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Environmental effect of the Coronavirus-19 determinants and lockdown on carbon emissions

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ABSTRACT

BACKGROUND AND OBJECTIVES: Coronavirus-19 has affected carbon emissions, which was declared as a pandemic by World Health Organization. Unprecedented environmental effects are being caused by Bangladesh's strict lockdown policies, which were implemented to stop the spread of Coronavirus-19. However, it is still unclear how the temporary halting and restart of industrial and commercial activities will affect the environment. In this study, it has been identified how Coronavirus-19 determinants like lockdown, daily confirmed cases, and daily confirmed deaths affect greenhouse gases.

METHODS: From March 18, 2020 to February 4, 2022 the data series is used for Bangladesh. To ensure that the data series were stationary, the Augmented Dickey–Fuller and Phillips–Perron tests were utilized. Johansen co-integration test was utilized to determine co-integration among variables. The Granger causality test was utilized to identify directional causes and effects between Coronavirus-19 determinants and carbon emissions and the Vector Error Correction Model was employed to determine short-run and long run connections.

FINDINGS: The study finds a bidirectional relationship between lockdown, carbon emissions and daily confirmed deaths, while a unidirectional association exists among Coronavirus-19 confirmed cases according to the Vector Error Correction Model. The Granger causality test also established the relationship between variables, except for daily confirmed cases. The pandemic's onset and subsequent lockdown resulted in decreased carbon dioxide emissions. The short-run link of carbon dioxide emissions with newly confirmed cases was corroborated by the directional relationship of variables, whereas there was a long-term and short-term association between confirmed deaths and lockdown.

CONCLUSION: The reduction in carbon emissions during the pandemic will not be long-lasting because it is anticipated that global economic activity will gradually return to the pre-Coronavirus-19 state. The directional and relational nature of lockdown offers the potential to connect carbon dioxide emissions to regular lives. During a lockdown, there is a connection between the atmosphere's changes and how natural organisms behave. Importantly, there is a room for investigation into how communities of organisms and the atmosphere would function without humans. The essential point is to stress that during the lockdown, the ecosystem is self-healing. Environmental activists and business people will find this study useful in developing future sustainable improvement strategies.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
46	3	6

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INTRODUCTION

In December 2019, Wuhan, China, faced a pandemic caused by an extremely infectious virus named coronavirus-19 (Covid-19) (Hui and Zumla, 2019). COVID-19 has had global quality of life and economic ramifications because of its long-term dissemination. Because of the COVID-19 susceptibility, the globe is on the verge of an unmanageable fatality rate. In order to limit the disease's transmission, most countries take some steps to tackle the spread of new emerging variants. According to recent research, successful viral control through widespread lockdowns has slowed the virus's transmission and enhanced the world's total quality of the environment indirectly (Sarfraz et al., 2021). In order to promote an active lifestyle, environmental quality is crucial. Toxic materials such as filth, smoking, intoxicants, and gases are all causes of environmental pollution. Carbon dioxide (CO_2) emissions tend to be the most significant cause of air pollution. Extensive exposure to hazardous environmental circumstances has been proven to be damaging to one's health, with a significant number of people dying each year because of air contamination. CO_2 is a known source of health issues, and it is raising the death rate (Huang et al., 2017). Bangladesh's economy is growing rapidly and the country's industrialization is critical to its development (Mahmood, 2011). According to Bit Error Rate (BER), the industry contributes more than 35% of the gross domestic product and grows at a pace of 13% per year on average. Dhaka, Rajshahi, Chattogram, Narayanganj, Gazipur, and Khulna, for example, are home to nearly all these enterprises (Sabur et al., 2012). There is currently no systematic inventory of air pollution emissions in Bangladesh. In Bangladesh, transportation and chemical contaminants are the most major sources of pollution (Mahmood, 2011). For decades, Bangladesh has been classified as one of the most contaminated nations on the planet. Dhaka is routinely recognized as being among the most contaminated metropolitan areas in the world. According to IQAir (Swiss-based air quality technology company), Bangladesh is once again the most polluted nation in the world. In light of these facts, it is imperative to look into how COVID-19 cases and deaths are affected by Bangladesh's environment. The latest analysis on environmental quality in the world's 50 most congested areas was conducted by Rodriguez-Urrego and Rodriguez-Urrego (2020) and claims Dhaka is the world's second most contaminated city with an estimated annual fine particulate matter ($PM_{2.5}$) level of 97.1 gram per cubic meter (g/m^3). Except for environmental efficiency and sustainability, COVID-19 has had an adverse influence on every aspect of life. To avoid the growth of COVID-19, the worldwide catastrophe people not to leave their houses. All major sectors like institutions, hotels, clubs, and restaurants in Bangladesh were shuttered during the near-global prohibitions. All less important commercial and social activities were closed during the lockdown in Bangladesh, which was enacted under the supervision of police personnel. The preliminary COVID-19 lockdown in Bangladesh helped people realize the severity of the sickness, prompting them to limit their mobility and as a result, influencing environmental circumstances. As a result, Bangladesh's lockdown steps were effective at preventing an increase in COVID cases while also enhancing the quality of the air in key cities throughout the region (Islam, 2020). People become less willing to properly dispose of and recycle their waste as they become more isolated in their homes. Environmental pollution as a result rises. Additionally, the restriction of staying in raises domestic waste, which puts more strain on the environment. As a result, the pandemic has an impact on environmental quality that is both positive and negative.Bangladesh is the world's most polluted country, with air pollution being a major concern. Because air pollution is uncontrollable, it has serious repercussions. Bangladesh has the weakest air quality index in 2020, ranking 162 out of 180 countries. In comparison to the same period in both 2018 and 2019, the air quality in 2020 during the lockdown improved. In comparison to 2018, the Air Quality Iindex (AQI) increased in 2019 by 9.00% and decreased by 9.57% in 2020. The AQI was discovered to be 16.74% lower in 2020 compared to 2019 when the two years were compared. During lockdown, air pollution decreased by up to 25–30% as a result of the closure of coal-fired power plants and other industrial operations. was discovered to have decreased by 36% during the COVID-19 spread out period compared to the same period in 2019, which may be attributable to a decrease in the use of fossil fuels and a ban on driving for vehicles to contain the virus's outbreak (Roy et al., 2020).In terms of pollution, it appears to have the worst performance (EPI, 2020). Carbon emissions are mostly caused by open waste burning, automobile exhaust, and unregulated industrial effluents. Many individuals die each year as a result of the numerous illnesses linked to air pollution (Mahmood, 2011). Their findings suggest that during the global epidemic, environmental factors reduced harmful CO_2 concentrations, improving air quality (Rojas et al., 2021). It implies that the use of automobiles, mobility, and economic activity all affect the emission of atmospheric pollutants such as carbon dioxide. As a result of the stoppage of these operations during COVID-19, carbon dioxide levels have dropped dramatically. According to the findings, environmental protection might be achieved by satisfying environmentally friendly pledges, lowering financial realities and life risks, and promoting environmental practices (Ozturk et al., 2021; Rehman et al., 2021). During the global lockdown period, there was a huge reduction in air pollution. According to research, when the number of verified cases increased exponentially, policymakers in several countries imposed tight controls to prevent the virus from spreading (Higham et al., 2021). The government of Bangladesh has ordered a nationwide lockdown due to the severity of the COVID-19 outbreak. Bangladesh's government imposed isolation measures, travel restrictions, and the closure of markets, factories, and various businesses and institutions. People's daily life have been drastically altered as a result of the lockdown, ensuring that World Health Organization (WHO) requirements are strictly followed. The length of the shutdown however, is determined by the intensity of verified infections in different places. COVID-19, like other countries, forced Bangladesh to shutdown its factories, mass transit, and other anthropogenic activities. Because air quality is inextricably linked to emissions, which are primarily caused by open waste burning, automobile exhaust, and unregulated industrial effluents, a strict lockdown will result in improved air quality. Due to China's industrial shutdown, Isaifan (2020) reported a considerable reduction in N_2O (nitrogen oxide) and carbon emissions (by 30 and 25 percent, respectively). As per recent statistics, 91% of the population lived in areas where the WHO has set minimum sustainability targets. As a result, this topic is extremely important to climatologists all around the planet. Moral conscience ensures a safe environment by reducing the emissions of smoke, CO_2 and NO_2 into the environment. As a result, it is critical to provide a safe state of the environment as needed to shield the environment while also maintaining a comfortable atmosphere in which to protect a person's existence. A study was carried out in Bangladesh to highlight the socioeconomic consequences of COVID-19 (Islam et al., 2020; Shammi et al., 2020; Anwar et al., 2020; Tamang et al., 2020). Climate change has been linked to COVID-19 transmission in some studies that have been conducted in Bangladesh (Hriroy et al., 2020; Islam et al., 2020). However, no research on the COVID-19 lockdown's influence on air quality in Bangladesh has been conducted to our knowledge. Many people's societal structures and lifestyles were dramatically altered because of the COVID-19 epidemic. Furthermore, global mobility limitations and required inspections have influenced carbon emissions. The goal of this study is to determine the impact of contaminant constituents and carbon emissions over the COVID-19 timeframe. As a result, the study emphasizes the underlying relationship between COVID-19 and carbon emissions. The goal of the research is to figure out how annual carbon dioxide emissions affect COVID lockdown durations. This study emphasizes the importance of sustaining the current weather conditions even after the lockdown limitations have been lifted. As a result, the research allows governments to recognize the need for environmental stability while also improving the quality of the environment. Lockdown measures have been effective in reducing ambient levels of air pollution (Khan et al., 2020; Masum and Pal, 2020). According to the studies, COVID-19 has greatly improved air quality and air pollution caused by carbon emissions has decreased dramatically throughout the pandemic crisis (Sarfraz et al., 2021). Data spanning a few weeks to a few months, from the local to the global scale, was used in recent studies to examine how COVID-19-related activities affected air pollutants and GHG (greenhouse gas) emissions. Lockdown procedures generally still have a poor understanding of their importance and effects. As far as we are aware, no research has looked into how CO_2 emissions in Bangladesh have been impacted by COVID-19-related activities. Researchers looked into how COVID-19 determinants like lockdown, daily confirmed cases, and daily confirmed deaths affected greenhouse gas emissions. The main objectives of this study, therefore, were to: i) investigate the effects of lockdown measures due to the COVID-19 pandemic on CO_2 emissions; and ii) investigate the effects of lockdown measures due to the COVID-19 pandemic on CO_2 emissions. The data series used covers Bangladesh from March 18, 2020, to February 04, 2022. This study has been carried out in Bangladesh in 2022.

MATERIAL AND METHODS

Daily data on daily confirmed deaths, confirmed cases, and lockdowns are used to investigate COVID-19's influence on CO_2 emissions. Data was collected for this study from March 18, 2020 to February 4, 2022. The data is broken down into three sections: before the shutdown; during the closure (both strict and partial); and after the shutdown (Sarfraz et al., 2021; Khan et al., 2020). To prevent the pandemic, Bangladesh's government imposed a 10-day curfew on March 26, 2020, which was eventually extended until May 30, 2020. Bangladesh was subjected to its second full lockdown from April 5, 2021 to April 28, 2021 and its third partial lockdown from July 1, 2021 to July 28, 2021. COVID-19 confirmed cases and confirmed death statistics are collected by the Directorate General of Health Services (DGHS). The Carbon emissions data was provided by the US Consulate in Dhaka and the Bangladesh Meteorological Department (BMD). Fig. 1 has shown the contribution of each study variables. In Fig. 1, this study used the natural logarithm of daily confirmed deaths (LNDD) and the natural logarithm of daily confirmed cases (LNDC).

From Fig. 1, it can be observed that carbon emissions decrease during the strict lockdown from March 20, 2020 to May 30, 2020; the same thing happens during the second full lockdown (April 5, 2021 to April 28, 2021); and the third partial lockdown (July 1, 2021 to July 28, 2021).To examine the link between lockdown, carbon emissions, daily confirmed death, and daily death, this study used a variety of statistical methods. The Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are used to look for the unit root in time series data. By employing the Schwartz criterion, this research ran a typical Vector Autregressive (VAR) model to get the best lag. After validating stationarity in the same order of data series, this work performed the Johansen co integration test. The Vector Error Correction Model (VECM) was used to assess short-run associations as well as the pace at which they were adjusted from short to long run. To check the direction of causality among the variables, this study used the Granger causality test. The methodological flowchart has shown in Fig. 2.

The lockdown is regarded as a dummy variable in this study (Sarfraz et al., 2021; Khan et al., 2020). The use of the dummy variable to assign the binary

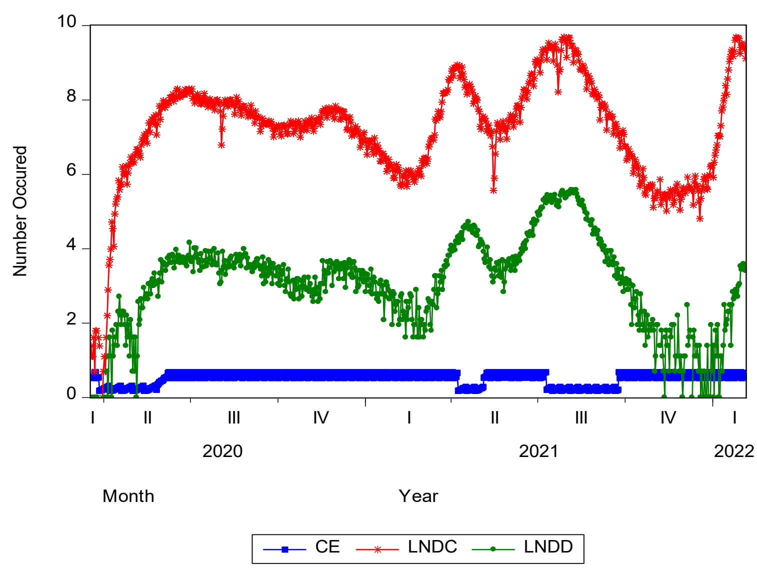

Fig. 1: Contributions of all the study variables

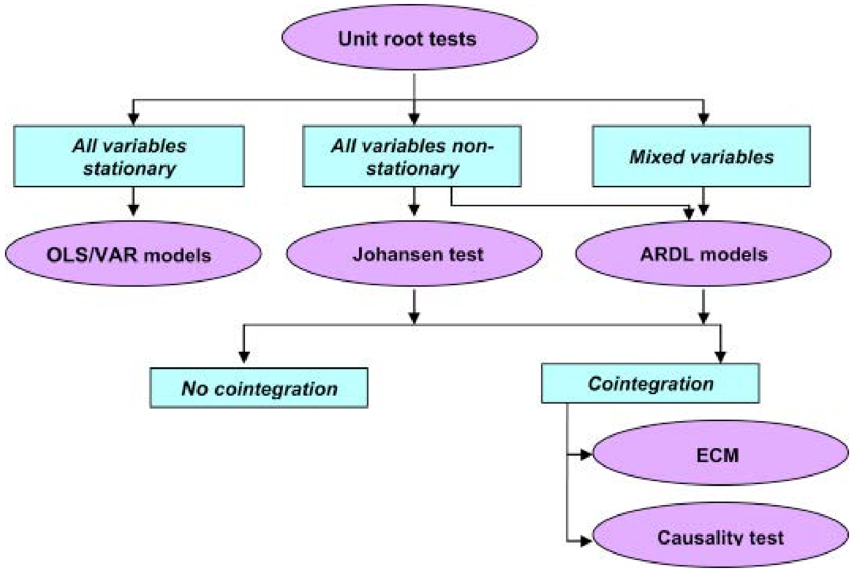

Fig. 2: The methodological flowchart

number is sensible; the lockout period has a value of 1 and the unlocked period has a value of 0.

ADF test

To determine whether the time series data has a unit root, an augmented Dickey–Fuller (ADF) test was used. The theoretical model is as using Eq. 1 (Cheung and Lai, 1995).

$$\Delta X_t = \alpha_0 + \alpha_1 t + \delta X_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta X_{t-i} + \varepsilon_t \quad (1)$$

Where, Δ is a first difference operator, X_t denotes any time series variables (economic growth, trade openness, and government final expenditure), α_0 is a constant, α_1 is a coefficient on a time trend, n isthe lag order of the autoregressive process, and ε_t denotes the random error term.

PP test

For the PP tests, the test regression is using Eq. 2 (Rothe and Sibbertsen, 2006).

$$\Delta y_t = \beta_0 + \beta' D_t + \tau y_{t-1} + u_t \quad (2)$$

Johansen's co-integration test

For selected non-stationary and integrated first-order time series data, Johansen's co-integration test was used to determine the presence of co integrating vectors. The test is run using a vector auto-regressive (VAR) model, which is defined using Eq. 3 (Dwyer, 2015).

$$X_t = \alpha + A_1 X_{t-1} + \cdots\cdots\cdots + A_p X_{p-1} + \vartheta_t \quad (3)$$

Where, X_t is an (n x 1)-dimension vector of variables $\sim I(1)$, and ϑ_t is an (n x 1)-dimension vector of innovations.

Therefore, Eq. 3 can be re-written using as Eqs. 4, 5 and 6 (Dwyer, 2015).

$$\Delta X_t = \alpha + \Pi X_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \vartheta_t \quad (4)$$

Where $\Pi = \sum_{i=1}^{p} A_i - I$ (5)

$$\Gamma_i = -\sum_{j=i+1}^{p} A_j \quad (6)$$

If Π has the rank $r < n$, then there will be ($n \times r$) matrices γ and δ, both having rank r in a way that Π = $\gamma\delta'$, whereas $\delta' X_t$ is stationary. Two likelihood ratio tests (LRTs) utilized to test the significance of the reduced rank of $\prod$ are defined as below.

Trace test

Here, the null hypothesis of *r* cointegrating vectors is tested against the alternative hypothesis of *n* cointegrating vectors. The corresponding test statistic is defined using Eq. 7 (Dwyer, 2015).

$$\zeta_{trace} = -N \sum_{i=r+1}^{n} \ln\left(1-\hat{\zeta}_i\right) \tag{7}$$

Where, *N* isthe sample size and $\hat{\zeta}_i$ denotes estimated eigenvalues ranked from largest to smallest.

Maximum eigenvalue test

Here, the null hypothesis of co integrating vectors *r* is tested against the alternative hypothesis of cointegrating vectors *r + 1*. The corresponding test statistic is defined using Eq. 8 (Dwyer, 2015).

$$\zeta_{max} = -N \ln\left(1-\hat{\zeta}_{r+1}\right) \tag{8}$$

Where, *N* and $\hat{\zeta}_i$ are defined the same as for the trace test.

VECM model

The Johansen's co-integration test was used, which shows that if two or more series are co-integrated, causality exists between them. It is based mostly on a VECM, which includes using Eq. 9 (Hansen and Seo, 2002).

$$\begin{bmatrix}\Delta CE_t\\ \Delta DC_t\\ \Delta DD_t\\ \Delta LD_t\end{bmatrix} = \begin{bmatrix}\mu_1\\ \mu_2\\ \mu_3\\ \mu_4\end{bmatrix} + \begin{bmatrix}B_{11i} & B_{12i} & B_{13i}\\ B_{21i} & B_{22i} & B_{23i}\\ B_{31i} & B_{32i} & B_{33i}\\ B_{41i} & B_{42i} & B_{43i}\end{bmatrix} \begin{bmatrix}\Delta CE_{t-i}\\ \Delta DC_{t-i}\\ \Delta DD_{t-i}\\ \Delta LD_{t-i}\end{bmatrix} + \begin{bmatrix}\theta_1\\ \theta_2\\ \theta_3\\ \theta_4\end{bmatrix}\left[ECT_{t-1}\right] + \begin{bmatrix}\gamma_{1t}\\ \gamma_{2t}\\ \gamma_{3t}\\ \gamma_{4t}\end{bmatrix} \tag{9}$$

Where, CE_t, DC_t, DD_t, and LD_t are carbon emission, daily confirmed cases, daily confirmed deaths and lockdown. ECT_{t-1} is an error-correction term.

Two different tests have been implemented based on the sources of causation as follows:

(a) Short-run causality specifies the underlying association between the time series variables in the short-run, determined through a merged test of the coefficients based on both the $F-$test and the χ^2 test.

(b) Long-run causality specifies the underlying association between the time series variables in the long run, which is tested through lagged Error Correction Term (ECT)in the VECM based on a $t-$test.

The Granger causation test

The Granger causality test establishes the bidirectional association between the variables by adhering to two fundamental principles: The consequence comes before the effect, and the cause holds unique insight into future values. The Granger causality test is estimated using Eqs. 10 and 11 (Guilkey and Salemi, 1982).

$$X_t = \beta_0 + \sum_{j=1}^{k} \beta_{1s} X_{t-s} + \sum_{i=1}^{m} \beta_{2i} Y_{t-m} + \varepsilon_{1t} \tag{10}$$

$$Y_t = \alpha_0 + \sum_{u=1}^{p} \alpha_{1u} Y_{t-u} + \sum_{h=1}^{n} \beta_{2h} + \varepsilon_{2t} \tag{11}$$

If estimated parameter β_{2i} is statistically significant, $\beta_{2i} \neq 0$ then $Y \rightarrow Granger\, cause\, X$ and vice versa.

RESULTS AND DISCUSSION

The Augmented Dickey-Fuller (ADF) and Phillips–Perron (PP) tests were used in our empirical study. Table 1 summarizes the study's findings.

The Akaike information criterion (AIC) was used to find the best lag structure. CO_2 emissions, COVID-19 determinants, and $PM_{2.5}$ levels are all constant at their current levels. According to the ADF and PP tests, all variables are I (0). The results of both tests suggest that the variables are I (1) because the study variables are stationary at first difference. According to Bahmani-Oskooee and Bohl (2000), the long-run connection is determined by the model's appropriate lag section. Using the traditional vector autoregressive (VAR) model, the optimal lag was calculated. The automatic lag specification, which

Table 1: Unit root test results

Variables	Level		First Difference	
	ADF	PP	ADF	PP
DC	-2.4123**	-3.7845**	-3.8745**	-25.1236**
DD	-2.9956**	-1.3625**	-6.5241**	-38.4125**
LD	-2.9237**	-3.2581**	-26.2545**	-26.1452**
CE	-3.4125**	-7.1584**	-6.8745**	-36.7120**

** refer significant at 5% levels of significance. For optimal lag, order SIC is used, and constant and time trend are included in level and first difference.

Table 2: VAR model for optimal lag selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-9505.826	NA	1009363.	28.01421	28.04750	28.02710
1	-6335.424	6284.774	95.58583	18.74941	18.94914	18.82672
2	-6211.132	244.5566	71.34815	17.45694*	18.82312*	18.59869
3	-6173.943	72.62535	68.83402	18.42104	18.95366	18.62722
4	-6151.543	43.41363	69.36710	18.42870	19.12776	18.69931
5	-6043.882	207.0787	54.38128	18.18522	19.05073	18.52026
6	-6002.224	79.51039	51.78429	18.13615	19.16811	18.53563

*indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion
SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Table 3: Unrestricted co integration rank test (trace) and maximum Eigen statistics

Unrestricted Cointegration Rank Test (Trace)					Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized	Eigenalue	Trace	0.05	Probability	Hypothesized	Eigenalue	Max-Eigen	0.05	Probability
No. of CE(s)	Eigenvalue	Statistic	Critical Value	P-value**	No. of CE(s)	Eigenvalue	Statistic	Critical Value	P-value**
None*	0.1179	116.95	47.85	0.0000	None *	0.117	85.85	27.58	0.0000
At most 1*	0.0215	31.09	29.79	0.0352	At most 1	0.021	14.87	21.13	0.2977
At most 2*	0.0147	16.22	15.49	0.0388	At most 2	0.014	10.17	14.26	0.2006
At most 3*	0.0088	6.046	3.84	0.0139	At most 3 *	0.008	6.04	3.84	0.0139

Trace test indicates 4 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis p-values (acquired by software)

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis p-values (acquired by software)

is "2," is chosen using the AIC Criterion (Sarfraz et al., 2020). The findings of Standard VAR model have shown is Table 2.

Table 3 summarizes the findings of the co integration test. The co integration test is used to determine whether variables have a long-term relationship. The trace test and max eigenvalues are further elaborated by the Johansen co integration test. The null hypothesis $r=r^*<k$ was severely rejected by the trace test, but the alternative hypothesis $r=k$ was accepted. The null hypothesis of max eigenvalues is like that of the trace test, except that the alternative is $r=r^*+1$. Under "all" conditions, the significance and co integration were confirmed, showing a 4-cointegrating equation at a 1% significance level. Under the "none" and "at most 3" conditions, the maximum eigenvalues are also significant, indicating two co integrating equations at a 1% significance level.

The findings of the trace and max eigenvalues test results are shown in Table 4. The long-run nexus between variables can be double-checked using this co integration equation. Although the nature of the relationship is negative and positive, the co-integration equation confirms the long-run link. The daily confirmed COVID-19 instances and the lockup

Table 4: Co-integration coefficient normalized

1 Cointegrating Equation(s)		Log likelihood	-6218.428
Normalized cointegrating coefficients (standard error in parentheses)			
CE	DC	DD	LD
1.000000	1.01E-05 (4.9E-06)	-0.000630 (0.00032)	0.392854 (0.02649)

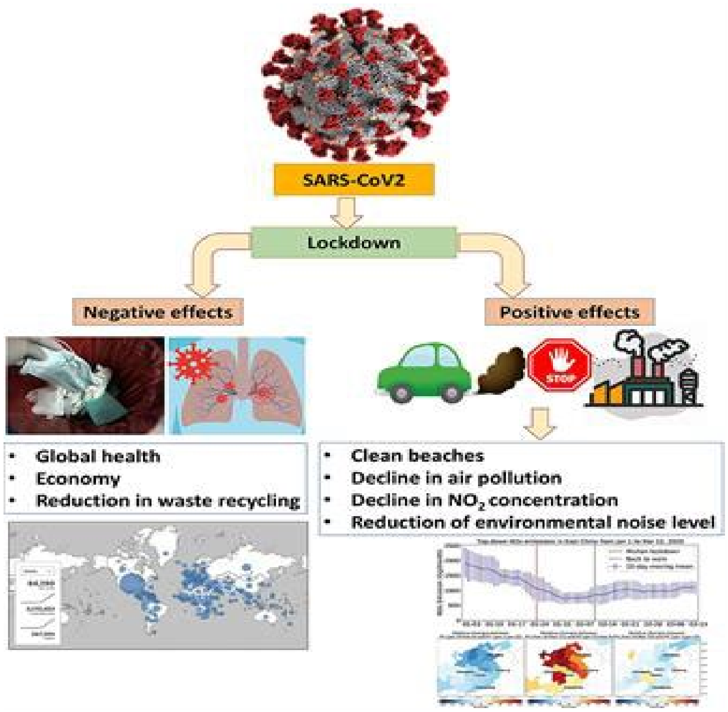

Fig. 3: COVID-19, lockdown and the effects on the world
(Kumar *et al.,* 2020)

have revealed a downward trend in carbon emissions. The daily-confirmed deaths, on the other hand, show a downward trend in carbon emissions.

COVID-19 has both beneficial and negative environmental implications, as shown in Fig. 3. The VECM results are shown in Table 5, which detail the short- and long-run associations as well as the causative direction of each variable separately. The short run and long run results of vector error correction model has shown in Table 5.

The 3rd difference of carbon emissions is bidirectionally related with daily confirmed death indicates that, $CE_3 \rightarrow DD_3$ at 5% level of significance. Carbon emissions is unidirectionally related with lockdown at 2nd, 3rd and 4th difference indicates that $CE_{234} \rightarrow LD_{234}$. The negative value of -2.04 shows that strict lockdown reduced the carbon emissions by 2.04% (Sarfraz et al., 2021; Andreoni, 2021). At 4th difference bidirectional relationship is observed between the carbon emission and lockdown (Rehman et al., 2021). At the 1%, 5%, and 10% levels of significance, daily confirmed cases at the first, second, third, and fourth difference have unidirectional and positive links with carbon emission (Amankwah-Amoah, 2020; Rume and Islam, 2020). On the other hand, daily confirmed cases and daily confirmed death are bidirectionally related with 1st and 3rd difference indicates that $CE_3 \leftrightarrow DD_1$ and $DC_3 \leftrightarrow DD_3$ at 1% level of significance. Daily death has

Table 5: Vector error correction for short-run and long run estimates

	Short run				Long run
Error Correction	ΔCE	ΔDC	ΔDD	ΔLD	ECT_{t-1}
$\Delta CE-1$		-822.3177	-16.38405	0.058511	
$\Delta CE-2$	----	69.87103	-14.17230	-2.043243**	-0.211106*
$\Delta CE-3$		-120.3471	-6.151469*	-1.048555*	
$\Delta CE-4$		-364.1135	-2.722536	3.034546*	
$\Delta DC-1$	1.35E-06*		0.001427*	8.14E-06	
$\Delta DC-2$	4.36E-06**	----	-0.000686	-3.56E-06	-122.7422
$\Delta DC-3$	8.59E-07**		7.48E-05*	4.53E-06	
$\Delta DC-4$	2.48E-06***		-0.000865	3.46E-06	
$\Delta DD-1$	0.000248	29.26039*		0.000223	
$\Delta DD-2$	2.67E-05	6.876815**		0.000616	
$\Delta DD-3$	-0.000336**	4.220957*	----	0.000160	16.29079*
$\Delta DD-4$	0.000299	-0.414999		0.001042***	
$\Delta LD-1$	0.021667	-35.88643	2.014360		
$\Delta LD-2$	0.025130	-415.4054**	-2.813864	----	-0.041968**
$\Delta LD-3$	-0.014291	646.9145**	0.294615		
$\Delta LD-4$	0.032560***	-189.3730	-7.601609**		
C	-0.000177	18.85935**	0.074174	-0.000326	

*, **, and *** are representative of 1%, 5%, and 10% levels of significance, respectively.

Table 6: The Granger causality test

Direction of causality	df	Chi-square	p-value
DC	4	9.23347**	0.0274
DD	4	12.87452*	0.2030
LD	4	5.69321	0.0021
ALL	12	22.36521*	0.0020

*, **, and *** are representative of 1%, 5%, and 10% levels of significance, respectively.

negative unidirectional link with carbon emissions at 3rd difference at 5% level of significance. At 10% level of significance lockdown has positive link with the carbon emissions at 4th difference. The long run cointegration results also shown in Table 5. The findings indicates that except daily confirmed cases all variables have long run relationship. At 1% level of significance carbon emissions and daily confirmed death and at 5% level of significance lockdown are significant for the long run. To investigate the causality among the study variables, Granger causality test has performed, and the results has been shown to Table 6. The connection patterns are discovered by examining empirical data sets for probabilistic causality theories. At 1% level of significance, carbon emissions, lockdown, daily confirmed deaths, and daily confirmed cases have all shown the significant link. Because the mortality rate is very certainly based on new verified cases, the newly confirmed fatalities have no bearing on the cross-check results. This outbreak is expanding, and people aren't getting good medical care yet, but none cannot predict how long it will last. As the death rate declines, medical professionals around the world continue to work on developing a proper therapy or vaccination.

Carbon emissions, COVID-19 daily confirmed cases, COVID-19 daily confirmed deaths, and lockdown are all stationary at the first difference, according to the ADF and PP tests. (Sarfraz et al., 2021; Rume and Islam, 2020). This study have chosen lag "2" by using standard VAR model employing AIC Criterion. Johansen co integration test such as Trace test and maximum eigen value test confirmed cointegration among the study variables. The COVID-19 lockup and daily confirmed COVID-19 incidents have showed a decrease trend in carbon emissions. On the other hand, daily confirmed deaths show a declining trend in carbon emissions. According to the VECM model, the third difference in carbon emissions is bidirectionally associated to a daily confirmed mortality at a 5%

level of significance in the short run. At the second, third, and fourth differences, carbon emissions are unidirectionally connected to lockdown. Strict lockdown reduced carbon emissions by 2.04%, as indicated by the negative number of -2.04. COVID-19's death has increased the number of confirmed cases. As if the new confirmed instances will increase the death rate, which is almost guaranteed to happen (Long and Li, 2021). Except for daily verified instances, the findings show that all factors have a long-term association (Abbasi et al., 2021; Sarfraz et al., 2021). Carbon emissions and daily confirmed deaths are significant at a 1% level of significance, and lockdowns are important at a 5% level of relevance in the long run. Examining empirical data sets for probabilistic causality theories reveals the link patterns. The lockout, new verified COVID-19 cases, and carbon emissions all exhibit strong connections, implying that the link is still active. CO_2 emissions are mostly caused by significant energy consumption in daily transportation, trade, industrial activity, and other activities (Tian et al., 2022; Yang et al., 2021). The COVID-19 global epidemic is first and probably most important a global serious health hazard with serious health and economic consequences, but it has also had positive effects on the environment that could serve as an example and encouragement for future changes in behavior that will help us achieve positive changes in the environment (Jia et al., 2021; Bar, 2021; Bray et al., 2021). The present worldwide pandemic has pushed us to pause and consider alternative scenarios. The lockdowns demonstrate that a cleaner environment is feasible (Ray *et al.,* 2021; Nguyen *et al.,* 2021; Rugani and Caro, 2020). The global epidemic is revealing a link between pollutant emissions and major economic activities like manufacturing, transportation, and energy production, as well as tiny disruptions at the city level. As a result, suitable techniques for preventing environmental degradation should be implemented. The lockout gives people confidence that human intervention in the environment can be minimized. Governments and individuals should use the tactics mentioned below to make positive changes in the environment (Khan et al., 2021) as: 1) Transportation management and safety checks; 2) Trains or buses i.e., public transportation, that runs smoothly; 3) Enhancing transit planning; 4) Using environmentally friendly products; 5) Chlorofluorocarbons (CFCs) should be used even less than conceivable; 6) Biofuels are increasingly being used; 7) supporting garbage recovery and recycling; 8) Neonicotinoids are being used less frequently; 9) Avoid the use of toxicants as much as possible; 10) Do not waste water unnecessarily; 11) Reforestation; 12) Before sewage enters the environment, it is treated and solid, suspended, and inorganic pollutants are removed. COVID-19 demonstrated that the world was ill-prepared to handle an increase in medical waste, but it also offers a chance to address a challenge that has substantial ramifications for reducing climate change, combating pollution, and developing robust medical systems. Strengthening systems to safely and sustainably reduce and manage medical waste is possible in light of the COVID-19 waste challenge and the pressing need to address environmental sustainability (Ray et al., 2022). Strong domestic rules and practices, regular measuring and reviewing, public transparency, support for behavior change and employment services, as well as increased budgets and financing, can all be used to achieve this. The use of sustainable packaging and shipping, safe and reusable personal protective equipment (PPE), recyclable or biodegradable materials, investments in non-burn waste disposal innovations, such as sterilizers, recycled content to support centralized treatment, and investment opportunities in the recycling industry to ensure components, like plastic products, can have a second life are all recommended (Nicolini et al., 2022). The current study has a few limitations. Daily completed tests, the number of clinical isolates, public resistance, internal migration, and other human behaviors, as well as cultural and economic factors, can all complicate COVID-19 transmission, and these factors were not considered in the study. Another limitation is that this study only look at Dhaka, the capital of Bangladesh. The study findings are also relied on data from the outside meteorological environment, which is one of the study's significant shortcomings. SARS-CoV-2 transmission, on the other hand, can be influenced by the environment.

CONCLUSION

The impact of the COVID-19 determinant and lockdown on carbon emissions was investigated in this study. The cointegration test verifies the long-term link between the chosen variables. According to the VECM model, there is a short-term and long-term relationship (bidirectional or unidirectional) between carbon emissions, daily confirmed deaths, daily confirmed cases, and lockdowns. The findings backed up the theory that lockdowns cause a reduction of carbon emissions. The existence of a relationship between study variables is established by the Granger causality test. Granger causality results have revealed that daily confirmed COVID-19 cases are of no consequence. During the COVID-19 incident, certain critical lessons were learned as outlined in this study. For human survival and existence, the environment is a very crucial factor. For a sustainable ecosystem, this research advises that governments, legislators, and corporations minimize harmful gas emissions. The findings of this study, on the other hand, will be valuable to policymakers and other management authorities in devising effective solutions to solve air pollution and global warming challenges. The study is significant because it can predict the association between air pollution and associated atmospheric variables such as reduced atmospheric temperature and greenhouse gas emissions. Future research on urban heat islands and their impact on overall environmental sustainability can benefit from the findings of this study. Because air pollution is one of the key drivers of urban heat islands, future studies on urban heat islands should consider this. To reduce emissions of significant air pollutants, urban planners should adopt suitable measures, such as lowering traffic congestion, enforcing the odd–even vehicle rule, vowing to drive one day less per week, and imposing tough rules for the toxic industry. During this COVID-19 lockdown period, governments and global environmentalists acknowledge that various shutdowns are required to break the cycle of future viral infections. The world also realized that environmental protection and ecological sustainability serve as primary deterrents to outbreaks. To avoid future pandemics, a sustainable ecosystem must be achieved. In terms of greenhouse gas emissions, the lessons learned from COVID-19 can be applied to the rest of the world. Global transportation, climate, and environmental policies that encourage carbon emissions must be changed, and concerned authorities must work hard to do so. Overall, the results give stakeholders and decision-makers guidance for creating and putting into action carbon emission control measures that will support a green life.

AUTHOR CONTRIBUTIONS

The study conceptualization, methodology, software, data analysis and validation were performed by R. Parvin. F. Tuj Johora performed the draft preparation. A. Alim performed the visualization and reviewed and editing the paper.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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PUBLISHER'S NOTE

ABBREVIATIONS

%	Percent
ADF	Augmented Dickey–Fuller
AIC	Akaike Information Criterion
AQI	Air quality index
BER	Bit error rate
BMD	Bangladesh Meteorological Department
CE	Carbon emissions
CFCS	Chlorofluorocarbons
CO_2	Carbon- di-oxide
COVID-19	Coronavirus -19
DC	Daily confirmed cases
DD	Daily confirmed deaths
DGHS	Directorate General of Health Services
GHG	Greenhouse gas
HQ	Hannan-Quinn information criterion
EPI	Experimental Performance Institute
FPE	Final prediction error
IUBAT	International University of Business Agriculture, and Technology
IQAir	Swiss-based air quality technology company
Lag	lagging behind
LD	Lockdown
LNDC	Natural logarithm of daily confirmed cases
LNDD	Natural logarithm of daily confirmed deaths
Log	Logarithm
LR	sequential modified LR test statistic
LRT	Likelihood ratio tests
NO_2	Nitrogen Dioxide
N_2O	Nitrogen oxide
$PM_{2.5}$	Fine particulate matter
PP	Phillips–Perron
PPE	Personal protective equipment
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SC	Schwarz information criterion
WHO	World Health Organization
VAR	Vector Autregressive
VECM	Vector Error Correction Model

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