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COVID-19, CO_2 Emissions and Energy Consumption in Asian Countries: An Application of Stirpat and Beck's Theory of Risky Society

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ABSTRACT

Since 2019, the global economy has faced unpredictable consequences of the COVID-19, which reshape various aspects and mechanisms of economic market sides. This paper aims to ascertain the linkage between COVID-19, carbon dioxide emissions, and energy consumption in 34 Asian countries throughout 1990–2019. To this end, the panel data approach based on the stochastic impact by regression on population, affluence, and technology (STIRPAT) is employed. The significant results reveal that the COVID-19 accelerates environmental pollution in Asia. Moreover, a 1% increase in total population and GDP per capita of the sampled Asian counties leads to increased CO_2 emissions by approximately 0.28% and 0.09%, respectively. Regarding energy consumption, renewable energy consumption has a negative coefficient, meaning that by using 1% more green energy resources in the examined Asian countries, the CO_2 emissions may reduce by nearly 0.17%. A 1% increase in fossil fuel consumption may increase carbon dioxide emissions by 1.43%. Establishing green finance funds to attract private investors in green energy projects is highly recommended as a central practical policy. These policies should be drawn attention by the policymakers in developing nations, particularly during and for post COVID era.

1. Introduction

Since 2019, the COVID-19 pandemic has been a significant concern for the global economy, especially for our global future, which should be a better place for all people worldwide. The COVID-19 is not only considered in terms of the new origin of mortality but also its consequences on the economic structures and mechanisms and even on daily livelihood are questionable and remarkable. If we consider the income per capita as a welfare indicator of countries, according to the World Bank report (Figure 1), all countries are experiencing a reduction in this variable, meaning the welfare problem in societies. This situation can be predicted at a worse level soon during 2021–2023 for emerging markets, developing nations, and less-developed countries with insufficient financial funds to make a rapid and efficient economic recovery under the COVID-19 circumstances.

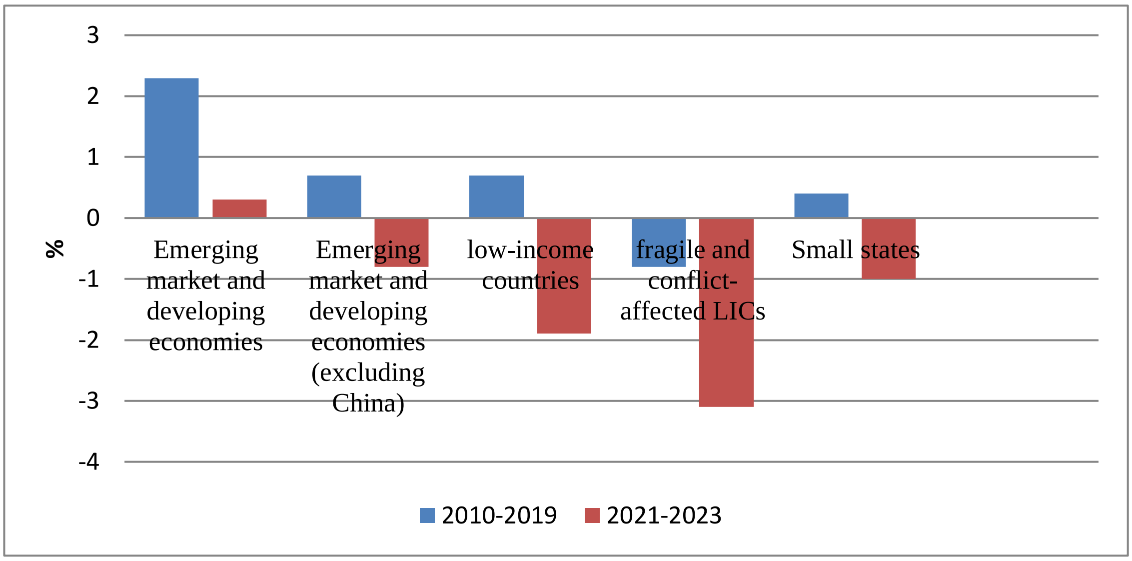

Figure 1. The income per capita in different groups of countries (%).

Note: the list of small states can be accessed from https://www.worldbank.org/en/country/smallstates/overview; LICs stands for low-income countries
Source: Authors' compilation from The World Bank (2021).

Generally, making the earth a better place for living is the main priority of international organizations, and they regularly represent recommendations and policies to countries to reach a better place with lower environmental pollution. Among these international organizations, the United Nations proposed 17 Sustainable Development Goals (SDGs) for countries to place as their priorities in planning and prospects. The related SDGs to climate change and environmental pollution are no poverty (SDG #1), affordable and clean energy (SDG # 7), sustainable cities and communities (SDG # 11), climate action (SDG #13), and life and land (SDG #15).

The critical point of view is that the ongoing challenge of the COVID-19 may adversely affect reaching the defined sustainable development goals in countries, particularly the ones with a lower level of development. New studies have discussed the negative impact of COVID-19 on sustainable development. For example, Fagbemi (2021) discussed that the pandemic of coronavirus harshly decelerates the progress of SDGs around the world, and it has become a potential threat for our globe. In another study, Marazziti et al. (2021) expressed that the COVID-19 helps countries combat climate change and air pollution. By employing stimulating policies, the countries can go faster in the energy transition from fossil fuels toward green energy resources. In a new study, Nundy et al. (2021) addressed the pandemic as a threat to achieving the SDGs, which causes a long delay in implementing sustainable development plans in countries.

The current challenge of the coronavirus outbreak and the necessity of countries to combat environmental pollution and lower the threat of climate change motivate us to carry out this research for the case of different regions in Asia. Despite a few groups of studies about the impact of COVID-19 on environmental pollution (e.g., see Andreoni 2021; Sikarwar et al. 2021; Zhang et al. 2021), the authors did not find any in-depth paper focusing on the regional study of the impact. Therefore, this paper tries to fill in this literature gap.

To academically measure the impact of COVID-19 on environmental pollution, general theoretical approaches such as stochastic impact by regression on population, affluence, and technology (STIRPAT) are carried out to evaluate the role of societies on environmental variables. These theoretical approaches have been employed by a vast number of scholars like Fan et al. (2006) for a group of countries, Wang et al. (2013) and Zhang and Zhao (2019) for China, and Gani (2021) for 59 countries.

The study case in this paper is Asian nations with impressive economic potential and a high contribution to carbon dioxide emissions worldwide. Based on the ADB's report of Asia 2050, it is predicted that by 2050, Asia will be the significant dominant economic player and carbon dioxide emitter in the world. Therefore, the study of the relationship between COVID-19, CO_2 emissions, GDP per capita, and energy consumption for the case of Asian nations is vital and worthy of investigation.

The research structure is as follows: First, the literature gap that the paper tries to fill is discussed in Section 2. The following section represents the theoretical approach to making empirical equations. Section 4 expresses information about data and econometric estimation. The empirical results are argued in Section 5, and lastly, Section 6 provides the concluding remarks and significant policy implications.

2. Literature review

Since last 2019, many scholars have studied the dimensions and consequences of the coronavirus pandemic from various economic, political, social, and other aspects. Based on the research problem of our paper, the group of studies exploring the environmental impacts of the COVID-19 has been addressed in this section.

In a study, Aghashariatmadari (2021) studied the impact of lockdown from the COVID-19 on air pollution in Tehran, Iran. He found out that the COVID-19's lockdown increased air pollution due to removing the traffic control policy and reducing using public transportation. Ghahremanloo et al. (2021) investigated the relationship in the case of East Asia, and the significant findings did not approve the significant impact of COVID-19 on environmental pollution. Andreoni (2021) sought to determine the impact of the pandemic on CO_2 reduction in Europe. He concluded that travel ban and lockdown due to the pandemic have a significant role in reducing carbon dioxide emissions. Using a global vector autoregressive approach, Smith et al. (2021) estimated the impact of the pandemic on fossil fuel consumption and carbon dioxide emissions. The significant findings revealed that there is not any relationship between the pandemic and environmental pollution in the long run. In another study, Wang et al. (2020) found out that a 1% decrease in the rate of COVID-19 cases may reduce CO_2 emissions by approximately 0.22%. Wang and Wang (2020) studied the impact of the pandemic on carbon emissions and concluded that trade protectionism under the COVID-19 leads to a higher energy intensity which may lead to higher CO_2 emissions in developing nations. In another new study, Hoang et al. (2021) revealed that the pandemic reduces the speed of progress of energy transition, and it urges countries to make policies to develop more sustainable energy resources. Zhang et al. (2021) evaluated the relationship between CO_2 emissions and energy consumption under the pandemic in China. The significant findings show that the policies, such as lockdown and vaccination, for controlling the pandemic can decrease carbon dioxide emissions in China, which is against the ideology of liberalism and mobility of labor and capital.

Considering the studies mentioned above, it can be expressed that there is a clear literature gap of evaluation of the relationship between environmental pollution and the COVID-19 for the case of Asian economies. Hence, this paper seeks to fill this literature gap through the STIRPAT approach.

3. Theoretical background

To measure the impact of the COVID-19 pandemic on environmental pollution in 38 Asian nations, we consider an approach based on the STIRPAT framework.

The STIRPAT approach is a well-known theoretical framework to evaluate the human impacts on the environment. This approach is the updated version of the IPAT model proposed by Ehrlich and Holdren (1971), who tried to find the linkage between environmental impact, population, and human well-being.

We can have the following conceptual framework to choose independent and explanatory variables.

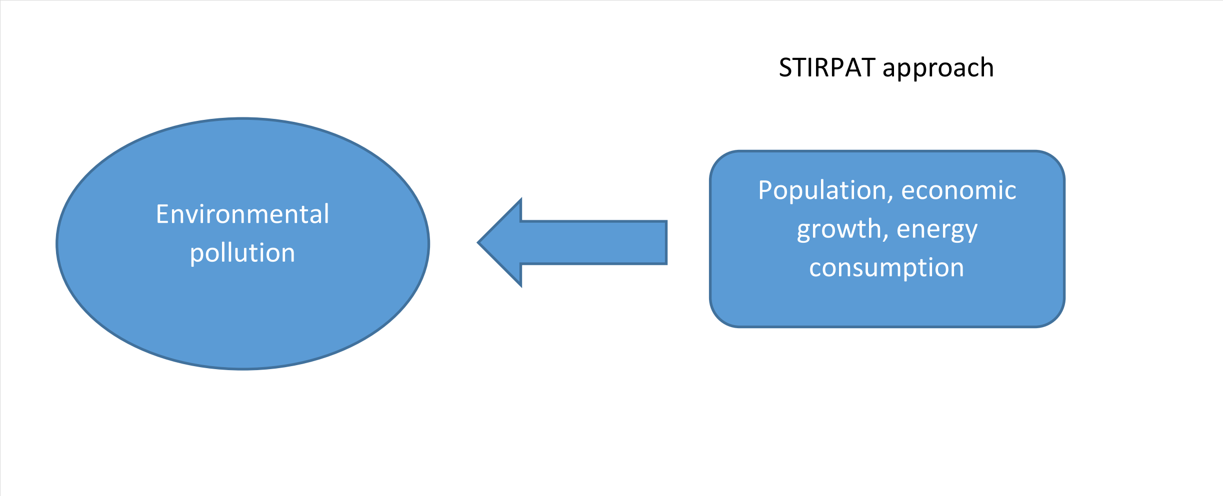

Figure 2. The conceptual framework of research.

Source: Authors

According to the aforementioned conceptual framework, the variables of the empirical model are determined as follows:

Environmental Pollution = F (COVID19, Population, economic growth, energy consumption) (1)

Considering proxies, the above equation can be transformed to the regression format in Equation (2):

$$lCOPC_{it} = \alpha_0 + \alpha_1 COVID_{it} + \alpha_3 lPOP_{it} + \alpha_4 lGDPPC_{it} + \alpha_5 lNREC_{it} + \alpha_6 lREC_{it} + \varepsilon_{it} \quad (2)$$

where COPC is CO_2 emissions per capita, COVID is a dummy variable. POP and GDPPC indicate total population and GDP per capita, while NREC and REC represent nonrenewable energy consumption and green energy consumption, respectively.

4. Data and methodology

Based on Equation (2), we have CO_2 emissions per capita as the dependent variable, COVID as an explanatory variable, and population, GDP per capita, renewable, and nonrenewable energy consumptions as control variables. All the data on the 34 Asian countries based on the United Nations geoscheme, including (Central Asia (Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan), Eastern Asia (China, Japan, Republic of Korea), South-Eastern Asia (Indonesia, Lao, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam), Southern Asia (Afghanistan, Bangladesh, Iran, India, Nepal Pakistan, Sri Lanka), Western Asia (Armenia, Azerbaijan, Bahrain, Cyprus, Georgia, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates)), throughout 1990–2019. Table 1 represents the descriptive information about the data of our model:

Table 1. Descriptive information of variables.

Variable	Symbol	Unit	Source
CO_2 emissions per capita	COPC	Metric tons per capita	World Bank, BP, EIA
COVID	COVID	It takes one over 2020 and zero in other years	WHO Coronavirus Dashboard
Total Population	POP	number	World Bank
GDP per capita	GDPPC	Current US$	World Bank
Renewable energy consumption	REC	Mtoe (Millions of tonnes of oil equivalent)	BP, EIA
Non-Renewable energy consumption	NREC	Mtoe (Millions of tonnes of oil equivalent)	BP, EIA

Source: Authors

Before applying the cointegration panel estimation, the preliminary checking through the panel unit root tests should be done to explore whether there is any unit root among series. To this end, we use four-panel unit root tests proposed by Breitung (2000), Pesaran (2007), Hadri (2000), and Im et al. (2003). If the series has a similar order of integration, the Pedroni cointegration (Pedroni 1999), Kao (1999), and Westerlund (2007) tests are applied to find out the presence of long-run relationship among variables. Having established the presence of long-run cointegration among variables, we contribute to estimating the long-run coefficients of explanatory variables using the fully modified OLS (FMOLS), which was proposed by Pedroni (2004) and had the following estimator:

If we consider the following panel data equation (Equation (3)) where Y and X have long-run cointegration:

$$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it} \quad (3)$$

The Pedroni's FMOLS estimator is:

$$\hat{\beta}^*_{FMOLS} = \frac{1}{N}\sum_{i=1}^{N}\left[\left(\sum_{t=1}^{T} X_{it} - \bar{X}_i\right)^2\right)^{-1}\left(\sum_{t=1}^{T}\left(X_{it} - \bar{X}_j\right)Y^*_{it} - T\hat{\gamma}_i\right)\right] \quad (4)$$

In Equation (4), Y^*_{it} is $Y_{it} - \bar{Y}_i - (\hat{\Omega}_{2,1,i}/\hat{\Omega}_{2,2,i})\Delta X_{it}$ and $\hat{\gamma}_i$ is$\hat{\Gamma}_{2,1,i} + \hat{\Omega}^0{}_{2,1,i} - (\hat{\Omega}_{2,1,i}/\hat{\Omega}_{2,2,i})(\hat{\Gamma}_{2,2,i} + \hat{\Omega}^0{}_{2,2,i})$.

Next, the panel Granger causality test based on error correction model (ECM) with two steps (Engel and Granger 1987) is applied to explore the direction of the relationship between variables. In the first step, the residuals are obtained from the estimation results by FMOLS, and then in the second step, the short-run ECM is evaluated. This Granger causality test for the main variables (CO_2 emissions per capita, GDP per capita, population, renewable energy consumption, and fossil fuels consumption) is based on Equation (5):

$$\Delta LCOPC_{it} = \alpha_{1i} + \sum_P \alpha_{11ip}\,\Delta LCOPC_{it-p} + \sum_P \alpha_{12ip}\,\Delta LGDPPC_{it-p} + \sum_P \alpha_{13ip}\,\Delta LREC_{it-p} + \sum_P \alpha_{14ip}\,\Delta LNREC_{it-p} + \varepsilon_{1it}$$

$$\Delta LGDPPC_{it} = \alpha_{2i} + \sum_P \alpha_{21ip}\,\Delta LCOPC_{it-p} + \sum_P \alpha_{22ip}\,\Delta LGDPPC_{it-p} + \sum_P \alpha_{23ip}\,\Delta LREC_{it-p} + \sum_P \alpha_{24ip}\,\Delta LNREC_{it-p} + \varepsilon_{2it}$$

$$\Delta LREC_{it} = \alpha_{4i} + \sum_P \alpha_{41ip}\,\Delta LCOPC_{it-p} + \sum_P \alpha_{42ip}\,\Delta LGDPPC_{it-p} + \sum_P \alpha_{43ip}\,\Delta LREC_{it-p} + \sum_P \alpha_{44ip}\,\Delta LNREC_{it-p} + \varepsilon_{4it}$$

$$\Delta LNREC_{it} = \alpha_{5i} + \sum_P \alpha_{51ip}\,\Delta LCOPC_{it-p} + \sum_P \alpha_{52ip}\,\Delta LGDPPC_{it-p} + \sum_P \alpha_{53ip}\,\Delta LREC_{it-p} + \sum_P \alpha_{54ip}\,\Delta LNREC_{it-p} + \varepsilon_{5it} \quad (5)$$

In Equation (5), Δ indicates the first difference of the variable, while *p* and ETC indicate the lag length (in this paper, the optimal lag length is based on the Akaike's information criterion (AIC) and the error correction term, respectively.

5. Empirical findings

The preliminary test of panel unit root controls of variables for our panel of Asian countries is performed, and the results are listed in Table 2.

Table 2. Results of panel unit root tests.

Variable	Breitung	CADF	Hadri	IPS w-stat
lCOPC	–0.714 (0.328)	–1.455 (0.644)	14.685* (0.00)	–.611 (0.332)
lPOP	0.108 (0.513)	–2.055 (0.194)	14.085* (0.00)	–1.394 (0.149)
lGDPPC	–0.358 (0.403)	–2.004 (0.174)	18.694* (0.00)	–0.793 (0.385)
lREC	2.594 (0.895)	–1.955 (0.410)	34.510* (0.00)	2.129 (0.984)
lNREC	0.165 (0.604)	–2.019 (0.219)	37.659* (0.00)	1.759 (0.847)

Note: * shows significance level at 0.01.
Source: Authors' compilation

It can be concluded that the variables of our model become integrated at the first difference (I(1)). Next, seven-panel cointegration tests (Pedroni 2004) are carried out. As represented in Table 3, most statistics are significant, allowing us to reject the null hypothesis (no cointegration).

Table 3. Panel cointegration test results.

Statistics	Within-dimension	
	Value	**Prob.**
Panel v-stat	1.324**	0.036
Panel rho-stat	–0.714	0.104
Panel PP-stat	–5.477*	0.00
Panel ADF-stat	–5.818*	0.00
	Between-dimension	
Group rho-stat	0.318	0.794
Group pp-stat	–5.115*	0.00
Group ADF-stat	–6.002*	0.00

Note: * and ** show significance levels at 0.01 and 0.05, respectively.
Source: Authors' compilation

To check the validation of Pedroni's cointegration test results, we employ two other panel cointegration tests, namely Kao's test (Kao, 1999) and Westerlund's test (Westerlund, 2007). The findings of the tests, shown in Tables 4 and 5, prove that the series are co-integrated.

Table 4. Robustness check for panel cointegration result (Kao test).

	t statistic	**Prob.**
ADF	–1.843*	0.012

Note: * shows significance level at 0.05.
Source: Authors' compilation

Table 5. Robustness check for panel cointegration result (Westerlund test).

	Value	**Prob.**	**Robust prob.**
$\mathbf{G_T}$	–3.980	0.616	0.011
$\mathbf{G_a}$	–7.414	0.894	0.027
$\mathbf{P_T}$	–8.575	0.715	0.027
$\mathbf{P_a}$	–4.480	0.932	0.188

Source: Authors' compilation

According to the abovementioned results of panel unit root tests and cointegration analyses, the fully modified OLS (FMOLS) estimator are employed to find out the coefficients (since the natural logarithm form of variables is considered, the coefficients can be interpreted as long-run elasticities) of impacts of explanatory variables on the dependent variable (CO_2 per capita). The significant findings, reported in Table 6, express that the impact of COVID is positive and statistically significant, mentioning that the pandemic outbreak accelerates the emissions of CO_2 in the sampled Asian countries by approximately 0.001%. This finding is in contrast to Madkour (2021) and Sikarwar et al. (2021), who found out the negative impact of COVID-19 on environmental pollution, while it is in line with Travaglio et al. (2021), who declare the positive relationship between the COVID-19 and air pollution.

The findings further reveal that population number and GDP per capita have a positive relationship with CO_2

emissions, indicating that a 1% increase in total population and GDP per capita of the sampled Asian counties leads to an increase in CO_2 emissions by approximately 0.28% 0.09%, respectively. Regarding energy consumption, renewable energy consumption has a negative coefficient, meaning that by using 1% more green energy resources in the examined Asian countries, the CO_2 emissions may reduce by nearly 0.17%. In comparison, a 1% increase in fossil fuel consumption may increase carbon dioxide emissions by 1.43%.

Table 6. FMOLS estimation results.

Explanatory variable	Coefficient	t-stat
COVID	–10.230*	0.037
lPOP	0.281*	0.094
lGDPPC	0.0.096*	0.043
lREC	–0.17**	0.085
lNREC	1.437**	0.028

Note: * and ** show significance levels at 0.01 and 0.05, respectively.
Source: Authors' compilation

The estimated coefficients, represented in Table 6, do not express the direction of causality between the series. Therefore, the short-run and long-run Granger causality tests for time-varying variables are carried out. Table 7 reports the results of the Granger causality test for our model.

Table 7. Panel Granger causality test.

Dependent variable	Explanatory variable				ECM
	ΔlCOPC	ΔlGDPPC	ΔlREC	ΔlNREC	
ΔlCOPC	-	0.261*	–0.219*	0.392*	–0.387* (–4.758)
ΔlGDPPC	0.194**	-	–0.094**	0.433*	–0.174* (–2.583)
ΔlREC	0.940	1.104	-	0.004	–0.493* (–4.119)
ΔlNREC	–0.393**	0.0490	0.116	-	–0.210* (–2.483)

Note: * and ** show significance levels at 0.01 and 0.05, respectively.
Source: Authors' compilation

The estimated coefficients of the Granger causality test, expressed in Table 7, indicate a short-run bi-directional relationship between CO_2 emissions and GDP per capita. It proves that any increase in GDP per capita leads to a higher level of air pollution and vice versa, any environmental pollution from carbon dioxide emissions may increase GDP per capita in the sampled Asian countries. Finally, a unidirectional linkage runs from renewable energy consumption and fossil fuels consumption to GDP per capita, indicating that a 1% increase in green energy consumption decreases GDP per capita by approximately 0.09%. In contrast, the GDP per capita in the sampled Asian countries increases about 0.4% by a 1% increase in fossil fuels consumption. Thus, it can be concluded that energy transition in the Asian nations will lead to a lower GDP per capita, while fossil fuels consumption as a significant contribution to environmental pollution plays a role of accelerator for GDP per capita.

6. Conclusions

This study attempts to examine the relationship between air pollution (with the proxy of CO_2 emissions per capita), COVID-19, and energy consumption for a panel of 34 Asian countries over the period 1990–2019. Our theoretical framework for the relationships is based on the STIRPAT approach. The estimation results from the FMOLS technique suggest that carbon dioxide emissions increase with the coronavirus outbreak, population number, GDP per capita, and fossil fuels consumption. In contrast, renewable energy consumption may lower CO_2 emissions per capita in the examined Asian nations. One of the interesting conclusions is that the sensitivity of CO_2 emissions to fossil fuels is higher than to other explanatory variables highlighting the importance of attention to the energy transition, energy intensity, and green energy projects in Asian countries.

The causal relationship among variables was studied using the panel error correction model. According to the results, it can be concluded that there is a bi-directional linkage between CO_2 emissions and GDP per capita, while unidirectional relationships are running from renewable energy consumption and fossil fuels consumption to GDP per capita.

According to the results mentioned above, the following concluding remarks can be represented:

Firstly, GDP per capita has a significant role in environmental protection and climate change. Any increase in GDP per capita may adversely affect environmental pollution due to higher consumption of fossil fuels in industrial and power sectors of Asian economies.

Second, since there is a positive impact from population growth to carbon dioxide emissions, it will be expressed that in many Asian nations, there are not any reliable regulations and rules to optimize the population and increase the energy consumption efficiency of households.

Third, there is a positive relationship between COVID-19 and CO_2 emissions in the examined Asian nations, meaning that the mismanagement of the COVID-19 may be considered a signal for increasing air pollution.

As practical policy implications during the COVID-19, the governments in Asian nations should pay more attention to motivating green energy projects using green finance instruments. Due to the financial challenge by the COVID-19 consequences and the lack of capital to invest in the green projects, using stimulating packages for foreign investors which provide appropriate interest rates and ROI will be fruitful. Furthermore, the policies to combat the COVID-19 outbreak should not be a restriction to trade liberalism, labor, and capital mobility among Asian countries.

Despite the impressive contributions of our paper to the existing literature, studying the relationship between COVID-19 and the development progress of countries will be worthy and remarkable for policymakers and scholars. Furthermore, applying research from the viewpoint of dynamic system models about the impacts of the pandemic on socio-economic aspects (through some popular theories like Beck's theory of risk society) of countries is highly recommended for future studies.

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