industrial wastes and encourage closed-loop production (Awan 2020a). The globalized world strives hard to devise sustainable policies to shift from blue to green (Awan et al. 2020). The emerging global issue is the high-level smog cause of negative healthcare sustainability. Smoke and fog combined to form 'smog' in the air to cause air pollution. Smog was popularized in the 1911's Manchester conference that proposed specific smog abatement policies to minimize death tools, which were affected millions of peoples and more than thousands of deaths in Great Britain during the autumn of 1909. The two most recognized types of smog, i.e., sulfurous

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smog and photochemical smog -coal fires, aggravated a higher concentration of suspended particulate matter that continued to harm human health. Traffic emissions and nitrous oxide emissions are caused to form photochemical smog that inflames breathing passage and lungs' effect. Thus, respiratory deaths are often higher because of an increased smog concentration level globally (Britannica 2019). In early 1952, lethal smog increased thousands of death tools in London caused by extreme weather conditions and industrial pollution. The Clean Air Act is done to mitigate smog concentration to safeguard health issues in Britain (Martinez 2020).

In many parts of the globalized world, winter smog threatened human life and other living beings to make breathing difficulties, leading to a greater risk of a resurgence of the SARS-CoV-2 virus (Sarfraz 2020). The earlier studies mainly worked on different air pollutions and their impact on the resurgence of COVID-19 cases across countries. Numerous air pollutants fill the literature, probably causing an increase in the susceptibility rate of COVID-19 cases worldwide (Travaglio et al. 2021; Persico and Johnson 2021; Isphording and Pestel 2021; Magazzino et al. 2020). These studies show that different air pollutants are causing an increase in COVID-19 cases and death rates via the channel of poor air quality that negatively affects the residents' healthcare status. In many instances, it is proven that due to adopted strict lockdown measures to contain coronavirus cases, air quality level substantially improved; however, once lockdown lifted, economic activities begin to increase, causing more healthcare damages worldwide (Yu et al. 2021, Bhat et al. 2021). Bashir et al. (2020) examined the relationship between air pollutants and the COVID-19 pandemic in California and found a positive correlation between the stated factors. The result implies that particulate matter, sulfur oxide, nitrogen dioxide, and carbon monoxide are mainly responsible for increasing COVID-19 cases in a country. The study concludes that there is a high need to control air pollutants through stringent environmental regulations to avoid infectious diseases, including COVID-19. Aydın et al. (2020) argued that Turkish air quality levels were considered unhealthy for sensitive groups before the pandemic emerges while it improves subsequent adoption of strict COVID-19 measures to contain the virus. Zoran et al. (2020) concluded that COVID-19 daily new cases directly impact different particulate matters and air quality levels in Milan, Italy. The country's warm weather would not support stopping the virus, while aerosol outdoor airborne might have the ability to diffuse the virus. The need to assess the cost of environmental pollution in terms of virus transmission is crucial for achieving global healthcare sustainability. Travaglio et al. (2021) analyzed the regional and sub-regional air pollution data across the UK. They found that nitrogen dioxide, nitrogen oxides, and ozone linked with the COVID-19 death tolls at the regional level, while nitrogen oxides found a detrimental factor at the sub-regional level. The particulate matter and nitrogen oxides increased the virus' infection rates in the UK Biobank. Thus, increased pollution causes the emergence of new cases of the virus that need to be contained through pollution abatement policies countrywide.

Comunian et al. (2020) found that particulate matters stimulate lung inflammation that ultimately increases the exposure of the COVID-19 symptoms in patients in Italy. The country needs to control air pollutants concentration in the atmosphere to reduce virus transmission's susceptibility. Maggazino et al. (2020) argued that particulate matters predominantly emit from the transport sector cause a high susceptibility rate of spreading coronavirus death rates through respiratory diseases in France. The transportation and logistics sectors should use green energy sources to reduce air pollutants to achieve the healthcare sustainability agenda. Liang et al. (2020) found that nitrogen dioxide increases the risk of coronavirus death tolls due to increasing urban combustion, which leads to significant healthcare issues in the USA. The targeted environmental and healthcare policies for higher emissions regions are needed to contain coronavirus disease, including limiting traffic combustion and urban air pollution, which are likely to cause greater exposure of the virus in a country. Othman and Latif (2021) concluded that a highly dense Malaysian urban population region has a greater risk of non-carcinogenic. In contrast, air pollution concentration is mainly controlled by the country's 'movement control order' containing coronavirus cases. The country needs carbon abatement policies to improve human health to reduce coronavirus death tolls. Ghahremanloo et al. (2021) confirmed that most of the air pollutants significantly decline in COVID-19. Nitrogen dioxide emissions substantially decrease in some East Asian countries during lockdown situations. Thus, the environmental impact of the COVID-19 pandemic found a significant positive on the air quality indicators across countries. Peralta et al. (2021) argued that the Mexican government adopts strict measures to contain coronavirus pandemic that further control primary criterion air pollutants in a country. The country needs to adopt more sustainable healthcare policies to move forward towards green growth agenda in the long run. Table 1 shows the recent strikes of the literature that confirmed the negative environmental externalities exacerbated COVID-19 cases.

Based on the stated literature, the study's contribution is to assess the incidence of COVID-19 cases by different kinds of air pollution that formed the smog. The more significant amounts of burning coal and SO_2 emissions increase smoke and fog in the air, combining them to form smog. Further, the photochemical smog initially found in the early 1950s was considered a new type of air pollution that caused smog. Transport and traffic emissions also contribute to the form of smog. Many other sources formed smog. This study confined our findings to the stated air pollution factors that caused

Table 1 Literature on emissions and COVID-19 nexus worldwide

Authors	Environmental pollutants	Results
Persico & Johson (2021)	Level of $PM_{2.5}$, PM_{10}, and O_3	The ease of environmental regulations increasing environmental pollution, causing the susceptibility of COVID-19 cases.
Vasquez-Apestegui et al. (2021)	Level of $PM_{2.5}$	The particulate matter found a transmission channel that increases COVID-19 cases in Lima, Peru.
De Angelis et al. (2021)	Level of $PM_{2.5}$, PM_{10}, and NO_2	Humidity, the annual concentration of $PM_{2.5}$, and PM_{10} causing COVID-19 cases and mortality in Lombardy, Italy.
Zhang et al. (2021)	Ambient air pollution and COVID-19 cases	The increased concentration of PM2.5, PM10, and NO_2 found detrimental factors that exacerbated COVID-19 cases in China.
Aabed and Lashin (2021)	CO_2 emissions	The concentration of carbon emissions in the air causing the spread of COVID-19 cases in a large panel of countries.
Konstantinoudis et al. (2021)	NO_2 and $PM_{2.5}$ emissions	NO_2 and $PM_{2.5}$ emissions are causing an increase in the COVID-19 mortality risk in the UK.
Marquès et al. (2021)	PM_{10}, NO_2 and O_3 level	The stated environmental pollutants causing a transmission channel of COVID-19 cases in most of the cases in Catalonia, Spain
Tung et al. (2021)	Particulate matter	The particulate matters negatively affected the health of the residents, causing an increase in COVID-19 cases.
Travaglio et al. (2021)	NO_2, NO and O_3	The concentration of stated pollutants correlated with the COVID-19 deaths in the UK.
Isphording and Pestel (2021)	The concentration of PM_{10} level and O_3	The particulate matter and ozone concentration are causing an increase in the severity of the COVID-19 pandemic.

smog, i.e., transport emissions, nitrous oxide emissions, and coal energy production. The study has a unique standing in the earlier work as minimal empirical work has been reported in a large panel of countries that have been covered in this study to collect data of 39 most affected countries of COVID-19 for analysis. The previous studies mostly limited their findings on the following aspects, which includes (i) social and administrative issues regarding the COVID-19 pandemic (Moon 2020; Anser et al. 2020a; Ansell et al. 2020), (ii) increased global poverty risk by spreading infectious diseases (Buheji et al. 2020; Anser et al. 2020b), (iii) COVID-19 measures decrease carbon emissions and increase fertility rate (Anser et al. 2020c; Han et al. 2021), (iv) financial depression in the time of COVID-19 (Thayer and Gildner 2020; Anser et al. 2021a; Ettman et al. 2020), (v) COVID-19 vaccination for cancer patients (Ribas et al. 2021), and (vi) behavioral changes and worries due to coronavirus spread (Barber and Kim 2021). At the same time, few studies show the prevalence of COVID-19 in photochemical smog, for instance, Straka et al. (2021), McClatchey et al. 2021, and Li et al. (2021). These studies are limited to show the few smog factors to assess environmental and health quality across countries. The current study has a broader domain and contributed extensively in the recent literature to monitor the concentration of different smog factors in the air that likely to cause an increasing number of COVID-19 cases in the cross-sectional panel of countries.

Based on the unique study's contribution, the study formulates the four most inspiring research questions that suggest policy formulations globally. First, to what extent can photochemical smog increase the newly infected coronavirus cases globally? This question determines the concentration of nitrous oxide emissions in the air that is likely to cause newly infected cases across countries. Second, does coal combustion spread coronavirus cases? The higher amount of burning coals formed smog that likely to become a carrier to spread new coronavirus cases globally. Third, does COVID-19 cases increase due to an increase in traffic emissions? This question argued that transportation emissions would also be a factor in producing smog, which is likely to cause an increase in COVID-19 cases due to increased healthcare issues. Finally, will smog exacerbate COVID-19 impact globally? The question is essential to determine the risk of mortality in highly dense urban population areas due to increasing pollution levels across countries.

The discussion comes to an end by examining the following research objectives of the study, which helps to make sustainable global healthcare policies, i.e.,

i) To analyze the impact of smog drivers on newly infected coronavirus cases in a cross-sectional panel of 39 countries.
ii) To determine the relationships between the studied factors in inter-temporal setting over the time horizon, and
iii) To examine the impact assessment between the variables in the different regime-based analysis.

The study empirically found the relationship between the stated factors by using Markov switching regression model

and variance decomposition analysis. The nonlinearities often exhibit in the linear regression models that need to assess discrete changes in regimes. Further, variance error shocks are assessed in an inter-temporal setting that determines the impact of different regressors on regressand over time.

Data and methodology

The study used three different smog drivers that likely to an increase in COVID-19 cases, i.e., transport emissions (denoted by SMOG_TE) as a percentage of fossil fuel combustion, nitrous oxide emissions (indicated by SMOG_N2O) in thousand metric tons of equivalent carbon emissions, and energy produced by coal fire (denoted by SMOG_CF) as a percentage of total electricity production. The recently available data of the stated variables on the World Bank (2021) database is used as a reference point. The study's regressand is COVID-19 cases (denoted by COVID19_CASES), where the data is obtained from Worldometer (2020) on 11th February 2021. The study used cross-sectional data of a panel of 39 countries selected based on the higher COVID-19 cases and greater smog concentrations nationwide. Figure 1 shows the aggregation of N_2O emissions in the atmosphere. Simultaneously, the number of COVID-19 registered cases is displayed on a global map with light blue (low concentration and less COVID-19 cases) and dark blue (high concentration and larger COVID cases) panel of 39 countries. The COVID-19 number counts show that the lowest infected patients are 236,333 in Croatia, while the highest infected cases are 27,897,214 in the USA on 11th February 2021. On the other hand, nitrous oxide emissions are lowest in Panama with the value of 1408 thousand metric tons of equivalent carbon emissions while highest in the USA, with 288,878 thousand metric tons of carbon equivalent. The smog traffic emissions and coal combustion are more increased in Sweden and South Africa while less elevated in Ukraine and Pakistan. The trend analysis shows different variations in the smog indicators and COVID-19 cases that vary from country to country in the designated sample of countries, which need critical assessment of the smog data to get any evidence of the exposure COVID-19 cases across countries.

Theoretical underpinning

The study's purpose is to critically analyze the concentration of different smog indicators into the air, possibly be the cause of the resurgence of coronavirus cases in a cross-sectional panel of 39 countries. The study proposed three main theories closely linked to the stated theme of the analysis, i.e., healthcare signalling theory, social-cost theory, and preventive theory. The first theory is related to the information channels through which the government and healthcare professionals signal the general public to be aware of the particular pandemic and suggest possible measures to avoid the disease. The theory's main drivers are information and communications channels, patients record, and awareness about the disease. The social-cost approach is related to the societal damages in increasing infected cases, death tolls, and rising healthcare expenditures. The societal cost can be of two types; one is in the form of patient's health sufferings and their out-of-pocket healthcare expenditures. Another is increasing

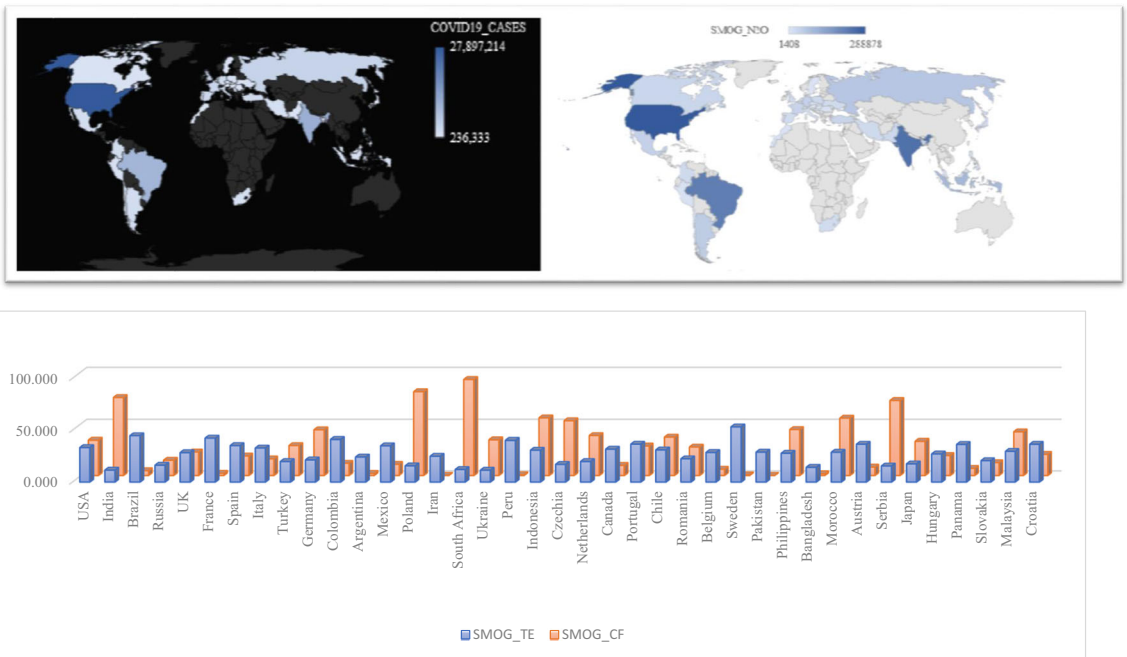

Fig. 1 Smog concentration and COVID-19 cases across countries. Source: Worldometer (2021) and World Bank (2021)

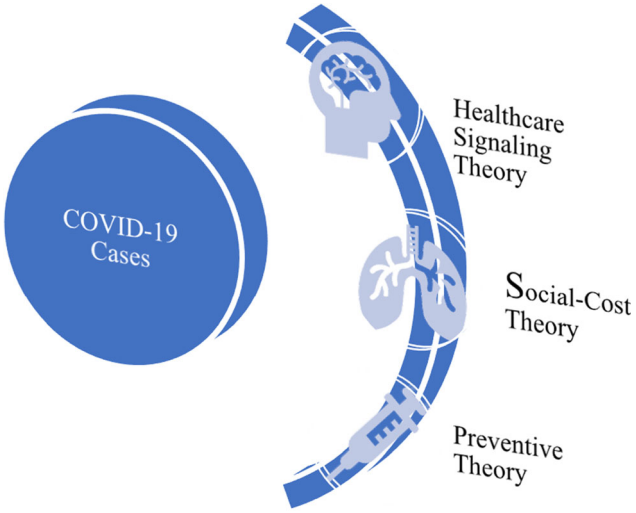

Fig. 2 Theoretical framework of the study. Source: Self-extract

national healthcare bill, insurance premiums, and incidental charges that would rapidly increase in the healthcare crisis. Finally, the preventive theory shows healthcare research and development expenditures' outcomes to get a solution to minimize the risk of infectious diseases through vaccine supplementation or medication. These theories were most evident in the time of the COVID-19 pandemic. The WHO declared the SARS-CoV-2 virus as a pandemic, and government and healthcare professionals inform the general public to safeguard from the coronavirus using different information channels. Thus, positive signalling spread globally, and safety measures have been initiated to minimize the virus' exposure. The societal costs exacerbated both in healthcare damages and monetary outlay in the wake of the COVID-19 pandemic. The higher spending of healthcare R&D expenditures makes a vaccine contain the coronavirus available to the general public in due time. Figure 2 shows the research framework of the study for ready reference.

Econometric framework

Based on the stated theories, the study disseminates the information about smog's vulnerability and its negative effect on the patient's respiratory system to expose coronavirus disease to endorse healthcare signalling theory. On the other hand, the study analyzed social-cost theory to assess the societal damages in infected coronavirus cases by smog concentration. Equation (1) shows a different smog indicator that served as air pollutants and possibly is the cause of an increase in coronavirus cases across countries, i.e.,

$$\begin{aligned} &\text{COVID19\_CASES} = \Gamma_0 + \Gamma_1\ \text{SMOG\_TE} + \Gamma_2 \text{SMOG\_N}\ 2\ \text{O} + \Gamma_3\ \text{SMOG\_CF} + \varepsilon \\ &\therefore \frac{\partial(\text{COVID19\_CASES})}{\partial(\text{SMOG\_TE})} > 0, \frac{\partial(\text{COVID19\_CASES})}{\partial(\text{SMOG\_N}\ 2\ \text{O})} > 0, \frac{\partial(\text{COVID19\_CASES})}{\partial(\text{SMOG\_CF})} \end{aligned} \tag{1}$$

Equation (1) shows that smog factors would likely cause exposure of COVDI-19 cases across countries. The following hypotheses need to be tested to assess the link between the stated variables, i.e.,

H1: The photochemical smog would likely increase COVID-19 cases across countries.
H2: The coal combustion would likely cause an increase in the COVID-19 cases, and
H3: The traffic emissions and COVID-19 cases would likely be a direct relationship between them.

The stated hypotheses need to be checked by statistical techniques. The study used the 'switching regression method' and 'variance decomposition analysis (VDA)' for robust inferences. The Markov two-stage switching regimes method is adopted to find the relationship between the smog factors and COVID-19 cases. On the other hand, the study used forecasting relationships between the stated variables by the VDA method. The switching regression methods have the following advantages over the conventional regression methods, i.e.,

i) Its mathematical computational procedure is relatively simple and tractable, valid in the likelihood functions.
ii) It helps to explore the hidden variables that are not observed primarily in the conventional regression models, and
iii) It is flexible, as one can use different regression functions in their estimation procedure to get other trends in changed regimes.

The VDA method is dynamically used in the VAR setting. The technique allows knowledge about the variability of the regressand explained by their regressors in inter-temporal settings. It understands the VAR model once fitted in a schematic fashion.

Results and discussion

Table 2 shows the descriptive statistics of the interested variables and found that the mean value of COVID-19 cases is 2,462,785 with a standard deviation of 4,747,195 and a high

Table 2 Descriptive statistics

Methods	COVID19_CASES	SMOG_CF	SMOG_N2O	SMOG_TE
Mean	2,462,785	27.47	39,319.36	27.76
Maximum	27,897,214	92.71	288,878	53.28
Minimum	236,333	0.14	1,408	11.41
Std. Dev.	4,747,195	24.60	64,409.08	10.12
Skewness	4.305	0.93	2.84	0.22
Kurtosis	22.680	3.10	10.14	2.52

COVID19_CASES show COVID-19 registered cases, SMOG_CF shows smog formation by coal fires, SMOG_N2O shows smog formation by nitrous oxide, and SMOG_TE shows smog formation by transport emissions

kurtosis value. The coal combustion, nitrous oxide emissions, and traffic emissions have an average value of 27.47% of total electricity production, 39,319.36 thousand metric tons of carbon equivalent, and 27.760% fossil fuel combustion. The nitrous oxide emissions have a higher value of standard deviation, positively skewed distribution, and higher kurtosis value compared to the other smog indicators, which shows a higher dispersion of the matters at a given time.

Table 3 shows the correlation estimates and found that nitrous oxide emissions positively correlate with COVID-19 cases with an estimated value of 0.89, $p < 0.00$. The coal fire and traffic emissions tend to show a low correlation with the COVID-19 cases. The result implies that photochemical smog produced by nitrous oxide emissions is highly toxic for human health, causing lungs and other respiratory infections, which is likely to increase coronavirus disease across countries. It is highly needed to improve human health by reducing air pollution through stringent environmental healthcare policies (Azam et al. 2019; Majeed and Ozturk 2020).

Table 4 shows the two-step, Markov, and switching regime regression approach and found that in regime-1, smog produced by coal fires, nitrous oxide emissions, and traffic emissions negatively affect human health, leading to an increase in the number counts of COVID-19 cases across countries. On the other hand, in regime-2, only nitrous oxide emissions exhibit a positive relationship with COVID-19 cases. The overall results confirmed that air pollution, in general, negatively impacts human health, which leads to exposing the lungs and other respiratory infections. Thus, it is more likely to reveal the affected peoples to the risk of coronavirus cases worldwide. Wang and Su (2020) argued that the COVID-19 pandemic decreases economic activities and traffic volume that support reducing nitrous oxide emissions and improve air quality level in the short run. However, once the lockdown situation is lifted, the economic process will begin to resume, and air pollution would exacerbate, negatively affecting human health. The carbon control measures should strictly define to reduce death counts globally. Islam et al. (2020) confirmed that a high level of pollution leads to more health sufferings that are likely to increase the death counts associated with COVID-19. Carbon monoxide, particulate matter, and nitrous oxide emissions are highly exposed to human health, leading to lung infection and other respiratory diseases, which may increase complications associated with COVID-19. Ma et al. (2020) emphasized the need to increase the knowledge gap about certain air pollutants that may cause to spread of the SARS_CoV-2 virus. The need to know the impacts of air pollution on COVID-19 cases is vital for understanding worldwide carbon abatement policies.

Table 3 Correlation matrix

Variables	COVID19_CASES	SMOG_CF	SMOG_N2O	SMOG_TE
COVID19_CASES	1			
	–			
SMOG_CF	0.08	1		
	(0.63)	–		
SMOG_N_2O	0.89	0.13	1	
	(0.00)	(0.41)	–	
SMOG_TE	0.07	− 0.57	0.01	1
	(0.64)	(0.00)	(0.95)	–

Small bracket shows probability values, COVID19_CASES show COVID-19 registered cases, SMOG_CF shows smog formation by coal fires, SMOG_N2O shows smog formation by nitrous oxide emissions, and SMOG_TE shows smog formation by transport emissions

Table 4 Markov switching regression (BFGS/Marquardt steps)

Variable	Coefficient	Std. error	z-Statistic	Prob.
Regime 1				
SMOG_CF	137900.3	59246.99	2.33	0.01
SMOG_N2O	84.46	5.59	15.11	0.00
SMOG_TE	130514.40	51285.33	2.54	0.01
C	− 5589576	1925383	− 2.90	0.00
Regime 2				
SMOG_CF	444.57	6692.43	0.06	0.94
SMOG_N2O	41.71	2.58	16.11	0.00
SMOG_TE	1200.10	16837.96	0.07	0.94
C	148592.60	612952.20	0.24	0.80
Common				
LOG(SIGMA)	13.39	0.13	95.95	0.00
Transition matrix parameters				
P11-C	1.04	1.21	0.86	0.38
P21-C	− 2.74	0.89	− 3.07	0.00
Mean dependent var	2462785	S.D. dependent var		4747195
S.E. of regression	3281051	Sum squared resid		3.23E+14
Durbin-Watson stat	2.38	Log-likelihood		− 586.60
Akaike info criterion	30.64	Schwarz criterion		31.11
Hannan-Quinn criteria.	30.81			

COVID19_CASES shows COVID-19 registered cases, SMOG_CF shows smog formation by coal fires, SMOG_N2O shows smog formation by nitrous oxide emissions, and SMOG_TE shows smog formation by transport emissions

Table 5 shows the estimates of VDA and found that smog air pollution would play a detrimental effect on human health, leading to an increase in the exposure of coronavirus disease across countries. The smog produced by nitrous oxide emissions would likely increase COVID-19 cases with a proportional variance of 33.90%, followed by the pollution produced by coal fires with a value of 6.64% and traffic emissions with a proportional variance of 2.00% over the time horizon. The smog concentration in the atmosphere is highly toxic that negatively affects the healthcare sustainability agenda. The policies to improve air quality and confine new COVID-19 cases are crucial for long-term sustainable growth.

Based on the stated results, the study highlighted the need to ensure socio-economic and industrial based policies to sustained business activities through artificial intelligence, process innovation, and industrial revolution, which help to achieve healthcare sustainability (Awan et al. 2021a, b). Environmental technology, the role of institutions, stringent environmental policies, and renewable energy demand played a vital role to minimize the cost of carbon emissions worldwide (Ahmed et al. 2020; Ahmed and Bhattacharya 2020). Sustainable innovation also is the viable factor to minimize exogenous shocks and attain a green and clean growth agenda (Awan 2020b; Ahmed and Ozturk 2018). The role of the supply chain process during a pandemic is essential in many aspects, as it ensures the free flow of preventive healthcare equipment to reduce the susceptibility of COVID-19 pandemic worldwide (Anser et al. 2021b). Carbon pricing is another policy option to mitigate carbon pollution (Nassani et al. 2019). The re-corrective measures are highly needed to move forward towards green development (Ahmed and Ahmed 2018; Anser et al. 2020d). Technological embodied supply chain processes would likely become more efficient to minimize adverse environmental shocks (Anser et al. 2020e).

Conclusions and policy implications

The study's primary purpose is to identify the significant atmospheric pollutants that formed a smog in the air that increase lungs and other respiratory diseases, which cause a transmission channel of sensitive increase coronavirus cases worldwide. The study's critical contribution is to project three main healthcare theories linked with infectious disease to

Table 5 Variance decomposition analysis of COVID-19 cases

2021	S.E.	COVID19_CASES	SMOG_CF	SMOG_N2O	SMOG_TE
March	437079.0	76.50	0.15	20.02	3.30
April	528964.9	64.34	2.90	30.49	2.25
May	559674.7	61.70	3.74	32.32	2.21
June	578686.7	59.18	5.89	32.81	2.10
July	588463.3	58.15	6.31	33.48	2.04
August	592896.8	57.80	6.43	33.73	2.01
September	595061.9	57.63	6.51	33.83	2.02
October	596213.8	57.50	6.61	33.86	2.01
November	596849.4	57.44	6.64	33.90	2.00

COVID19_CASES shows COVID-19 registered cases, SMOG_CF shows smog formation by coal fires, SMOG_N2O shows smog formation by nitrous oxide emissions, and SMOG_TE shows smog formation by transport emissions

prepare themselves for the emergence of pandemic plague. Healthcare signalling theory provides a signal to the general public about the outbreak of epidemic disease. In contrast, the social-cost view found the societal damages in healthcare sufferings and out-of-pocket healthcare expenditures. Finally, the prevention theory is designed to get out of the epidemic through make a designated vaccine or medication formulations. This study worked on the first two stated theories, as the emergence of smog causes a severe respiratory disease that may lead to being infected with the SARS_CoV-2 virus. Simultaneously, its societal damage in the concentration of different air pollutants on patients' health suffering is analyzed through computational methods. The study results confirmed the adverse effects of N_2O emissions, coal combustion, and traffic emissions on patients' health that exposed the coronavirus disease. The forecast relationship confirmed that N_2O emissions would likely have a higher variance in increasing COVID-19 cases, followed by coal combustion and traffic emissions. Based on the stated results, the study proposed the three critical policies related to smog control measures that possibly be minimized new COVID-19 cases across countries, i.e.,

i) The photochemical smog concentrations should be reduced by adopting the clean environmental plan, introducing a clean air plan by sustainable fueling, implementing vehicle emissions control measures through electrified vehicles, cutting industrial and power plant emissions by imposing carbon taxes, and reducing marine emissions through compliant fuels. All these measures would be helpful to achieve healthcare sustainability agenda across countries.
ii) The reduction of nitrogen oxide is essential to minimize healthcare issues. The 'catalytic reduction' is vital to lowering the nitrogen oxide levels. The industry and vehicles can use this process to filter out oxides into nitrogen and oxygen. The efficient use of LPG and CNG further reduce volatile organic compounds, and
iii) The use of energy-efficient appliances, smart building designs, use of renewable fuels, limiting wood fuels, and sustainable education, all these measures would help to minimize air pollution level that supports to achieve healthcare sustainability agenda globally. The combustion of fossil fuels has a larger share of air pollution that needs to be reduced by smart pollution control technologies (Rehman et al. 2021; Baloch et al. 2021). Introducing clean power sources is also a desirable step to improve air quality.

The toxicity of anthropogenic activities leads to more death tolls from infectious diseases, including COVID-19. The low immune system and high pollution level are directly linked together. The increased need to improve air quality indicators is desirable to prevent contagious diseases. Society needs to take care of its surroundings and minimize the waste that causes increased healthcare costs, leading to increased COVID-19 cases. Moreover, academia and research scientists need to identify the causal factors that likely to cause the spread of COVID-19 cases globally. Environmental policies should frame with regulatory authorities to monitor air quality levels and reduce air pollution levels by adopting cleaner technologies (Ahmed 2020), using renewable fuels (Ahmed et al. 2021), smart building designing (Eini et al. 2021), and the imposition of emissions-cap trading and carbon taxes (Zaman et al. 2021). These measures would reduce smog formation and ultimately improve human health to reduce coronavirus disease incidence globally.

The study is limited to access few environmental factors that likely to cause an increase in COVID-19 cases. Future research would likely extend it by socio-economic, environmental, and healthcare logistics supply factors to assess the COVID-19 vulnerability across different segments of the society.

Author contribution MKA: Conceptualization, Methodology, Writing-Reviewing and Editing. DIG: Conceptualization, Methodology, Formal Analysis. MAK: Methodology, Formal Analysis. AAN: Supervision, Resources, Software. KZ. Software, Formal Analysis, Resources. MMQA: Resources, visualization, Formal Analysis.

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